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Three essays on trade dynamics, trade policy uncertainty and business cycle

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Thèse de doctorat



Three Essays on Trade Dynamics, Trade Policy Uncertainty and Business Cycle

Thèse de doctorat de l'Institut Polytechnique de Paris
préparée à l'École polytechnique

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Thèse présentée et soutenue à Palaiseau, le 07 Juillet 2023, par

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¹Certainly, you can attribute my laziness as a valid criticism, and I wholeheartedly agree with it. :)

Contents

Page No.

| | |
|--|-----------|
| General Introduction | 5 |
| Introduction Générale | 11 |
| 1 Trade Policy Uncertainty, Learning and Export Decision | 19 |
| 1 Introduction | 20 |
| 2 General assumptions | 24 |
| 2.1 Consumer's demand | 24 |
| 2.2 Firms' problem | 25 |
| 3 Sunk cost and learning | 28 |
| 3.1 No TPU case | 28 |
| 3.2 TPU case | 29 |
| 4 Fixed cost and learning | 34 |
| 4.1 No TPU case | 34 |
| 4.2 TPU case | 35 |
| 5 Suggestive evidence of good news effect | 39 |
| 5.1 Data | 41 |
| 5.2 Reduced-form analysis | 42 |
| 5.2.1 Regression-based specifications | 43 |
| 5.2.2 Imputation-based specifications | 47 |
| 6 Conclusion | 50 |
| References | 52 |
| Appendix | 54 |
| 2 Firm-level export and import survival over the business cycle | 85 |
| 1 Introduction | 86 |
| 2 Empirical evidence on firm export/import dynamics and business cycle | 91 |
| 2.1 Data and variables | 91 |
| 2.2 Evidence: export/import entry and exit over the business cycle | 93 |
| 2.2.1 Trade is cyclical & extensive margin importance in the long-run | 93 |
| 2.2.2 Entry/exit rates and the business cycle | 94 |

| | | |
|----------|---|------------|
| 2.2.3 | Differences in firm-level characteristics of entrants, exiters and continuers over the business cycle | 95 |
| 2.2.4 | Entry to export/import probability over the business cycle | 96 |
| 2.2.5 | Persistent effects of conditions at birth | 98 |
| 2.3 | Remarks on trade dynamics and business cycle | 103 |
| 3 | The hazard rate of exiting export/import markets | 103 |
| 3.1 | Empirical methodology | 103 |
| 3.2 | Export duration: entry conditions and business cycle | 107 |
| 3.3 | Import duration: entry conditions and business cycle | 109 |
| 3.4 | Bivariate duration | 110 |
| 3.4.1 | A multilevel two-state logit model | 110 |
| 3.4.2 | Results | 111 |
| 3.5 | Summary of results | 112 |
| 4 | Discussion of results | 113 |
| 6 | Conclusion | 114 |
| | References | 117 |
| | Appendix | 121 |
| 3 | Incomplete Contracts and Outcome-Based Trade Agreements | 135 |
| 1 | Introduction | 136 |
| 2 | Model with neither uncertainty nor contracting costs | 139 |
| 2.1 | Supply side problem | 140 |
| 2.2 | Demand side problem | 140 |
| 2.3 | Importing sector policy instruments and welfare functions | 140 |
| 2.4 | Equilibria | 141 |
| 2.4.1 | Efficient equilibrium | 142 |
| 2.4.2 | Nash equilibrium (NE) | 142 |
| 2.4.3 | NE with import volume constraint | 143 |
| 3 | State uncertainty and costs of contracting | 145 |
| 4 | Optimal agreement choice: non state-contingent outcome-based agreement vs the others | 147 |
| 4.1 | Uncertainty over the consumption externality γ | 147 |
| 4.2 | Uncertainty over the production externality σ | 154 |

| | | |
|-----|---|------------|
| 4.3 | Uncertainty over the home demand shifter α | 157 |
| 6 | Conclusion | 161 |
| | References | 163 |
| | Appendix | 164 |
| | Conclusion | 181 |

General Introduction

In this dissertation, I investigate how trade policy uncertainty and firms' learning about idiosyncratic demand shock jointly affect exporting decisions, the dependence of the duration of new export and import spells on business cycle conditions at birth and in the current year, and the optimal choice between trade-outcome-based agreements, such as the Expanding Trade chapter in the Phase One deal, and policy-instrument-based agreements, such as the WTO, in a framework where contracting is costly and state is uncertain.

The process of globalization has advanced significantly in recent decades, with the creation of institutions such as GATT/WTO, EU, and various preferential trade agreements. The world trade to GDP ratio increased from 24.99% in 1970 to 57.58% in 2018. These developments have brought many benefits, including increased economic growth, improved living standards, and greater access to goods and services. However, despite these efforts, international trade remains vulnerable and is subject to various uncertainties and shocks.² A prominent example is trade policy uncertainty, as evidenced recently by Brexit and the US-China trade war. In 2016, a referendum was held in the UK on whether to leave the European Union, and the majority voted in favor of leaving. This decision created a significant amount of uncertainty in terms of trade policy between the UK and other countries, particularly with the EU. Born et al. (2019) show that the Brexit vote has caused a UK output loss of 1.7% to 2.5% by year-end 2018 and find that expectations- and policy uncertainty-augmented vector autoregressions can explain much of the gap in economic performance between the UK and a synthetic control economy. Graziano et al. (2021) estimate that the increase in the probability of Brexit after the referendum lowered EU-UK bilateral export values between 11-20%. It wasn't until the signature of the EU-UK Trade and Cooperation Agreement on 30 December 2020 that the trade policy uncertainty between the two was resolved. Besides trade policy uncertainty, macroeconomic fluctuation affects firms' trade participation. A bunch of papers on international macroeconomics such as Calderón et al. (2007), di Giovanni et al. (2018), and Duval et al. (2016), document a positive correlation between bilateral trade and business cycle synchronization. The 2008 financial crisis resulted in a great trade collapse during which world trade dropped by 30% in nominal terms, and 18% in real terms.

²The topic of international trade and uncertainty has been studied for a long time. Pomery (1984) conducted an early literature review on uncertainty in trade models. With the availability of more disaggregated data in recent years, researchers have been able to study the effect of uncertainty/shock, such as trade policy uncertainty and the business cycle, on international trade at a more detailed level, leading to new insights.

Furthermore, firms' trade decisions can be influenced by internal uncertainties that intrinsically arise from their exporting or importing activities, namely firms' idiosyncratic shock. Eaton et al. (2007) have documented that new exporters typically start small and exit the export market quickly. However, conditional on surviving, they experience rapid growth at the beginning and are less likely to exit as they age in the export market. These new exporters account for about half of the total expansion in merchandise trade in the long run. Similar patterns can also be observed in importer dynamics. These findings suggest that trade dynamics is age dependent and firms' trade decisions are subject to idiosyncratic shocks, which are distinct from external trade policy uncertainties and macroeconomic shocks. There is a growing literature that studies firms' trade dynamics. Alessandria et al. (2021) provide a survey of the literature on the dynamics of firms in foreign markets. Several different models are proposed to explain the dynamics of new exporters, including the demand learning model and customer base accumulation model. The aforementioned facts highlight the important effects that external shocks, i.e., trade policy uncertainty and the business cycle and internal idiosyncratic shocks have on firms' trade decisions, which motivates the first two chapters of my dissertation.

Although the creation of GATT/WTO has significantly contributed to the reduction of trade policy uncertainty, member countries have been granted a significant amount of discretion over policy instruments. Since drafting trade agreements is costly, they are incomplete contracts in nature. As mentioned in Horn, Maggi, and Staiger (2010), the negotiation of the WTO agreement lasted for approximately 8 years and resulted in a document comprising 24,000 pages. However, despite its length, the WTO agreement remains incomplete, as it places largely non-contingent constraints on governments' policy choices, and excludes many relevant policy instruments from its provisions.³ For instance, under the WTO agreement, member countries are only required to set a MFN tariff no greater than the rigid bound tariff, which creates policy uncertainty. Importing countries have the incentive to set a higher trade barrier to manipulate the terms-of-trade and extract extra profits from abroad, resulting in welfare inefficiency. Therefore, exporters continually face the risk of an increase in tariffs once the applied MFN tariff is below the bound tariff. Nevertheless, in some cases, an increase in tariffs can be reasonable for importing countries. For example, if home consumption generates more pollution in certain years, importing countries can deal with this issue by lifting tariffs, which can be welfare-improving. Additionally, while border instruments such as tariffs are relatively well-regulated, member countries can choose to employ domestic instruments instead to intervene in international trade. The US has expressed dissatisfaction with the functioning of the WTO and has blocked the reappointment of Appellate Body members since 2016 in order to push for its reform. Meanwhile, the US has turned to a novel trade agreement, the Phase One deal, to address trade-related problems with China. Instead of imposing constraints on policy instruments, the Phase One deal includes a two-year \$200 billion purchase commitment of China from the US, implying that an outcome-based agreement, i.e., agreements that impose constraints on equilibrium outcomes such as trade volumes, can be preferred under certain conditions. The

³Horn, Maggi, and Staiger (2010) also quote the trade-law literature that emphasizes the difficulties of drafting an agreement that is comprehensive in policy coverage and is highly contingent.

question then becomes how to design a better trade agreement that restricts member countries' inefficient alteration of policy instruments while still allowing efficient alteration, which motivates the third chapter of my dissertation.⁴

Before summarizing the three chapters, I would like to highlight the main contributions of each chapter to the existing literature. Chapter 1 is based on the literature on trade policy uncertainty (TPU) and the literature on new exporters dynamics. Handley and Limão series of papers study exporters' entry into foreign markets under TPU. They build a model based on the canonical sunk cost model and introduce a TPU process that follows a Markov chain. Nevertheless, in their model, exporters' per-period profits are not age-dependent and the difference between the value of entering now and entering later is only driven by the future worse tariff states (Bernanke's *bad news principle*). Meanwhile, the literature on new exporters dynamics documents that exporting decision is age-dependent. This literature mainly focuses on the problem of post-entry dynamics while it hasn't formally studied entry decisions under TPU. Chapter 1 tries to build a bridge between the two pieces of literature and constructs a model that incorporates both trade policy uncertainty and demand learning to study export decisions. The model provides several novel insights into export decisions and is almost always tractable. Both good news and bad news affect exporters' entry decisions. Additionally, I empirically test the model's prediction by examining the anticipation effect of trade agreements. Unlike the previous literature on the anticipation effect of preferential trade agreements such as Egger et al. (2020), I study product-level entry and focus on a specific set of products among WTO countries of which the bad news channel is shut down. I employ the recently developed two-way fixed effects estimator that allows heterogeneous treatment effects and find suggestive evidence.

Chapter 2 examines the survival of firms in the exporting/importing market over the business cycle. More precisely, we study the effect of business cycle conditions at birth and in the current year on firms' survival, controlling for the initial characteristics of export/import spells. Chapter 2 is based on the literature on the empirical firm dynamics and the business cycle (first), the literature on export participation dynamics (second), and the literature on the relationship between the business cycle and trade dynamics (third). The first literature examines the relationships between macroeconomic conditions at birth and firm characteristics over their lifetime while it hasn't studied exporting/importing firms' survival over the business cycle. The second literature finds that hazard rates out of exporting/importing fall along an exporter/importer life cycle while it doesn't examine the effect of macroeconomic conditions at birth in survival performance. The existing third literature has mainly focused on the short-run effects of the 2008-2009 Great Recession and found the extensive margin is little affected while we use the data with a longer time span and focus on the effect on the extensive margin, namely survival. In terms of empirical methodology, we study separately/jointly the exporting/importing survival at the firm/firm-country level and employ different business cycle measures.

⁴To be more specific, terms-of-trade manipulation can motivate inefficient alteration, while efficient alteration can be motivated by the need to react to state uncertainty.

Chapter 3 is based on Horn, Maggi and Staiger (2006,2010) where they study the endogenous choice of policy-instrument-based agreements in an incomplete contract framework in which contracting is costly and the state is uncertain. Inspired by the signature of the Phase One deal, I introduce trade-outcome-based agreements in their framework and mainly focus on the comparison between trade-outcome-based agreements and policy-instrument-based agreements. More precisely, chapter 3 concentrates on the trade-off between solving terms-of-trade manipulation and better reacting to state uncertainty when comparing different agreements. The chapter gives clear pairwise and triple-wise comparisons between the non-state-contingent outcome-based agreement and other instrument-based agreements and the results can be graphically illustrated. Now I turn to the summary of each chapter.

Chapter 1 is entitled *Trade Policy Uncertainty, Learning and Export Decision*, which includes both theoretical and empirical works. This paper has been motivated by the recent sharp increase in trade policy uncertainty (TPU). The paper examines the impact of TPU on a potential exporter's decision to enter the export market. Handley and Limão series of papers have shown that TPU reduces the entry of potential exporters due to Bernanke's *bad news principle*. The study aims to verify if the result that TPU reduces entry is robust in models that deviate from classical sunk cost models by introducing demand learning.

The paper studies both sunk cost learning and fixed cost learning models, where potential exporters hold prior beliefs and receive a signal at the end of their entry period (one-period learning). TPU follows a three-state Markov chain (high/intermediate/low tariff state), and the study focuses on entry cutoff in the intermediate state. Denote high(low) tariff state by bad(good) news state. The analysis shows that the effect of TPU on entry cutoff is ambiguous and depends on the impact of both bad news and good news. The bad news discourages entry as potential entrants can prevent future losses by waiting. On the other hand, good news has a positive effect on entry cutoff in sunk cost learning models. It is because, ex-ante, having more knowledge on demand is better than having no knowledge and early learning brings extra value. Moreover, in the fixed cost learning model, future good news can even deter firms' current entry. As there exists endogenous exit in the fixed cost learning model, entry-cutoff firms may only care about the scenario with high demand posterior belief in the future good news state. Nevertheless, the probability of having a high posterior belief is only one-half which is risky. Therefore, if the high posterior belief is not high enough, given a lower tariff in the future good news state, cutoff firms may prefer to defer their entry and choose to start exporting and learning in the future good news state.

Given that good news matters in my models but not in Handley and Limão's partial equilibrium model, my empirical strategy is to shut down the bad news channel entirely and test only the effect of good news. Within the WTO country pairs, I study the product lines for which the positive applied MFN tariff equals the bound tariff, thus shutting down their bad news. I consider the signature of the trade agreement as good news. My empirical results show that the probability of a product being traded bilaterally starts to increase from 6 years before the

signature, which is consistent with the model prediction that good news encourages firms' entry.

Chapter 2 is entitled *Firm-level Export and Import Survival over the Business Cycle*. It is an empirical work co-authored with Gregory Corcos, Silvano Esteve-Pérez and Salvador Gil-Pareja. The paper contributes to the literature by examining the effect of macroeconomic conditions at birth on French exporters' and/or importers' long-run performance, specifically survival. While previous studies have focused on the relationship between the number of exporters/importers and the business cycle, this study examines survival hazard over the export/import lifetime. The paper is related to two main strands of literature, namely the empirical firm dynamics and business cycle literature and the export participation dynamics literature.

We first show that gross exit rates are higher than gross entry rates during downturns, leading to a fall in foreign market participation. The analysis also shows that entrants at bad times are smaller but more productive, and the productivity threshold for exiters is higher during recessions. The probit regressions on the transition to entry confirm the increase in the productivity cutoff during downturns. We further find evidence of persistent effects of recessions on some firm-level characteristics over their export/import lifetimes.

The paper's main contribution is estimating survival models to assess how the business cycle conditions when firms begin to export and/or import affects their survival chances over their export/import lifetimes, accounting for spell-specific age-dependence (i.e., ongoing experience or duration dependence) and the state of the economy (overall business cycle effects). We find that while the overall hazard of leaving export/import markets is higher during downturns, exporters/importers born at bad macroeconomics conditions have lower hazard of ending their export/import spells. This finding is robust to the use of different business cycle measures. We also estimate bivariate duration models which suggest that the joint pattern of firm's export and import duration tends to be either long-long or short-short.

Chapter 3 is entitled *Incomplete Contracts and Outcome-Based Trade Agreements* which is a theoretical work. This paper has been motivated by the Expanding Trade chapter of the US-China Phase One trade deal signed on January 15, 2020, that includes a two-year \$200 billion purchase commitment by China from the US. I compare outcome-based agreements, namely import volume constraints, with instrument-based agreements, namely constraints on domestic and/or border instruments in an incomplete-contract framework where contracting is costly and the state is uncertain. The optimal agreement is endogenously chosen to maximize global expected welfare net of contracting costs.

The study identifies the circumstances under which a rigid outcome-based agreement is optimal, considering three sources of state uncertainty, i.e., consumption externality, production externality, and demand shifter. The paper focuses on the trade-off between lifting market access barriers, namely terms-of-trade manipulation, and reacting to state uncertainty. The sole cross-border inefficiency that a trade agreement is intended to solve is the terms-of-trade externality. There also exist two domestic externalities, i.e., consumption and production externalities, lead-

ing to a positive optimal tariff. I focus on the sector where home is the importing country. The sector welfare can be studied independently due to the partial equilibrium setting. The foreign government is assumed to be policy-passive in the home-importing sector.

The paper argues that once import volume is contracted, it is unnecessary to contract on both trade outcomes and policy instruments. In this case, importing country maximizes its welfare without manipulating foreign welfare. As there is no state uncertainty, the non-state-contingent agreement on import volume is able to reach the first best outcome. As there is state uncertainty, its relative performance is high under the uncertainty of home consumption externality, followed by the uncertainty of home production externality, and then followed by the uncertainty of home demand shifter. The main message of this paper is that a rigid outcome-based agreement is able to solve the baseline terms-of-trade manipulation efficiently and gives extra flexibility regarding the choice of policy instruments to the importing county. Whether the extra flexibility is appealing depends on the source of uncertainty. To put it another way, foreign welfare is forced to remain invariant across different realizations of the state under the non-state-contingent agreement on import volume. In this case, importing country cannot manipulate foreign welfare, which is welfare efficient. However, it must bear all the variation due to state uncertainty, which can be welfare inefficient.

Version française de l'introduction

Dans cette thèse, j'étudie comment l'incertitude des politiques commerciales et l'apprentissage des entreprises sur les chocs idiosyncratiques de demande affectent conjointement les décisions d'exportation, la dépendance de la durée des nouvelles périodes d'exportation et d'importation sur les conditions du cycle économique à la naissance et dans l'année en cours, ainsi que le choix optimal entre des accords basés sur les résultats commerciaux, tels que le chapitre d'expansion commerciale dans l'accord de phase un, et des accords basés sur les instruments politiques, tels que l'OMC, dans un cadre où la contractualisation est coûteuse et l'état est incertain.

Le processus de mondialisation a considérablement progressé au cours des dernières décennies, avec la création d'institutions telles que le GATT/OMC, l'UE et divers accords commerciaux préférentiels. Le ratio commerce mondial/PIB est passé de 24,99% en 1970 à 57,58% en 2018. Ces évolutions ont apporté de nombreux avantages, notamment une croissance économique accrue, une amélioration des niveaux de vie et un accès accru aux biens et services. Cependant, malgré ces efforts, le commerce international reste vulnérable et est soumis à diverses incertitudes et chocs.⁵ Un exemple important est l'incertitude liée à la politique commerciale, comme le montrent récemment le Brexit et la guerre commerciale entre les États-Unis et la Chine. En 2016, un référendum a été organisé au Royaume-Uni sur la question de savoir s'il devait quitter l'Union européenne, et la majorité a voté en faveur du départ. Cette décision a créé une quantité significative d'incertitude en termes de politique commerciale entre le Royaume-Uni et d'autres pays, en particulier avec l'UE. Born et al. (2019) montrent que le vote du Brexit a causé une perte de production de 1,7% à 2,5% pour le Royaume-Uni d'ici la fin de 2018, et constatent que des vecteurs autorégressifs augmentés par l'incertitude des espérances et des politiques peuvent expliquer une grande partie de l'écart de performance économique entre le Royaume-Uni et une économie de contrôle synthétique. Graziano et al. (2021) estiment que l'augmentation de la probabilité du Brexit après le référendum a fait baisser les valeurs d'exportation bilatérales UE-Royaume-Uni entre 11 et 20%. Ce n'est qu'avec la signature de l'Accord de Commerce et de Coopération entre l'UE et le Royaume-Uni le 30 décembre 2020 que l'incertitude de la politique commerciale entre les deux parties a été résolue. En plus de l'incertitude liée à la politique commerciale, les fluctuations macroéconomiques affectent la participation commerciale des entreprises. Un certain nombre d'articles sur la macroéconomie internationale, tels que Calderón et al. (2007), di Giovanni et al. (2018) et Duval et al. (2016), documentent une corrélation positive entre le commerce bilatéral et la synchronisation des cycles économiques. La crise financière de 2008 a entraîné un effondrement du commerce mondial, au cours duquel le commerce mondial a chuté de 30% en termes nominaux et de 18% en termes réels.

De plus, les décisions commerciales des entreprises peuvent être influencées par des incertitudes

⁵Le sujet du commerce international et de l'incertitude a été étudié depuis longtemps. Pomery (1984) a mené une revue de littérature précoce sur l'incertitude dans les modèles de commerce. Avec la disponibilité de données plus désagrégées ces dernières années, les chercheurs ont pu étudier l'effet de l'incertitude/du choc, tel que l'incertitude liée à la politique commerciale et le cycle économique, sur le commerce international à un niveau plus détaillé, conduisant à de nouvelles perspectives.

internes qui découlent intrinsèquement de leurs activités d'exportation ou d'importation, à savoir les chocs idiosyncratiques des entreprises. Eaton et al. (2007) documentent que les nouveaux exportateurs commencent généralement petit et sortent rapidement du marché de l'exportation. Cependant, conditionnellement à leur survie, ils connaissent une croissance rapide au début et sont moins susceptibles de sortir du marché en vieillissant dans le marché de l'exportation. Ces nouveaux exportateurs représentent environ la moitié de l'expansion totale des échanges de marchandises à long terme. Des modèles similaires peuvent également être observés dans les dynamiques d'importation. Ces découvertes suggèrent que la dynamique commerciale dépend de l'âge et que les décisions commerciales des entreprises sont soumises à des chocs idiosyncratiques, distincts des incertitudes des politiques commerciales et des chocs macroéconomiques extérieurs. Il existe une littérature croissante qui étudie la dynamique commerciale des entreprises. Alessandria et al. (2021) fournissent une enquête sur la littérature sur la dynamique des entreprises dans les marchés étrangers. Plusieurs modèles différents sont proposés pour expliquer la dynamique des nouveaux exportateurs, notamment le modèle d'apprentissage de la demande et le modèle d'accumulation de la clientèle. Les faits mentionnés ci-dessus mettent en évidence les effets importants que les chocs externes, c'est-à-dire l'incertitude de la politique commerciale et le cycle économique, ainsi que les chocs internes idiosyncratiques ont sur les décisions commerciales des entreprises, ce qui motive les deux premiers chapitres de ma thèse.

Bien que la création du GATT/OMC ait contribué de manière significative à la réduction de l'incertitude liée aux politiques commerciales, les pays membres se sont vu accorder une grande marge de manœuvre quant aux instruments politiques à leur disposition. Puisque la rédaction des accords commerciaux est coûteuse, ces accords sont de nature incomplète. Comme mentionné dans Horn, Maggi et Staiger (2010), la négociation de l'accord de l'OMC a duré environ 8 ans et a donné lieu à un document de 24 000 pages. Cependant, malgré sa longueur, l'accord de l'OMC reste incomplet car il impose des contraintes largement non contingentes sur les choix politiques des gouvernements et exclut de nombreux instruments politiques pertinentes de ses dispositions.⁶ Par exemple, dans le cadre de l'accord de l'OMC, les pays membres ne sont tenus de fixer qu'un droit de douane MFN inférieur ou égal au droit de douane consolidé rigide, ce qui crée une incertitude politique. Les pays importateurs ont l'incitation à ériger une barrière commerciale plus élevée pour manipuler les termes de l'échange et extraire des profits supplémentaires de l'étranger, ce qui entraîne une inefficience du bien-être. Par conséquent, les exportateurs sont constamment confrontés au risque d'une augmentation des droits de douane une fois que le droit de douane MFN appliqué est inférieur au droit de douane consolidé. Néanmoins, dans certains cas, une augmentation des droits de douane peut être justifiée pour les pays importateurs. Par exemple, si la consommation nationale génère plus de pollution pendant certaines années, les pays importateurs peuvent résoudre ce problème en augmentant les droits de douane, ce qui peut améliorer le bien-être. De plus, bien que les instruments de frontière tels que les droits de douane soient relativement bien réglementés, les pays membres peuvent choisir d'utiliser des instruments domestiques pour intervenir dans le commerce international. Les États-Unis ont

⁶Horn, Maggi et Staiger (2010) citent également la littérature sur le droit commercial qui souligne les difficultés de rédiger un accord qui est exhaustif en termes de couverture de politiques et hautement contingent.

exprimé leur insatisfaction quant au fonctionnement de l'OMC et ont bloqué la réélection des membres du corps d'appel depuis 2016 afin de pousser à sa réforme. Pendant ce temps, les États-Unis se sont tournés vers un nouvel accord commercial, l'accord de Phase Un, pour résoudre les problèmes liés au commerce avec la Chine. Au lieu d'imposer des contraintes sur les instruments de politique, l'accord de Phase Un comprend un engagement d'achat de la Chine auprès des États-Unis de 200 milliards de dollars sur deux ans, ce qui implique qu'un accord basé sur les résultats, c'est-à-dire un accord qui impose des contraintes sur les résultats d'équilibre tels que les volumes d'échange, peut être préféré dans certaines conditions. La question est alors de savoir comment concevoir un meilleur accord commercial qui restreint l'altération inefficace des instruments de politique des pays membres tout en permettant une altération efficace, ce qui motive le troisième chapitre de ma thèse.⁷

Avant de résumer les trois chapitres, je voudrais mettre en évidence les principales contributions de chaque chapitre à la littérature existante. Le Chapitre 1 s'appuie sur la littérature sur l'incertitude liée à la politique commerciale (IPC) et sur la littérature sur la dynamique des nouveaux exportateurs. La série d'articles de Handley et Limão étudie l'entrée des exportateurs sur les marchés étrangers sous IPC. Ils construisent un modèle basé sur le modèle canonique des coûts irrécupérables et introduisent un processus d'IPC qui suit une chaîne de Markov. Néanmoins, dans leur modèle, les profits par période des exportateurs ne dépendent pas de leur âge et la différence entre la valeur de l'entrée maintenant et plus tard est uniquement liée aux futurs états de tarifs pires (le principe de "mauvaises nouvelles" de Bernanke). En même temps, la littérature sur la dynamique des nouveaux exportateurs montre que la décision d'exportation dépend de l'âge. Cette littérature se concentre principalement sur le problème de la dynamique post-entrée, tandis qu'elle n'a pas étudié formellement les décisions d'entrée sous IPC. Le Chapitre 1 tente de construire un pont entre les deux pièces de la littérature et construit un modèle qui intègre à la fois l'incertitude liée à la politique commerciale et l'apprentissage de la demande pour étudier les décisions d'exportation. Le modèle fournit plusieurs nouvelles perspectives sur les décisions d'exportation et est presque toujours traçable. Les bonnes et les mauvaises nouvelles affectent les décisions d'entrée des exportateurs. De plus, j'ai testé empiriquement les prédictions du modèle en examinant l'effet d'anticipation des accords commerciaux. Contrairement à la littérature précédente sur l'effet d'anticipation des accords commerciaux préférentiels tels que Egger et al. (2020), j'ai étudié l'entrée au niveau des produits et me suis concentré sur un ensemble spécifique de produits parmi les pays de l'OMC dont le canal de "mauvaises nouvelles" est fermé. J'ai utilisé l'estimateur récemment développé à effets fixes two-way qui permet des effets de traitement hétérogènes et trouvé des preuves suggestives.

Le chapitre 2 examine la survie des entreprises sur le marché de l'exportation/importation pendant le cycle économique. Plus précisément, nous étudions l'effet des conditions du cycle économique à la naissance et dans l'année en cours sur la survie des entreprises, en contrôlant les caractéristiques initiales des périodes d'exportation/importation. Le chapitre 2 repose sur

⁷Pour être plus précis, la manipulation des termes de l'échange peut motiver une altération inefficace, tandis qu'une altération efficace peut être motivée par la nécessité de réagir à l'incertitude de l'état.

la littérature sur la dynamique des entreprises et le cycle économique (première), la littérature sur la dynamique de la participation à l'exportation (deuxième) et la littérature sur la relation entre le cycle économique et la dynamique commerciale (troisième). La première littérature examine les relations entre les conditions macroéconomiques à la naissance et les caractéristiques des entreprises tout au long de leur vie, mais n'a pas étudié la survie des entreprises d'exportation/importation sur le cycle économique. La deuxième littérature constate que les taux de risque de sortie de l'exportation/importation diminuent le long du cycle de vie des exportateurs/importateurs, mais n'examine pas l'effet des conditions macroéconomiques à la naissance sur la performance de survie. La troisième littérature existante s'est principalement concentrée sur les effets à court terme de la Grande Récession de 2008-2009 et a constaté que la marge extensive est peu affectée, alors que nous utilisons des données sur une période plus longue et nous concentrons sur l'effet sur la marge extensive, à savoir la survie. En termes de méthodologie empirique, nous étudions séparément/conjointement la survie d'exportation/importation au niveau de l'entreprise/l'entreprise-pays et nous utilisons différentes mesures de cycle économique.

Le chapitre 3 est basé sur Horn, Maggi et Staiger (2006, 2010) qui étudient le choix endogène d'accords basés sur des instruments de politique dans un cadre de contrat incomplet dans lequel la contractualisation est coûteuse et l'état est incertain. Inspiré par la signature de l'accord de Phase Un, j'introduis des accords basés sur les résultats commerciaux dans leur modèle et me concentre principalement sur la comparaison entre les accords basés sur les résultats commerciaux et les accords basés sur les instruments de politique. Plus précisément, le chapitre 3 se concentre sur le compromis entre la résolution de la manipulation des termes de l'échange et une meilleure réaction à l'incertitude de l'état lors de la comparaison des différents accords. Le chapitre donne des comparaisons claires par paires et par triplets entre l'accord basé sur les résultats non contingents à l'état et les autres accords basés sur des instruments, et les résultats peuvent être illustrés graphiquement. Maintenant, je passe à la synthèse de chaque chapitre.

Le chapitre 1 est intitulé *Incertitude de la politique commerciale, apprentissage et décision d'exportation*, comprenant à la fois des travaux théoriques et empiriques. Ce papier est motivé par l'augmentation récente de l'incertitude de la politique commerciale (IPC). L'étude examine l'impact de l'IPC sur la décision d'un exportateur potentiel d'entrer sur le marché de l'exportation. Les travaux de Handley et Limão ont montré que l'IPC réduit l'entrée des exportateurs potentiels en raison du *principe des mauvaises nouvelles* de Bernanke. L'étude vise à vérifier si le résultat selon lequel l'IPC réduit l'entrée est robuste dans les modèles qui s'éloignent des modèles classiques de coûts irrécupérables en introduisant l'apprentissage de la demande.

Le document étudie à la fois les modèles d'apprentissage avec les coûts irrécupérables et avec les coûts fixes, où les exportateurs potentiels ont des croyances antérieures et reçoivent un signal à la fin de leur période d'entrée (apprentissage durant une période). L'IPC suit une chaîne de Markov à trois états (état de tarif élevé/intermédiaire/faible), et l'étude se concentre sur le seuil d'entrée dans l'état intermédiaire. Désignez l'état de tarif élevé (faible) par l'état de

mauvaises (bonnes) nouvelles. L'analyse montre que l'effet de l'IPC sur le seuil d'entrée est ambigu et dépend de l'impact à la fois des mauvaises et des bonnes nouvelles. Les mauvaises nouvelles découragent l'entrée car les entrants potentiels peuvent éviter les pertes futures en attendant. D'autre part, les bonnes nouvelles ont un effet positif sur le seuil d'entrée dans les modèles d'apprentissage avec les coûts irrécupérables. C'est parce que, ex-ante, avoir plus de connaissances sur la demande est meilleur que de ne pas en avoir et que l'apprentissage précoce apporte une valeur supplémentaire. De plus, dans le modèle d'apprentissage avec les coûts fixes, les futures bonnes nouvelles peuvent même dissuader l'entrée actuelle des entreprises. Comme il existe une sortie endogène dans le modèle d'apprentissage avec les coûts fixes, les entreprises au seuil d'entrée ne se préoccupent peut-être que du scénario avec une haute croyance postérieure en la demande dans l'état de bonnes nouvelles futures. Néanmoins, la probabilité d'avoir une haute croyance postérieure n'est que d'une demi, ce qui est risqué. Par conséquent, si la haute croyance postérieure n'est pas assez élevée, compte tenu d'un tarif plus faible dans l'état de bonnes nouvelles futures, les entreprises au seuil d'entrée peuvent préférer différer leur entrée et choisir de commencer à exporter et à apprendre dans l'état de bonnes nouvelles futures.

Étant donné que les bonnes nouvelles sont importantes dans mes modèles mais pas dans le modèle d'équilibre partiel de Handley et Limão, ma stratégie empirique consiste à éliminer entièrement le canal des mauvaises nouvelles et à tester uniquement l'effet des bonnes nouvelles. Au sein des paires de pays de l'OMC, j'étudie les lignes de produits pour lesquelles le tarif MFN appliqué positif est égal au tarif consolidé, éliminant ainsi leurs mauvaises nouvelles. Je considère la signature de l'accord commercial comme une bonne nouvelle. Mes résultats empiriques montrent que la probabilité qu'un produit soit échangé bilatéralement commence à augmenter 6 ans avant la signature, ce qui est conforme à la prédiction du modèle selon laquelle les bonnes nouvelles encouragent l'entrée des entreprises.

Le chapitre 2 s'intitule *Survie des exportateurs et importateurs au niveau des entreprises sur le cycle économique* et est un travail empirique co-écrit avec Gregory Corcos, Silvano Esteve-Pérez et Salvador Gil-Pareja. Le papier contribue à la littérature en examinant l'effet des conditions macroéconomiques au moment de la naissance sur la performance à long terme des exportateurs et/ou importateurs français, en particulier leur survie. Alors que les études précédentes se sont concentrées sur la relation entre le nombre d'exportateurs/importateurs et le cycle économique, cette étude examine le risque de survie sur la durée de vie à l'exportation/importation. Le papier est lié à deux principaux courants de la littérature, à savoir la littérature sur la dynamique des entreprises et le cycle économique et la littérature sur la dynamique de la participation à l'exportation.

Nous montrons d'abord que les taux de sortie bruts sont plus élevés que les taux d'entrée bruts pendant les périodes de ralentissement, ce qui entraîne une baisse de la participation au marché étranger. L'analyse montre également que les nouveaux entrants en période difficile sont plus petits mais plus productifs, et que le seuil de productivité pour les sortants est plus élevé pendant les récessions. Les régressions probit sur la transition vers l'entrée confirment l'augmentation

du seuil de productivité pendant les périodes de ralentissement. Nous trouvons également des preuves d'effets persistants des récessions sur certaines caractéristiques au niveau de l'entreprise sur leur durée de vie à l'exportation/importation.

La principale contribution du papier est l'estimation de modèles de survie pour évaluer comment les conditions cycliques lors du début de l'exportation et/ou de l'importation affectent les chances de survie des entreprises au cours de leur durée de vie à l'exportation/importation, en tenant compte de la dépendance de l'âge spécifique à chaque période (i.e., l'expérience en cours ou la dépendance à la durée) et de l'état de l'économie (effets globaux du cycle économique). Nous constatons que, bien que le risque global de quitter les marchés d'exportation/importation soit plus élevé pendant les périodes de ralentissement, les exportateurs/importateurs nés dans des conditions macroéconomiques défavorables ont un risque plus faible de mettre fin à leur durée de vie à l'exportation/importation. Cette découverte est robuste à l'utilisation de différentes mesures de cycle économique. Nous estimons également des modèles de durée bivariés qui suggèrent que le modèle de durée d'exportation et d'importation des entreprises tend à être soit long-long, soit court-court.

Le chapitre 3 s'intitule *Contrats incomplets et accords commerciaux basés sur les résultats* et s'agit d'un travail théorique. Ce papier a été motivé par le chapitre sur l'Expansion du Commerce de l'accord commercial de Phase Un entre les États-Unis et la Chine signé le 15 janvier 2020, qui comprend un engagement d'achat de 200 milliards de dollars sur deux ans par la Chine auprès des États-Unis. Je compare les accords basés sur les résultats, à savoir les contraintes sur le volume d'importation, avec les accords basés sur les instruments, à savoir les contraintes sur les instruments domestiques et/ou frontaliers, dans un cadre de contrat incomplet où la contractualisation est coûteuse et l'état est incertain. L'accord optimal est choisi de manière endogène pour maximiser le bien-être mondial prévu net des coûts de contractualisation.

L'étude identifie les circonstances dans lesquelles un accord rigide basé sur les résultats est optimal, en considérant trois sources d'incertitude de l'état, à savoir l'externalité de consommation, l'externalité de production et le facteur de déplacement de la demande. Le papier se concentre sur le compromis entre la levée des barrières d'accès au marché, à savoir la manipulation des termes de l'échange, et la réaction à l'incertitude de l'état. La seule inefficacité transfrontalière qu'un accord commercial vise à résoudre est l'externalité des termes de l'échange. Il existe également deux externalités domestiques, à savoir les externalités de consommation et de production, conduisant à un tarif optimal positif. Je me concentre sur le secteur où le pays d'importation est le pays d'origine. Le bien-être du secteur peut être étudié de manière indépendante en raison du cadre de l'équilibre partiel. Le gouvernement étranger est supposé être passif en terme de politique dans le secteur d'importation du pays d'origine.

Le document affirme qu'une fois que le volume d'importation est contracté, il n'est pas nécessaire de contracter à la fois sur les résultats commerciaux et les instruments de politique. Dans ce cas, le pays importateur maximise son bien-être sans manipuler le bien-être étranger. Quand il n'y a pas d'incertitude d'état, l'accord non contingent à l'état sur le volume d'importation

est capable d'atteindre le premier meilleur résultat. Lorsqu'il y a de l'incertitude d'état, sa performance relative est élevée en cas d'incertitude concernant l'externalité de consommation, suivie de l'incertitude concernant l'externalité de production, puis de l'incertitude concernant le facteur du déplacement de la demande. Le message principal de ce document est qu'un accord rigide basé sur les résultats est capable de résoudre efficacement la manipulation des termes de l'échange de la base et offre une flexibilité supplémentaire en ce qui concerne le choix des instruments de politique pour le pays importateur. Si la flexibilité supplémentaire est attrayante dépend de la source d'incertitude. En d'autres termes, le bien-être étranger est contraint de rester invariant à travers différentes réalisations de l'état en vertu de l'accord non contingent à l'état sur le volume d'importation. Dans ce cas, le pays importateur ne peut pas manipuler le bien-être étranger, ce qui est efficace en termes de bien-être. Cependant, il doit supporter toutes les variations dues à l'incertitude d'état, ce qui peut être inefficace en termes de bien-être.

Chapter 1

Trade Policy Uncertainty, Learning and Export Decision

Abstract

I revisit Handley and Limão (2017) partial equilibrium model and study a firm's decision to start exporting under trade policy uncertainty (TPU) in the presence of demand uncertainty and learning. Handley and Limão (2017) show that TPU only reduces exporters' entry due to Bernanke's bad news principle while I find their result is not robust in settings where export decision is also driven by demand learning. I first examine the effect of TPU on the timing of entry in both sunk cost learning and fixed cost learning models. As in Handley and Limão (2017), future bad news generates an option value of waiting which deters exporters' entry. Moreover, in my models, future good news matters and affects early and late entry differently as early and late entrants hold different demand beliefs. The intuitive option value of waiting can be compensated by extra benefits of early learning due to early entry. I second examine the effect of variance of posterior beliefs on entry decision which sheds light on how export decision is affected by TPU as exporting age varies. The prediction of good news effect is tested using HS6 product-level exports between WTO countries. I shut down the bad news channel by focusing on the product lines of which the positive applied MFN tariff equals to bound tariff and take the signature of trade agreements as the future good news. For these product lines that face no risk of a higher tariff, the probability of a bilateral product-level trade flow being positive starts to increase 6 years before the signature of the trade agreement, which suggests that the good news channel may actually work.

Keywords: Learning, Trade policy uncertainty

1. Introduction

A growing body of empirical evidence has suggested that when making export decision, potential exporters take not only applied tariffs but also trade policy uncertainty (TPU) into account.¹ That's why during the Uruguay round, one major goal of WTO was to increase the amount of trade under binding commitments.² For a long time, much effort has been made to strengthen trade relationship between countries and TPU has decreased a lot especially during 90s.³ However, in recent years, there has been a sharp increase in TPU.⁴ In G20 emerging economies, the percentage of import product lines subject to any imposed temporary trade barriers gradually increased from 0.56 percent in 1995 to 2.78 percent in 2013. In Europe, after four years of negotiation, the UK and EU finally reached a Brexit deal at the end of 2020. Since December 2019, the Appellate Body of the World Trade Organization (WTO) has ceased functioning as the US blocked judge reappointment in order to reform the WTO. In fact, even a trade war is not far away from today's international market. The intense trade dispute between the US and China has been ongoing for more than two years since 2018. Furthermore, trade policy is being used to deal with non-trade issues more often in recent years.⁵ Although the sharp increase in TPU over the last few years is mainly driven by the threat of higher tariffs, it doesn't mean that a lower tariff world is impossible. The Trans-Pacific Partnership (TPP) was signed during the presidency of Obama and could have been successful if the Trump administration hadn't opposed the deal.⁶ As for the current US and China dispute, the "Phase One" Deal was signed on January 15, 2020 and there is a possibility that a preferential trade agreement can be established after Trump's presidency.

In addition to TPU, potential exporters' entry decision can be affected by other factors. Recent literature finds that export dynamics is age dependent. Eaton, Eslava, Kugler, et al. (2007) firstly document that new exporters usually start small and exit export market quickly. Conditional on surviving, they grow fast at the beginning and become less likely to exit as export age increases. Demand learning is one of the mechanisms that can well explain findings on new exporters' dynamics.

In this paper, I study a potential exporter's decision to start exporting under TPU in the presence of demand learning. The goal is to verify if the result such that TPU reduces entry is robust in models that deviate from classical sunk cost model. Common wisdom is that TPU reduces exporters' entry. In canonical models with heterogeneous firms like Melitz (2003) and Das et al. (2007), sunk entry cost matters.⁷ Introducing TPU in a sunk cost model creates an option value of waiting which deters exporters' entry as pointed out by Handley and Limão (2017). However, Baley et al. (2020) argue that despite the dramatic increase in policy uncertainty, US

¹See Crowley et al. (2018), Handley (2014), Handley and Limão (2015) and Handley and Limão (2017).

²Bound tariffs are specific commitments made by individual WTO member governments which is the maximum MFN tariff level for a given commodity line. See a brief discussion on WTO binding commitments in Handley (2014). Using applied and bound tariffs data from 1996 to 2009, Bacchetta and Piermartini (2011) find that for bound tariff lines, the probability of an increase (decrease) in applied tariffs became lower (higher).

³There was a massive reduction of TPU as many countries were granted access to WTO during 90s.

⁴Caldara et al. (2020) construct a monthly TPU index based on the frequency of TPU-related terms mentioned in major newspapers and find that the average level of the TPU index has reached unprecedentedly high levels since 2017. Similarly, Baker et al. (2016) develop a monthly TPU index for the US based on the frequency of articles that discuss TPU-related topics in over 2,000 US newspapers. They discover that the index has risen sharply in recent years. Using the same method, they find that Brexit/EU economic uncertainty accounted for a significant proportion of the UK's total economic policy uncertainty after 2016.

⁵Since 2018, the Japan-South Korea trade dispute has been initiated as a response to a historical dispute over comfort women and forced labor during World War II. In 2020, president Macron stopped the negotiation on the EU-Mercosur trade agreement in order to force Brazil to deal with the severe deforestation problem in the Amazon rainforest.

⁶It is still unclear whether Biden administration will reenter the agreement.

⁷See also a discussion on sunk cost, fixed cost and uncertainty in Alessandria, Arkolakis, et al. (2021).

exports relative to GDP grew by 17 percent between 2016 and 2019, which raises the question of whether increasing TPU is an obstacle to entrants.⁸ If learning drives new exporter dynamics, it might be able to encourage firms' early entry under TPU. From the TPU perspective, by incorporating demand learning, I am able to explore the effect of TPU on entry with and without sunk cost. From the demand learning perspective, by adding TPU, my model also sheds light on the effect of exporting age on firms' export decisions under TPU.

I study both sunk cost learning and fixed cost learning models.⁹ Learning only lasts one period. Potential exporters hold prior belief. If they choose to enter, they will receive a signal at the end of their entry period and no more signals will be received after. Therefore, their posterior belief is constant after the entry period and can be either good or bad with equal probability, which depends on the signal they have received. Like Handley and Limão (2017), I assume that TPU follows a three-state Markov chain - good news state, intermediate state, and bad news state.¹⁰ I focus on entry cutoff in intermediate state. Entry cutoff firms are those who are indifferent between entering and waiting in the current state. In my model, there are 2 effects of TPU. One is the same as that of H&L and follows a *bad news principle* which was proposed in Bernanke (1983).¹¹ Bad news discourages exporters' entry since potential entrants can prevent loss in future possible bad state by waiting. More precisely, intermediate-state entry cutoff firms prefer to wait in bad state.¹² A higher tariff in bad state only reduces the profits of early entry and makes early entry less appealing. The other effect comes from good news. If entry cutoff firms choose to enter(wait) in the current intermediate-state period, they will hold posterior(prior) belief in the next period. Therefore, future possible good news affects the value of entry and waiting differently. Combining the two effects above, the net effect of TPU is ambiguous.

Unlike H&L model, good news matters in my model as new exporters are different from old ones. More specifically, I show that, in sunk cost learning model, the effect of good news on intermediate-state entry cutoff is always positive. Cutoff firms are willing to enter in good state. A lower tariff in good state increases the profits of both early entry and waiting. Without per period fixed cost, per period expected export profit is always positive using CES demand and exporters keep exporting whatever the posterior belief they hold. In Lemma 2, I show that tariff reduction in good state benefits early entry relatively more and encourages firms' early entry. It is because, in per period profit function, the expectation of the posterior belief-related term is greater than that of the prior belief-related term. When the tariff is lower in the future good state, firms are more willing to start exporting and acquire more knowledge about their demand. In other words, potential entrants prefer to export in the future possible good state with more knowledge.

Moreover, I show that in fixed cost learning model, the effect of future good news on entry cutoff can be negative. Using fixed cost, there is endogenous exit given that per period expected export profit can be negative. In both TPU and no TPU cases, entry cutoff firms make negative profit in their entry period in order to benefit from extra profits in future better scenarios. As good state tariff is not low enough, in good state, intermediate-state entry cutoff firms make positive profit only conditional on holding good posterior belief. In this case, if good belief is

⁸They propose a two-country general equilibrium model to explain the trade promotion effect of TPU. There exists cross-border information friction which generates uncertainty about the other country's endowment. Therefore, terms-of-trade is uncertain, which affects domestic exporting decisions. Higher uncertainty can promote trade in some cases since trade can be seen as a way of risk sharing. Nevertheless, they don't consider firm-level entry decisions.

⁹Handley and Limão (H&L) use sunk cost to generate state dependence. Since demand learning also generates state dependence, I can study the effect of TPU using fixed cost only.

¹⁰Good news/intermediate/bad news state refers to low/medium/high tariff state respectively.

¹¹Throughout the rest of the paper, H&L refers to Handley and Limão.

¹²In fixed cost learning model, the condition such that intermediate-state entry cutoff firms prefer to wait in bad state and enter in good state is not always satisfied. Some extra restrictions need to be imposed.

not sufficiently greater than prior belief, reducing good state tariff will increase the profits of waiting relatively more and deter entry. Namely, while good posterior belief is greater than prior belief, the probability of obtaining good posterior belief is only one half, which is risky. Given the risk of not reaching the best-case scenario of a low tariff and a good posterior belief, and the fact that firms incur negative expected profits during the entry period, a late entry in the future good state can be preferred if the good posterior belief is not favorable enough. If good state tariff is sufficiently low, intermediate-state cutoff exporters will be able to make positive profit conditional on bad belief. In this case, reducing good state tariff increases profits of early entry more, which is similar to sunk cost learning model.

I explore the effect of pure uncertainty by modelling TPU as a mean-preserving spread of tariff. Enlarging the difference between bad and good state tariffs increases TPU. Since per period profit is a convex function of tariff, the net marginal negative effect of bad news on early entry becomes smaller as bad state tariff increases. As the good state tariff decreases, the net marginal effect of good news on early entry becomes positive and increases if learning is profitable enough. As bad and good states are close to intermediate state, marginal negative effect of bad news dominates and TPU deters exporters' entry. However, as bad and good states become very different, marginal effect of good news can be positive and dominate marginal negative effect of bad news. Therefore, it's possible that a high TPU induces more entry.

I also explore the effect of the variance of posterior beliefs on entry threshold under TPU relative to no TPU case. In both TPU and no TPU cases, entry threshold is a function of posterior-beliefs variance and the relative change of these two thresholds depends on TPU process. As the variance of posterior beliefs increases and learning becomes more profitable, the effect of the variance of posterior beliefs on relative entry threshold is monotonic in sunk cost learning model but not in fixed cost learning model. Since the variance of posterior beliefs correlates negatively with exporters' age, my model is able to shed light on the effect of TPU across different ages.

In addition to my theoretical contributions, I test empirically my model prediction. Given that good news matters in my models but not in H&L partial equilibrium model, my empirical strategy is to test the good news effect. However, empirically, it is challenging to distinguish between the bad news channel and the good news channel as they often occur simultaneously. For instance, a future trade agreement can imply a lower risk of a higher tariff (bad news channel) and a higher chance of a lower tariff (good news channel). In this case, both channels have an effect on the export decision, making it difficult to determine whether the entry decision change is driven by the good news effect or the bad news effect. In order to test the good news channel separately, my strategy is to shut down the bad news channel entirely and test only the good news effect. More specifically, I study the product lines in which the positive applied MFN tariff equals the bound tariff, i.e., the maximal MFN tariff level that can be imposed. I consider the signature of the trade agreement as good news. After a trade agreement is signed, the applied MFN tariff can be replaced by a lower bilateral preferential tariff. Faced with the future possible signature of the trade agreement, a reduction in future applied tariffs becomes more probable and my sunk cost learning model predicts that there should be more entry before the official signature of a trade agreement. I focus on the WTO country pairs and use the product-level entry as an indirect measure of the firm entry following Handley (2014). My empirical results indicate that there is more product entry before the year of the signature and the findings are robust to different specifications. The probability of a product being traded bilaterally begins to increase six years before the signature, suggesting that future good news has a positive effect on current entry and the good news channel works.

The current paper builds on two independent pieces of literature - the literature on exports under TPU and the literature on firm dynamics. Using a sunk cost model, Handley (2014) and Handley and Limão (2015) study the effect of TPU on entry cutoff. In a partial equilibrium,

they predict that increasing TPU deters firms' early entry more.¹³ Handley and Limão (2017) extend their partial equilibrium model to a general equilibrium model where aggregate price is an endogenous variable. The entry deterrence effect is not robust in some extreme cases.¹⁴ Based on the canonical Melitz model, Feng et al. (2017) assume that per-period fixed export cost is increasing in total mass of exporting firms and uncertainty reduction is equivalent to lower expectation of tariff payments. Therefore, a decrease in TPU selects more(less) productive firms into(out of) the exporting market. However, in the models above, new entrants are similar to incumbents and there is no age dependence.

The canonical sunk cost model is not the only way to study the effect of TPU. Alessandria, Khan, et al. (2019) introduce TPU into a (s, \bar{s}) inventory model and study the effect of yearly TPU shock on monthly import flow. Unlike H&L, they focus on the fluctuation of high frequency trade flow within each year. Using a DSGE model with endogenous customer accumulation, Steinberg (2019) numerically disentangles the cost of Brexit TPU from other macroeconomic factors. The entry threshold is analytically intractable. Conversely, my paper tries to analyze the entry threshold analytically and I aim to build a model as simple as possible.

Empirically, Handley (2014) studies the effect of tariff binding commitments during the Uruguay Round using Australian import data and predicts that the growth of product varieties would have been 7% lower if Uruguay Round had not been implemented. In a counterfactual exercise, Handley and Limão (2015) find that if Portugal's accession to European Community had only reduced applied tariffs but not TPU, it would have achieved only 20 percent of the total predicted growth for entry and less than 30 percent for total exports. In a general equilibrium framework, Handley and Limão (2017) study the increase of China's export to the US during the period of China's WTO accession and estimate an effect of reducing TPU being equivalent to a decrease in permanent tariff on Chinese goods by 13 percentage points.¹⁵ Using H&L framework, Crowley et al. (2018) study the indirect effect of anti-dumping duties using Chinese export data between 2000 and 2009. They assume that, within a firm, imposing anti-dumping duty on a product-market pair generates TPU on this product and closely-related products in other markets. They also assume that policy information can be transferred across neighboring exporters. The empirical findings support their assumptions. Alessandria, Khan, et al. (2019) find that each year before the annual revision of China's MFN status, imports from China rose. However, this temporary trade increase cannot compensate for the overall trade-dampening effect in the long term.

In the firm dynamics literature, demand learning is one of the mechanisms used to model new entrants' behavior.¹⁶ Jovanovic (1982) studies firm dynamics by assuming that firms learn gradually and imperfectly about their unobserved type. Arkolakis et al. (2018) incorporate Jovanovic's Bayesian learning in a standard monopolistically competitive environment with firm productivity heterogeneity. They find that the model predictions are consistent with empirical findings using Colombian manufacturing plant-level data. Albornoz et al. (2012) develop a model where firms' exporting profitability is correlated over time and across destinations and the knowledge on profitability is obtained through experimentation. Their model explains why new exporters export little, exit easily, and why firms enter foreign markets sequentially. Using a fixed-effect strategy, Berman et al. (2019) show that a few empirical findings such as firm-market-specific prices and the negative correlation between the variance of growth rates and

¹³Their model is able to give a closed form solution of entry threshold.

¹⁴In a general equilibrium model, if the current realization of intermediate state tariff τ_1 is close to bad state tariff τ_2 , TPU can encourage firms' entry. As τ_1 is close to τ_2 , the future tariff cannot be much higher than the current intermediate tariff and the TPU process will be unfavorable to foreign domestic firms, which leads to less entry of foreign domestic firms and pushes up foreign price.

¹⁵Feng et al. (2017) find that after China's accession to WTO, in the US market, new Chinese exporters are more productive while those who exit are less productive.

¹⁶See also Timoshenko (2015a) and Timoshenko (2015b).

age can be explained by Bayesian demand learning while alternative demand side mechanisms fail to explain these findings. Chen et al. (2019) provide direct evidence of export learning by exploiting the data on sales forecast of Japanese firms. Other mechanisms have also been proposed to model new exporter dynamics.¹⁷

The literature on new exporter dynamics above hasn't formally studied entry decisions under TPU, as it mainly focuses on the problem of post-entry dynamics. Furthermore, Handley and Limão's series of papers on exporters' entry under TPU haven't taken into consideration the post-entry specialty of new exporters. This paper attempts to bridge the two pieces of literature by employing a simplified demand learning mechanism to study exporter's entry decisions under TPU using a partial equilibrium framework.

The remainder of the paper is organized as follows: Section 2 provides a general setting. In Section 3, a benchmark model is presented, where TPU is studied using the sunk cost learning model. The fixed cost learning model is presented in Section 4. Section 5 provides a discussion of the suggestive evidence, and Section 6 concludes the paper.

2. General assumptions

In this section, I provide a general setting which is applicable to both sunk cost learning and fixed cost learning models. In sunk cost learning model, per period fixed cost f is assumed to be 0 while in fixed cost learning model, sunk entry cost S is assumed to be 0. I consider a small open economy where monopolistically competitive exporters produce differentiated goods and foreign aggregate variables are taken as constant. There are infinite periods.

2.1. Consumer's demand

Representative consumer spends a fixed share of income on homogeneous goods and the remaining on differentiated goods. The utility function is:

$$U_t = C_t^\mu Y_t^{1-\mu} \quad (1)$$

Where C_t is the aggregate consumption of differentiated goods and Y_t is the aggregate consumption of homogeneous goods.¹⁸ Both are tradable. The aggregate consumption of differentiated goods is

$$C_t = \left[\int_{\omega \in \Omega_t} (e^{a_t(\omega)})^{\frac{1}{\sigma}} q_t(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad (2)$$

Where $a_t(\omega)$ is the demand shock realization of variety $\omega \in \Omega_t$ in period t . Consumer maximizes C_t such that budget constraint $\int_{\omega \in \Omega_t} p_t(\omega) q_t(\omega) d\omega = P_t C_t \leq \mu R_t$ is satisfied. P_t is aggregate price index and R_t is aggregate revenue.¹⁹ I assume that foreign aggregate variables are constant which are not affected by the small economy. The solution of consumer's problem is

$$q_t(\omega) = e^{a_t(\omega)} \left(\frac{p_t(\omega)}{P_t} \right)^{-\sigma} C_t \quad (3)$$

¹⁷Ruhl and Willis (2017), Foster et al. (2016), Piveteau (2016) and **fitzgerald2016** propose demand accumulation model. Aeberhardt et al. (2014) and Eaton, Eslava, Krizan, et al. (2014) propose matching and learning model.

¹⁸Competitive homogeneous goods sector pins down the wage at unity.

¹⁹ $P_t = \left[\int_{\omega \in \Omega_t} e^{a_t(\omega)} p_t(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$

2.2. Firms' problem

Potential exporters of differentiated goods know their own productivity φ . At the beginning of each period, they can observe the realization of trade policy τ in the current period. In addition, they face an idiosyncratic demand shock. Figure 1 illustrates how demand shock evolves for a particular firm. Enter means export for the first time. If a firm enters in period t , at the beginning of period t , it will draw a true underlying demand parameter θ (θ_H or θ_L) which is unobservable and $\theta_H \geq \theta_L$. The realization of demand shock a_t in period t could be either θ_H or θ_L and its probability distribution depends on θ that firm draws. a_t is observable at the end of entry period t . p is assumed to be greater than $\frac{1}{2}$, which means the probability of $a_t = \theta_H$ is higher as $\theta = \theta_H$. By observing a_t , firm is able to form a posterior expectation about its true underlying demand parameter θ . For a firm that hasn't entered the export market, it has no demand shock to observe and holds only prior expectation.

I also assume that, for a firm that enters in period t , if it exports in period $t + 1$, $t + 2$, and so on, the demand shock realization will be its true underlying demand parameter θ that it has drawn in the entry period t . However, it can no longer observe its demand shock realizations from period $t + 1$ to period infinite.²⁰ I need to mention that assuming a multiple-period learning process is not a problem for the sunk cost learning model. In the sunk cost learning model, once a firm chooses to start to export, it doesn't exist the export market endogenously as there is no per-period fixed cost and per-period profits are always positive.²¹ When comparing the value of entering against waiting, I compare the value of starting to export&learn right now with the value of starting to export&learn later. As firms don't exit endogenously after entry, the total export&learning value is deterministic and exogenous. A potential exporter's value is a function of its productivity and current trade policy realization. Given that writing the value of exporting recursively using a multiple-period learning process is still feasible, assuming a multiple-period learning process would be similar to the one-period learning process and the results should also be similar.

However, in the fixed-cost learning model, firms' per-period profits can be negative and firms can choose to exit exporting markets endogenously. In this case, the value of exporting versus the value of waiting in the current period depends on the firm's current specific learning process and all its future possible paths. In other words, all firms (fresh+incumbents) are potential exporters in the current period. A firm that exported in the last period may endogenously choose to exit in the current period and re-enter in the future periods. Firms' value is a function of their productivity, the current trade policy realization, and their specific learning process. Therefore, the problem becomes intractable once I include a multiple-period learning process. In the section of the fixed-cost learning model, I show that even with the one-period learning process, the problem is not fully tractable and future possible lower tariffs can actually deter firms' current entry.

²⁰ Assuming one-period learning simplifies the dynamic problem. One-period learning cannot fully capture firm's learning dynamics across different periods while it can still provide some insights into how demand learning and TPU jointly affect firm's entry decision. Assuming demand shock realizations from period $t + 1$ to period infinite are no longer observed implies that firm no longer observes its export revenue after period t . As $p = 1$, firms are assumed to be able to observe their true underlying demand parameter θ at the end of period t .

²¹ It is also because learning brings a higher value than not learning ex-ante.

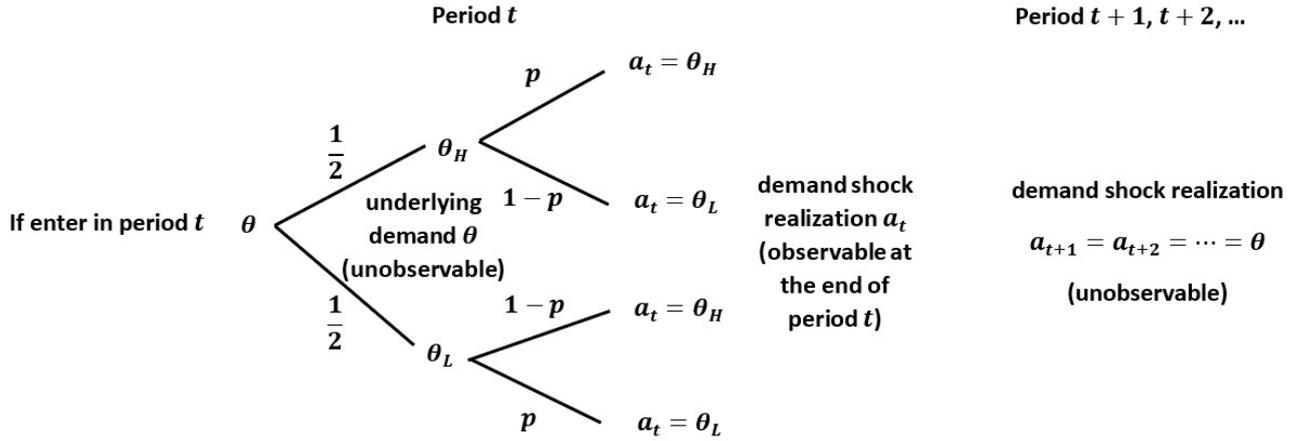


Figure 1: Demand shock

As in Handley and Limão (2017), the TPU process follows a three-state Markov chain. If the current state is high tariff state τ_2 (low tariff state τ_0), the state in the next period will also be τ_2 (τ_0). If the current state is intermediate tariff state τ_1 , with probability $1 - \gamma$, the state will be τ_1 in the next period and with probability $\gamma\lambda_2$ ($\gamma(1 - \lambda_2)$), the state will be τ_2 (τ_0) in the next period. I assume that $\tau_2 \geq \tau_1 \geq \tau_0$. τ_2 is bad news state and τ_0 is good news state. I focus on firm's entry decision in intermediate state τ_1 and also study the effect of pure uncertainty by assuming that τ_2 and τ_0 are a mean-preserving spread of τ_1 and $\tau_1 = \lambda_2\tau_2 + (1 - \lambda_2)\tau_0$. The mean-preserving spread can be rewritten as $\tau_2 = \delta\tau_1$ and $\tau_0 = \frac{1-\lambda_2\delta}{1-\lambda_2}\tau_1$ with $\delta \geq 1$ and $\tau_0 \geq 1$. Figure 2 illustrates the TPU process.²²

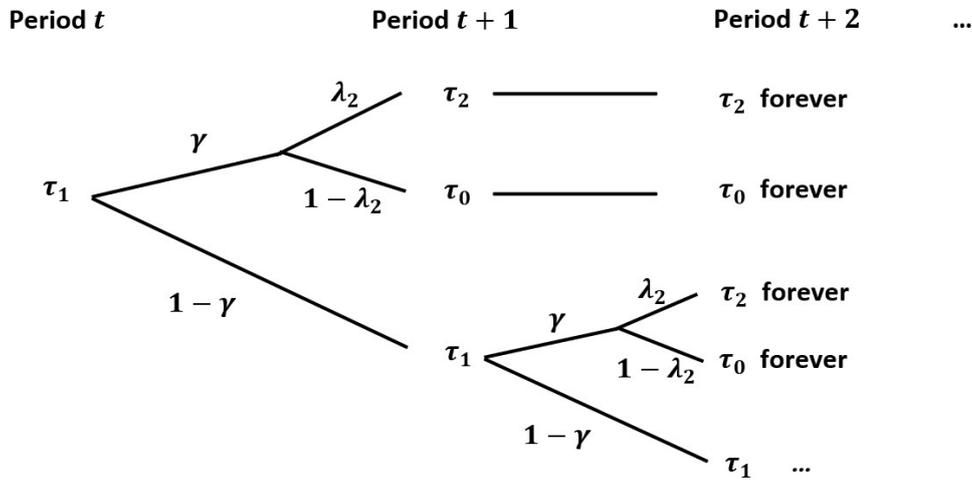


Figure 2: TPU process

As a firm decides to export in period t , the quantity of goods being exported doesn't affect its learning about demand shock at the end of period t . Therefore, once a firm chooses to export in period t , it produces a quantity such that the expected profit of current period is maximized. For an exporter with productivity φ that exports in period t , its conditional expected per period

²²A more complicated TPU process can be introduced if it follows a first-order stochastic dominance process, which implies that as the tariff goes up, it is weakly less likely that the tariff becomes lower. Nevertheless, introducing a more complicated TPU process shouldn't alter my main results.

profit in period t will be

$$E_t \pi_t(\varphi, \tau_t, \bar{a}_t) = E_t \left(\frac{p_t q_t}{\tau_t} - \frac{q_t}{\varphi} - f | \varphi, \tau_t, \bar{a}_t \right) \quad (4)$$

Where $\tau_t \geq 1$ is the realization of ad valorem tariff in period t which is observable at the beginning of period t and \bar{a}_t is firm's past demand shock realization.²³ f is per period fixed cost. If period t is firm's entry period, it will make production decision without any information about its underlying demand parameter θ at the beginning of period t . If its entry period is period $t - i$ with $i \geq 1$, in period t , the firm will make production decision based on the signal $\bar{a}_t = a_{t-i}$ it has received in entry period $t - i$.²⁴ The exporter in period t maximizes $E_t \pi_t$ by choosing production quantity q_t conditional on its private information φ , \bar{a}_t and public information τ_t given that $p_t = \left(\frac{e^{a_t} \mu R}{q_t} \right)^{\frac{1}{\sigma}} P^{\frac{\sigma-1}{\sigma}}$.²⁵ The quantity being chosen is

$$q_t = \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma} \left(\frac{b_t \varphi}{\tau_t} \right)^{\sigma} \frac{\mu R}{P^{1-\sigma}} \quad (5)$$

Where b_t is firm's belief about its demand shock realization in period t . More specifically, if $t - i$ is entry period and $\bar{a}_t = a_{t-i} = \theta_H$, firm's belief in period t will be a high posterior belief $b_t(\bar{a}_t = \theta_H) = E_t \left(e^{\frac{a_t}{\sigma}} | \bar{a}_t = \theta_H \right) = b_H$. If $\bar{a}_t = a_{t-i} = \theta_L$, firm's belief in period t will be a low posterior belief $b_t(\bar{a}_t = \theta_L) = E_t \left(e^{\frac{a_t}{\sigma}} | \bar{a}_t = \theta_L \right) = b_L$. If t is entry period, firm's belief in period t will be a prior belief $b_t = E_t \left(e^{\frac{a_t}{\sigma}} \right) = b_M$ which is an unconditional expectation. Firms don't forget their posterior belief even if they stop exporting. As shown in Appendix A, $b_H \geq b_M \geq b_L > 0$ and $b_H + b_L = 2b_M$, which can be rewritten as $b_H = \varepsilon b_M$ and $b_L = (2 - \varepsilon) b_M$ with $\varepsilon \in [1, 2)$. Figure 3 illustrates the belief process where $\frac{1}{2}$ is the unconditional probability such that belief is high b_H (low b_L). Bring the quantity decision back into expected profit function and the solution of per period expected profit of exporting is

$$E_t \pi_t(\varphi, \tau_t, \bar{a}_t) = \frac{(\sigma - 1)^{\sigma-1}}{\sigma^{\sigma}} b_t^{\sigma} \tau_t^{-\sigma} \varphi^{\sigma-1} \frac{\mu R}{P^{1-\sigma}} - f \quad (6)$$

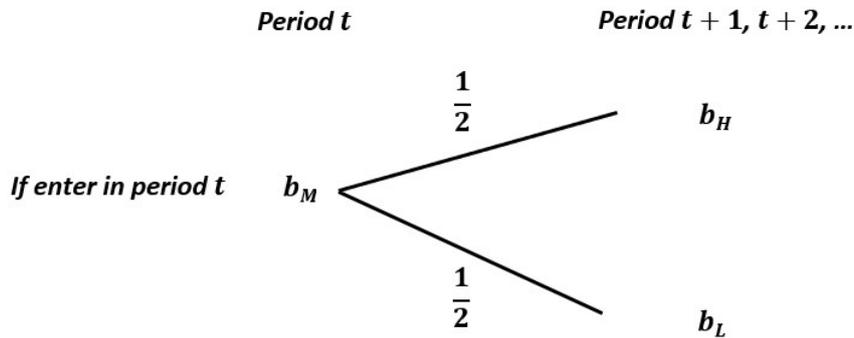


Figure 3: Demand belief

²³The result of iceberg cost is very similar to that of ad valorem tariff.

²⁴Because I assume that learning process only lasts one period. If period t is entry period, \bar{a}_t will be empty. If period $t - i$ is entry period, $\bar{a}_t = a_{t-i}$.

²⁵As foreign aggregate variables are assumed to be constant, $R_t = R$ and $P_t = P$. The learning process lasts for one period and only the entry period price can be observed at the end of entry period, which means firms can only observe their export revenue in the entry period.

The solution of exporter's conditional per period expected profit depends on her productivity φ , current trade policy realization τ and her current belief b . Equation (6) can be rewritten as

$$\pi(\varphi, \tau, b) = b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k - f \quad (7)$$

Where $k = \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} \frac{\mu R}{P^{1-\sigma}}$ is a constant. Recall that the unconditional probability of having a high belief b_H (low belief b_L) is $\frac{1}{2}$ and $b_H + b_L = 2b_M$. There is $\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma \geq b_M^\sigma$ as $\sigma > 1$. Unconditionally, exporter prefers knowing the signal to not knowing the signal, which is equivalent to saying that exporter prefers more knowledge about her true underlying demand parameter.²⁶

3. Sunk cost and learning

In this section, I introduce one-period demand learning in the partial equilibrium model of Handley and Limão (2017) where potential exporters pay sunk cost S to enter and there is no per period fixed cost ($f = 0$). Table 1 compares H&L partial equilibrium model with my sunk cost learning model. If there is no demand learning and $b_H = b_L = b_M$, sunk cost learning model will be equivalent to H&L partial equilibrium model. Therefore, H&L partial equilibrium model can be seen as a special case of my model. However, as there is no fixed cost, neither models can capture endogenous exit.²⁷ I first give the benchmark entry threshold φ_1 in a no TPU case and then consider a case with TPU.

| | H&L (2017) | sunk cost learning |
|--|--|--|
| sunk entry cost | $S > 0$ | $S > 0$ |
| fixed cost | $f = 0$ | $f = 0$ |
| endogenous exit | no | no |
| expected per period profit | $b_M^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$ | $b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$ b_M if entry period; b_H or b_L otherwise |
| solution of $\frac{\varphi_{1u}}{\varphi_1}$ relative entry threshold under TPU | explicit | explicit |
| bad news effect | negative | negative |
| good news effect | no | positive |
| TPU deters entry only $\frac{\varphi_{1u}}{\varphi_1} \geq 1$ | yes | depends |

Table 1: Difference between H&L (2017) and sunk cost learning model

3.1. No TPU case

Define φ_1 as the entry threshold in a case where there is no TPU and tariff is constant τ_1 for all periods. Define $\Pi_e(\varphi, \tau)$ as the expected value of exporting after entry (after paying sunk cost) with entry condition being τ and φ . In the absence of TPU, for potential exporters, entry condition remains the same in each period. Therefore, waiting cannot generate additional profits

²⁶The inequality I have in a demand learning model is similar to that in a passive customer base accumulation model, where ex-ante exporting brings a higher expected value of the customer-base-related terms compared to not exporting.

²⁷In the latter section, I show that fixed cost complicates the model much. Therefore, I don't further study a model where both sunk cost and fixed cost are included.

and entry cutoff firms are those whose expected value of exporting after entry equals sunk entry cost S . We have

$$\Pi_e(\varphi_1, \tau_1) = \pi(\varphi_1, \tau_1, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \left[\pi(\varphi_1, \tau_1, b_H) + \pi(\varphi_1, \tau_1, b_L) \right] = S \quad (8)$$

$$\Leftrightarrow \varphi_1^{\sigma-1} = \frac{S\tau_1^\sigma}{\left[b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} (b_H^\sigma + b_L^\sigma) \right] k} \quad (9)$$

$$\Rightarrow \varphi_1^{*\sigma-1} \Big|_{b_H=b_L=b_M} = \frac{S\tau_1^\sigma}{\left[b_M^\sigma + \frac{\beta}{1-\beta} b_M^\sigma \right] k} \quad (10)$$

Where β is the discount factor which combines the true discount rate and an exogenous death shock. φ_1^* is H&L entry threshold without TPU. Recall that $\frac{1}{2}(b_H^\sigma + b_L^\sigma) \geq b_M^\sigma$. Therefore, $\varphi_1 \leq \varphi_1^*$ and demand learning can bring extra entrants. Since $b_H = \varepsilon b_M$ and $b_L = (2 - \varepsilon)b_M$, as the variance measure of posterior beliefs ε increases, φ_1 decreases and there will be more entrants.²⁸ The higher the variance measure of belief ε , the more profitable learning becomes.

3.2. TPU case

In this section, I consider a case with TPU. The expected value of exporting after entry $\Pi_e(\varphi, \tau)$ can be rewritten using a recursive formula.²⁹

$$\Pi_e(\varphi, \tau) = f(\varphi, \tau) + \beta E_\tau \Pi_e(\varphi, \tau') \quad (11)$$

Where τ is the current trade policy realization and τ' is the trade policy realization in the next period. Unlike H&L (2017), $f(\varphi, \tau)$ is no longer the current per period profit $\pi(\varphi, \tau, b)$. The prior belief in the entry period b_M is different from those in post-entry periods (b_H or b_L) and this difference needs to be taken into account when writing $f(\varphi, \tau)$. Therefore, in $f(\varphi, \tau)$, factor $\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma$ appears. Define $\Pi(\varphi, \tau)$ as the expected value under trade policy τ for a firm φ .

$$\Pi(\varphi, \tau) = \max \left\{ \Pi_e(\varphi, \tau) - S, \beta E_\tau \Pi(\varphi, \tau') \right\} \quad (12)$$

The value of $\Pi(\varphi, \tau)$ is the maximum between entering in the current period $\Pi_e(\varphi, \tau) - S$ and waiting in the current period $\beta E_\tau \Pi(\varphi, \tau')$. Minus each side by $\Pi_e(\varphi, \tau) - S$ in (12) and bring (11) into (12).

$$\Pi(\varphi, \tau) - \Pi_e(\varphi, \tau) + S = \max \left\{ 0, \beta E_\tau \left[\Pi(\varphi, \tau') - \Pi_e(\varphi, \tau') + S \right] - f(\varphi, \tau) + (1 - \beta) S \right\} \quad (13)$$

$\Pi(\varphi, \tau) - \Pi_e(\varphi, \tau) + S$ is the value net of the profits of entering in the current period. If it's positive, firm φ will choose to wait in the current period. If it's 0, firm φ will enter in the current period. Define $V(\varphi, \tau) = \Pi(\varphi, \tau) - \Pi_e(\varphi, \tau) + S$ as the net value of waiting. The above equation can be rewritten as

$$V(\varphi, \tau) = \max \left\{ 0, \beta E_\tau V(\varphi, \tau') - f(\varphi, \tau) + (1 - \beta) S \right\} \quad (14)$$

I am only interested in the entry threshold in intermediate tariff state $\tau_1 - \varphi_{1u}$. φ_{1u} firms are indifferent between entering and waiting under τ_1 . Therefore, the following condition should be satisfied.

$$\beta E_{\tau_1} V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_1) + (1 - \beta) S = 0 \quad (15)$$

²⁸Note that ε is not the actual variance of posterior beliefs but they are positively correlated. In this paper, I refer to ε as the variance measure of posterior beliefs.

²⁹See Appendix B for more details.

Equation (15) implies that $V(\varphi_{1u}, \tau_1) = 0$. $V(\varphi_{1u}, \tau_0) = 0$ and $V(\varphi_{1u}, \tau_2) > 0$ are also satisfied. φ_{1u} firm is willing to enter in low tariff state τ_0 and wait in high tariff state τ_2 .³⁰ The explicit solution of $\frac{\varphi_{1u}}{\varphi_1}$ is³¹

$$\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} = \frac{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)}{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (16)$$

Where $b(\varepsilon) = \varepsilon^\sigma + (2 - \varepsilon)^\sigma$ and $b(\varepsilon) - 2 \geq 0$. Good belief b_H is replaced by εb_M and bad belief b_L is replaced by $(2 - \varepsilon)b_M$. In the above equation, all b_M terms cancel out. As $\varepsilon = 1$, $b_H = b_L = b_M$ and we have H&L solution $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$.

$$\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} \Big|_{\varepsilon=1} = \frac{1 + \frac{\beta}{1-\beta}\gamma\lambda_2}{1 + \frac{\beta}{1-\beta}\gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \geq 1 \quad (17)$$

In H&L, $\varphi_{1u}^* \geq \varphi_1^*$. Firm's entry threshold is greater under TPU and TPU only deters firm's entry. Additionally, the negative effect of TPU is exclusively due to the high tariff τ_2 , which is referred to as *bad news principle*. However, in equation (16), low tariff state τ_0 also affects the solution of $\frac{\varphi_{1u}}{\varphi_1}$. Good news τ_0 matters because learning is introduced, and incumbents and potential exporters hold different beliefs. In the absence of TPU, the solution of $\frac{\varphi_{1u}}{\varphi_1}$ simply equals 1.

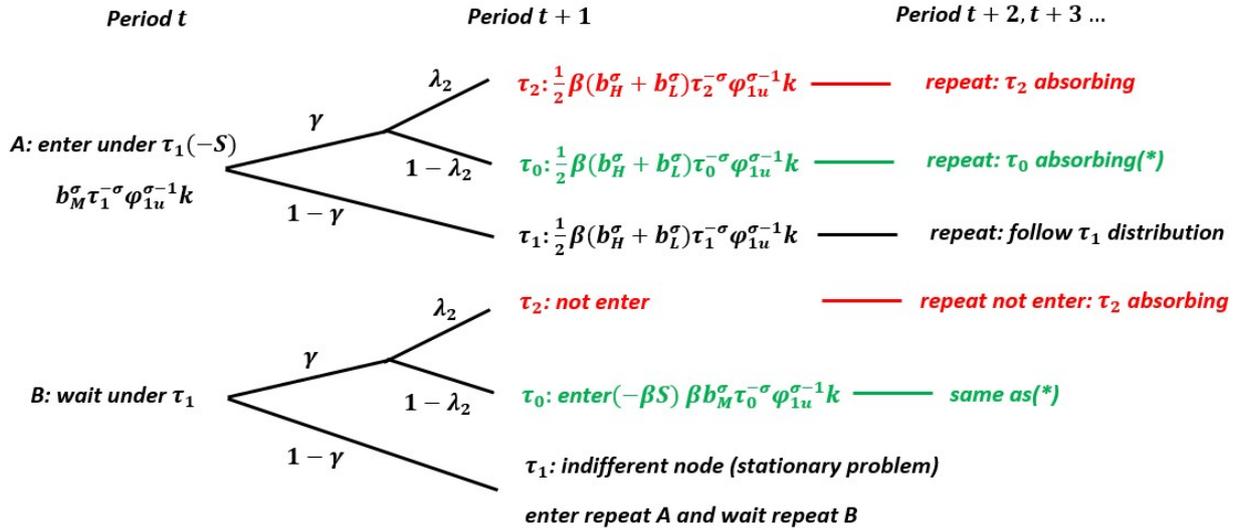


Figure 4: Sunk cost decision tree

Figure 4 depicts the decision tree of entry cutoff firms φ_{1u} . φ_{1u} firms are indifferent between entering and waiting in intermediate tariff state τ_1 . The terms highlighted in red are those related to bad news τ_2 , while the ones highlighted in green are those related to good news τ_0 .³² There are two following lemmas.

³⁰See more discussion on the value function $V(\varphi, \tau)$ in Appendix C

³¹ $\frac{\varphi_{1u}}{\varphi_1}$ is the relative entry threshold under TPU. See Appendix D for more details.

³²There are actually two additional terms in black that are also related to τ_2 and τ_0 : *repeat: follow τ_1 distribution*

Lemma 1

Bad news principal: increasing bad state tariff τ_2 increases $\frac{\varphi_{1u}}{\varphi_1}$ and deters firms' early entry under TPU.

Proof: from equation (16), it's easy to verify that $\frac{\varphi_{1u}}{\varphi_1}$ increases in τ_2 .

The intuition behind bad news principal is simple. Let us focus on the red terms in Figure 4. Since entry cutoff firms φ_{1u} are willing to wait under τ_2 , increasing bad state tariff τ_2 has no effect on the value of red term in option B - waiting under τ_1 . However, a higher τ_2 will reduce the value of red term in option A - entering under τ_1 directly. Therefore, future possible bad state creates an option value of waiting and a higher bad state tariff only deters firms' early entry more. It is also easy to verify that as the probability of reaching bad tariff state λ_2 increases, $\frac{\varphi_{1u}}{\varphi_1}$ increases and there are fewer entrants under TPU.³³

Lemma 2

Good news principal: decreasing good state tariff τ_0 decreases $\frac{\varphi_{1u}}{\varphi_1}$ and encourages firms' early entry under TPU.

Proof: from equation (16), it's easy to verify that $\frac{\varphi_{1u}}{\varphi_1}$ increases in τ_0 .

Now let us focus on the green terms in Figure 4. Since entry cutoff firms φ_{1u} are willing to enter in low tariff state τ_0 , decreasing good state tariff τ_0 increases value of green terms in both option A and option B - entering and waiting under τ_1 simultaneously. Recall that $b_H^\sigma + b_L^\sigma \geq b_M^\sigma$. Learning can bring extra profits and entering early means learning early. Therefore, the effect of decreasing τ_0 is magnified by early learning and decreasing τ_0 encourages firms' early entry more. In other words, firms prefer to have more knowledge about their underlying demand parameter as good news comes.³⁴ In order to capture the pure effect of uncertainty, I consider a special case where TPU is a mean-preserving spread (MPS). Substitute τ_2 by $\delta\tau_1$ and τ_0 by $\frac{1-\lambda_2\delta}{1-\lambda_2}\tau_1$. The solution of $\frac{\varphi_{1u}}{\varphi_1}$ is

$$\begin{aligned} & \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} \Big|_{MPS} \\ &= \frac{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)}{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma\lambda_2\delta^{-\sigma} + \gamma(1-\lambda_2) \left(\frac{1-\lambda_2\delta}{1-\lambda_2}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \delta^{-\sigma}} \end{aligned} \quad (18)$$

δ measures the distance between high tariff τ_2 and intermediate tariff τ_1 . The larger δ is, the higher the variance of tariff shock is. Therefore, δ is one of the TPU measures. There is a following proposition.

and τ_1 : *indifferent node*. However, upon closer examination, these terms are found to simply repeat the red and green terms. If option A is chosen in the indifferent node, the two black terms will cancel out from period $t + 2$. If option B is chosen, then the two black terms will repeat the same thing as in period $t + 1$ from period $t + 2$ onwards. Therefore, the red and green terms effectively capture the sign of the marginal effects of τ_2 and τ_0 on the entry threshold φ_{1u} .

³³See Appendix E for more details.

³⁴It will be easier to understand good news principal if we consider demand learning as another form of passive customer base accumulation. When good news comes, firms always prefer to have a larger customer base at the same time.

Proposition 1

As the level of TPU increases from zero - $\delta = 1$, $\frac{\varphi_{1u}}{\varphi_1}$ initially increases, resulting in fewer entrants. However, $\frac{\varphi_{1u}}{\varphi_1}$ may start to decrease if δ becomes sufficiently large, leading to more entrants.

Proof: instead of taking the first and second derivative of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$ regarding δ , take the first and second derivative of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$. It is easy to verify that $\frac{\partial^2 \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \delta^2} > 0$ (convexity) and $\left. \frac{\partial \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \delta} \right|_{\delta=1} < 0$.

Recall that, bad news τ_2 only affects red terms in option *A* - enter under τ_1 while good news τ_0 affects green terms in both option *A* - enter under τ_1 and option *B* - wait under τ_1 . Therefore, the net negative effect of bad news on early entry persists for multiple periods in bad state while the net positive effect of good news on early entry is only for one period in good state.³⁵ Also recall that per period profit $\pi(\varphi, \tau, b) = b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$ is a convex function of tariff τ .³⁶ As τ increases, the marginal negative effect of τ on $\pi(\varphi, \tau, b)$ decreases. The overall net marginal effect of TPU measure δ on early entry through bad and good news channels jointly depends on the number of periods being influenced and the magnitude of marginal effect of τ on per period profit. When $\delta = 1$, $\tau_2 = \tau_0 = \tau_1$ and there is no TPU. In this case, it is trivial that the entry threshold under TPU - φ_{1u} is equal to the entry threshold under trade policy certainty - φ_1 . As a small TPU δ is imposed, bad state tariff $\tau_2 = \delta \tau_1$ increases slightly above τ_1 and good state tariff $\tau_0 = \frac{1-\lambda_2 \delta}{1-\lambda_2} \tau_1$ decreases slightly below τ_1 . In this case, the magnitude of marginal effect through bad news and good news on per period profit is similar as the probability of reaching both states is considered. However, since more periods in bad state are influenced by bad news, bad news effect dominates good news effect and there are fewer entrants under TPU. As δ keeps increasing and the gap between bad news τ_2 and good news τ_0 becomes larger, the difference between marginal negative effect through bad news and marginal positive effect through good news on per period profit increases (due to the convexity of profit function). For a sufficiently large δ , it is possible that the one-period positive effect through good news dominates multiple-period negative effect through bad news. In this case, $\frac{\varphi_{1u}}{\varphi_1}$ may decrease below one and TPU can encourage firms' early entry.

H&L (2017) use the probability of a tariff change γ as a measure of TPU. In their partial equilibrium model, as γ increases, there are fewer entrants under TPU because of *bad news principal*. However, in my model, γ cannot determine if the effect of TPU on entry cutoff is negative or not. There is a following proposition.

Proposition 2

The probability of a tariff change γ only affects the magnitude of TPU effect but not the sign/direction (positive or negative) of TPU effect.

Proof: by taking the first derivative of $\frac{\varphi_{1u}}{\varphi_1}$ regarding γ , it is easy to verify that $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \gamma} \geq 0$ if and only if $\frac{\varphi_{1u}}{\varphi_1} \geq 1$ and $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \gamma} \leq 0$ if and only if $\frac{\varphi_{1u}}{\varphi_1} \leq 1$. See Appendix F for more details.

³⁵It is because I assume that learning only lasts one period.

³⁶The convexity still holds using linear demand. It also holds using iceberg cost as the elasticity of substitution σ is greater than 1. Part of the convexity is due to the assumption of ad valorem tariff since for given price p and quantity q , firm's revenue $\frac{pq}{\tau}$ is a convex function of τ .

The intuition is straightforward. γ is the probability of a tariff change and it doesn't alter the shape of tariff shock. Only λ_2 , τ_2 and τ_0 can alter the shape of tariff shock.³⁷ Therefore, γ cannot determine whether the net effect of TPU is negative ($\frac{\varphi_{1u}}{\varphi_1} \geq 1$) or not ($\frac{\varphi_{1u}}{\varphi_1} \leq 1$). And a higher γ only magnifies the net effect of TPU since there is a higher probability of tariff shock hitting.

I also examine the effect of the variance measure of posterior beliefs ε . The expectation of posterior belief related term $\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma = \frac{1}{2}(\varepsilon b_M)^\sigma + \frac{1}{2}((2-\varepsilon)b_M)^\sigma$ is an increasing function of ε , meaning that higher ε leads to higher profits from learning. A higher ε makes option A - early entry more appealing because of the benefits of early learning, causing the entry cutoff under TPU φ_{1u} to decrease. However, as ε increases, according to equation (9), the entry threshold in a no TPU case φ_1 will also decrease.³⁸ Therefore, the ratio of the entry cutoffs under TPU and no TPU $\frac{\varphi_{1u}}{\varphi_1}$ can capture the relative change of the two entry thresholds and there is a following proposition.

Proposition 3

The relative entry threshold $\frac{\varphi_{1u}}{\varphi_1}$ is increasing in ε if and only if $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} < \tau_1^{-\sigma}$ and decreasing in ε otherwise. A TPU process such that $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} \leq \tau_1^{-\sigma}$ can never bring relatively more entrants under TPU.

Proof: take the first derivative of $\frac{\varphi_{1u}}{\varphi_1}$ regarding ε and its monotonicity depends on the relationship between $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma}$ and $\tau_1^{-\sigma}$. As $\varepsilon = 1$, $\frac{\varphi_{1u}}{\varphi_1}$ is H&L solution which is greater than 1. As $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} \leq \tau_1^{-\sigma}$, $\frac{\varphi_{1u}}{\varphi_1}$ is a non-decreasing function of ε and φ_{1u} is always greater than φ_1 . See Appendix G for more details.

Recall that per period profit is $\pi(\varphi, \tau, b) = b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$. Therefore, $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma}$ can be seen as an inverted weighted average of tariff shock. If $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} < \tau_1^{-\sigma}$, it means that the imposed tariff shock is less favorable than the intermediate tariff τ_1 . In this case, even though a higher ε decreases both φ_{1u} and φ_1 , φ_1 decreases more since the profits of learning are proportional to tariff. In order to have relatively more entrants under TPU, there should be a TPU process favorable enough such that $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} > \tau_1^{-\sigma}$.³⁹ Similarly, as we increase intermediate tariff τ_1 , both φ_{1u} and φ_1 increase. Moreover, it is easy to verify that $\frac{\varphi_{1u}}{\varphi_1}$ is decreasing in τ_1 from equation (16). Compared to no TPU case, a higher intermediate tariff τ_1 deters firms' early entry relatively less under TPU. As τ_1 increases, both τ_2 and τ_0 become relatively lower. Therefore, bad news effect is relatively weaker and good news effect is relatively stronger. The effect of TPU becomes relatively more positive, which makes the cost of increasing τ_1 relatively smaller under TPU.

In this section, I introduce one-period learning in H&L partial equilibrium model using sunk cost. Like H&L, I obtain a closed-form solution and H&L model is nested in my new model. However, using only sunk cost, there is no endogenous exit. In the next section, I use per period fixed cost instead of sunk cost and also focus on the entry decision under TPU. Using fixed cost, the model becomes less tractable.

³⁷ γ can be seen as a common factor of tariff shock. As γ increases, the probability of reaching high tariff state τ_2 and low tariff state τ_0 increases proportionally.

³⁸Recall that TPU related parameters - τ_2 , τ_0 , λ_2 , γ and δ only affect φ_{1u} but not φ_1 .

³⁹Using a mean-preserving spread, $\lambda_2\tau_2^{-\sigma} + (1-\lambda_2)\tau_0^{-\sigma} > \tau_1^{-\sigma}$ is satisfied.

4. Fixed cost and learning

In this section, I study a model with fixed cost and learning but without sunk cost. Using fixed cost, the per period expected profit of exporting $\pi(\varphi, \tau, b)$ can be negative. Facing a negative expected profit, exporter may choose to exit the export market endogenously. Table 2 compares fixed cost learning model with sunk cost learning model and H&L model. One major difference here is that there is no explicit solution of relative entry threshold $\frac{\varphi_{1u}}{\varphi_1}$. In addition, the marginal effect of good news τ_0 can be negative.

| | H&L (2017) | sunk cost learning | fixed cost learning |
|---|--|--|--|
| sunk entry cost | $S > 0$ | $S > 0$ | $S = 0$ |
| fixed cost | $f = 0$ | $f = 0$ | $f > 0$ |
| endogenous exit | no | no | yes |
| expected per period profit | $b_M^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$ | $b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k$ b_M if entry period; b_H or b_L otherwise | $b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k - f$ b_M if entry period; b_H or b_L otherwise |
| solution of $\frac{\varphi_{1u}}{\varphi_1}$ relative entry threshold under TPU | explicit | explicit | implicit |
| bad news effect | negative | negative | negative (weak) |
| good news effect | no | positive | depends |
| TPU deters entry only $\frac{\varphi_{1u}}{\varphi_1} \geq 1$ | yes | depends | depends |

Table 2: Difference between the three models

4.1. No TPU case

Recall that φ_1 is the entry threshold when there is no TPU and tariff is constant τ_1 . $\Pi_e(\varphi, \tau)$ is the expected value of exporting with entry condition being τ and φ . As before, since there is no TPU, entry condition is the same across each period and waiting cannot bring extra profits. Therefore, entry cutoff firms are those whose expected value of exporting equals to 0. We have

$$\Pi_e(\varphi_1, \tau_1) = \pi(\varphi_1, \tau_1, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \left(\max\{\pi(\varphi_1, \tau_1, b_H), 0\} + \max\{\pi(\varphi_1, \tau_1, b_L)\} \right) = 0 \quad (19)$$

$$\Leftrightarrow \pi(\varphi_1, \tau_1, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \pi(\varphi_1, \tau_1, b_H) = 0 \quad (20)$$

$$\Leftrightarrow \varphi_1^{\sigma-1} = \frac{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) f}{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) k} \tau_1^\sigma \quad (21)$$

$$\Rightarrow \varphi_1^{*\sigma-1} |_{b_H=b_M=b_L} = \frac{f}{b_M^\sigma k} \tau_1^\sigma \quad (22)$$

The left-hand side of equation (19) gives the expression of expected value of exporting. Since $\pi(\varphi, \tau, b_L) \leq \pi(\varphi, \tau, b_M) \leq \pi(\varphi, \tau, b_H)$, equation (19) implies that $\pi(\varphi_1, \tau_1, b_L) \leq \pi(\varphi_1, \tau_1, b_M) \leq 0 \leq \pi(\varphi_1, \tau_1, b_H)$ should be satisfied. Hence, equation (19) can be rewritten as equation (20). In order to benefit from future positive expected profits conditional on receiving a good signal and having high belief b_H , entry cutoff firms φ_1 are willing to suffer from a negative expected profit in the entry period. φ_1^* is the entry cutoff without demand learning which is also the zero per-period profit cutoff conditional on prior belief b_M .⁴⁰ $\varphi_1 < \varphi_1^*$ and learning encourages firms'

⁴⁰ $\pi(\varphi_1^*, \tau_1, b_M) = 0$ and φ_1^* is the zero per-period profit cutoff.

early entry. Recall that $b_H = \varepsilon b_M$. Like sunk cost learning model, as the variance measure of belief ε increases, φ_1 decreases and there are more entrants.

In sunk cost learning model, without per period fixed cost, per period profit is always positive whatever the scenario is and entry firms take both good and bad beliefs into account. However, using fixed cost, exporters won't export with a negative per period profit if there is no more learning. In other words, for post-learning periods, entry firms take only the scenarios with positive profits into consideration. Because of free exit, loosely speaking, entry firms are willing to take more risks. In the current case, φ_1 firms only care about how good $\pi(\varphi_1, \tau_1, b_H)$ is while they don't care about how bad $\pi(\varphi_1, \tau_1, b_L)$ is. This difference between sunk cost learning and fixed cost learning models results in different properties of good and bad news under TPU.

4.2. TPU case

Recall that, in sunk cost learning model, intermediate-state entry cutoff firms φ_{1u} are willing to enter in low tariff state τ_0 but wait in high tariff state τ_2 . However, using fixed cost, this condition may not hold and some extra assumptions need to be imposed. In the rest of the section, I assume that φ_{1u} firms prefer to enter under τ_0 and wait under τ_2 , which seems to be a reasonable assumption. Following similar steps as in sunk cost learning model, the implicit solution of $\frac{\varphi_{1u}}{\varphi_1}$ is⁴¹

$$\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} = \frac{\text{numerator}}{\text{denominator}} \quad (23)$$

$$\begin{aligned} \text{numerator} = & \left(1 - (1 - \gamma)\beta \left(-\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} + 1\right) - \gamma\lambda_2\beta \left(-\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1\right)\right. \\ & \left. - \gamma(1 - \lambda_2)\beta \left(\frac{1}{2} - \frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}\right) + \frac{\beta\gamma\lambda_2}{1 - \beta} - \frac{\beta\gamma\lambda_2}{1 - \beta}\beta \left(-\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1\right)\right) \frac{1 + \frac{1}{2}\frac{\beta}{1 - \beta}\varepsilon^\sigma}{1 + \frac{1}{2}\frac{\beta}{1 - \beta}} \end{aligned} \quad (24)$$

$$\begin{aligned} \text{denominator} = & 1 + (1 - \gamma)\beta \left(\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_1, b_H}\varepsilon^\sigma - 1\right) + \gamma\lambda_2\beta \left(\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_2, b_H}\varepsilon^\sigma - 1\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} \\ & + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \\ & + \frac{\beta\gamma\lambda_2}{1 - \beta} \left(\frac{\tau_2}{\tau_1}\right)^{1 - \sigma} + \frac{\beta\gamma\lambda_2}{1 - \beta}\beta \left(\frac{1}{2}\mathbb{1}_{\varphi_{1u}, \tau_2, b_H}\varepsilon^\sigma - 1\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} \end{aligned} \quad (25)$$

Where $\max\{\pi(\varphi, \tau, b), 0\} \equiv \mathbb{1}_{\varphi, \tau, b}\pi(\varphi, \tau, b) \equiv \tilde{\pi}(\varphi, \tau, b)$. There are three indicators $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H}$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H}$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}$ that are undetermined. In order to obtain an exact solution of $\frac{\varphi_{1u}}{\varphi_1}$, I need to discuss the value of three indicators case by case. In Appendix I, I present all six possible solutions. Based on the assumption such that entry cutoff firms φ_{1u} are willing to enter in low tariff state τ_0 but wait in high tariff state τ_2 , the decision tree of φ_{1u} firms is illustrated in Figure 5. In the best case scenario, $\tilde{\pi}(\varphi_{1u}, \tau_0, b_H) > 0$ and φ_{1u} firms should be able to make a positive profit. In the worst case scenario, $\tilde{\pi}(\varphi_{1u}, \tau_2, b_L) = 0$ and φ_{1u} firms cannot make a positive profit.⁴² If there is no TPU and $\tau_2 = \tau_0 = \tau_1$, φ_{1u} will be equal to φ_1 .

As before, in Figure 5, the red terms capture the effect of TPU through bad news τ_2 and the green terms capture the effect of TPU through good news τ_0 . Increasing bad state tariff τ_2 weakly decreases the value of upper red terms while having no effect on the value of lower

⁴¹See Appendix H for more details. In Appendix H, I also show that $\pi(\varphi_{1u}, \tau_1, b_M) < 0$. φ_{1u} firms make negative profit in the entry period in order to benefit from future possible higher profits due to demand learning.

⁴²If $\tilde{\pi}(\varphi_{1u}, \tau_2, b_L) > 0$, φ_{1u} firms will strictly prefer to enter under τ_1 , which contradicts its definition.

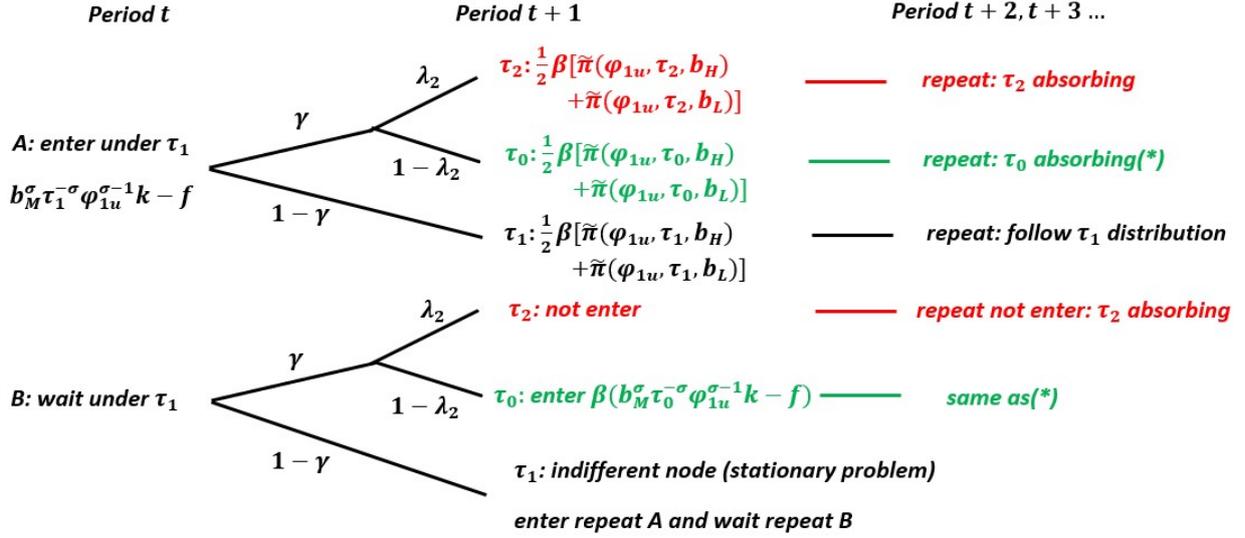


Figure 5: Fixed cost decision tree

red terms. Therefore, bad news weakly deters firms' early entry. Reducing good state tariff τ_0 increases both the value of upper green terms and the value of lower green terms. However, since the relationship between $\frac{1}{2} (b_H^\sigma + \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} b_L^\sigma)$ and b_M^σ can be ambiguous when $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$, the effect of good news is unclear. As the three indicators jointly depend on productivity, TPU process, and learning process, the entry cutoff ratio $\frac{\varphi_{1u}}{\varphi_1}$ is implicit. Nevertheless, given a specific set of values for each indicator, the solution becomes explicit and I can examine its properties just like in the sunk cost learning model. Certainly, some bound constraints need to be satisfied so as to reach the specific equilibrium. In the rest of the current section, I choose not to study the property within each particular equilibrium. Rather, I compare the entry threshold under TPU - φ_{1u} with the entry threshold under zero TPU - φ_1 in a simpler way. More precisely, I focus on the export decision of φ_1 firms under TPU. Recall that the expected value in intermediate tariff state τ_1 of a firm φ is

$$\Pi(\varphi, \tau_1) = \max \{ \Pi_e(\varphi, \tau_1), \beta E_{\tau_1} \Pi(\varphi, \tau') \} \quad (26)$$

Where $\Pi_e(\varphi, \tau_1)$ is the value of entering under τ_1 and $\beta E_{\tau_1} \Pi(\varphi, \tau')$ is the value of waiting under τ_1 . Define $Diff(\varphi, \tau_1) = \Pi_e(\varphi, \tau_1) - \beta E_{\tau_1} \Pi(\varphi, \tau')$ as the net difference between the value of entering and the value of waiting under τ_1 . If $Diff(\varphi, \tau_1) > 0$, firm φ will prefer to enter under τ_1 . Otherwise firm φ will prefer to wait under τ_1 . Therefore, as long as $Diff(\varphi_1, \tau_1) > 0$, φ_1 firms prefer to enter under TPU and there will be more entrants. Conversely, when $Diff(\varphi_1, \tau_1) < 0$, φ_1 firms prefer to wait under TPU and there will be fewer entrants.⁴³ The sign of $Diff(\varphi_1, \tau_1)$ can be used to determine the order of size between φ_1 and φ_{1u} , but it gives less information on the relative value of φ_{1u} compared to φ_1 . There is a following lemma.

Lemma 3

$Diff(\varphi_1, \tau_1)$ is proportional to $Sdiff(\varphi_1, \tau_1)$ which is

$$Sdiff(\varphi_1, \tau_1) = - \frac{\pi(\varphi_1, \tau_1, b_H)}{1 - \beta} + \frac{\lambda_2}{1 - \beta} \tilde{\pi}(\varphi_1, \tau_2, b_H) \quad (27)$$

⁴³In order to make $Diff(\varphi_1, \tau_1) > 0$ be equivalent to $\varphi_1 > \varphi_{1u}$ and $Diff(\varphi_1, \tau_1) < 0$ be equivalent to $\varphi_1 < \varphi_{1u}$, a condition such that $Diff(\varphi, \tau_1)$ passes through zero line once from below as φ increases should be imposed. A sufficient condition such that $Diff(\varphi, \tau_1)$ is an increasing function of φ is that $1 - \beta(1 - \gamma) + \beta\gamma(1 - \lambda_2) \left(\frac{1}{2} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} + \beta\gamma\lambda_2 \left(\frac{1}{2} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} > 0$.

Proof: recall that φ_1 is entry threshold in no TPU case where trade policy is constant τ_1 . Therefore, φ_1 firms are willing to enter in good state τ_0 and wait in bad state τ_2 . I show that, assuming φ_1 firms are willing to enter(wait) under τ_1 as TPU is imposed, $Diff(\varphi_1, \tau_1)$ is proportional to $Sdiff(\varphi_1, \tau_1)$. For both assumptions - enter and wait under τ_1 , the proportion is an increasing function of γ and β . See Appendix J for more details.

The probability of a tariff change γ doesn't affect the sign of $Diff(\varphi_1, \tau_1)$ and the intuition is the same as in sunk cost learning model. $Sdiff(\varphi_1, \tau_1)$ can be rewritten as

$$Sdiff(\varphi_1, \tau_1) = L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2) + G(\varphi_1, \tau_0) \quad (28)$$

Where

$$L(\varphi_1, \tau_1) = -\frac{\pi(\varphi_1, \tau_1, b_H)}{1-\beta} = -\frac{b_H^\sigma \tau_1^{-\sigma} \varphi_1^{\sigma-1} k - f}{1-\beta} \quad (29)$$

$$B(\varphi_1, \tau_2) = \frac{\lambda_2 \tilde{\pi}(\varphi_1, \tau_2, b_H)}{1-\beta} = \frac{\lambda_2 \max\{b_H^\sigma \tau_2^{-\sigma} \varphi_1^{\sigma-1} k - f, 0\}}{1-\beta} \quad (30)$$

$$\begin{aligned} G(\varphi_1, \tau_0) &= (1-\lambda_2) \left(\pi(\varphi_1, \tau_0, b_H) + \tilde{\pi}(\varphi_1, \tau_0, b_L) - 2\pi(\varphi_1, \tau_0, b_M) \right) \\ &= (1-\lambda_2) \left(b_H^\sigma \tau_0^{-\sigma} \varphi_1^{\sigma-1} k + \max\{b_L^\sigma \tau_0^{-\sigma} \varphi_1^{\sigma-1} k - f, 0\} - 2b_M^\sigma \tau_0^{-\sigma} \varphi_1^{\sigma-1} k + f \right) \end{aligned} \quad (31)$$

$L(\varphi_1, \tau_1)$ captures the net loss in intermediate state τ_1 . As TPU is introduced, φ_1 firms get access to τ_1 with less probability and earn fewer profits under τ_1 compared to the no TPU case. $B(\varphi_1, \tau_2)$ and $G(\varphi_1, \tau_0)$ capture the net gain of bad news and good news separately.⁴⁴ When $\tau_2 = \tau_0 = \tau_1$, $Sdiff(\varphi_1, \tau_1) = 0$ and $\varphi_{1u} = \varphi_1$. $\frac{\partial B(\varphi_1, \tau_2)}{\partial \tau_2}$ and $\frac{\partial G(\varphi_1, \tau_0)}{\partial \tau_0}$ measure the marginal effect of TPU on φ_1 firms' relative profits of early entry through bad and good news separately. As in sunk cost learning model, bad news affects multiple periods while good news only affects one period. Therefore, there is a factor $\frac{1}{1-\beta}$ in bad news term $B(\varphi_1, \tau_2)$. There are two following lemmas.

Lemma 4

Bad news principal: for φ_1 firms, an increase in the bad state tariff τ_2 weakly decreases the relative profits of early entry.

Proof: from equation (30), it's easy to verify that $B(\varphi_1, \tau_2)$ is a weakly decreasing function of τ_2 . Therefore, the marginal effect of TPU through high tariff τ_2 on relative early entry profits is negative and bad news weakly deters φ_1 firms' entry.

An increase in bad state tariff τ_2 weakly reduces the net gain under bad news $B(\varphi_1, \tau_2)$ and early entry becomes less appealing for φ_1 firms. Using fixed cost f , the expected per period profit $\tilde{\pi}(\varphi_1, \tau_2, b_H)$ is bounded above 0. Therefore, once $\tilde{\pi}(\varphi_1, \tau_2, b_H) = 0$, bad news τ_2 has no more effect on φ_1 firms' profits and a higher τ_2 cannot deter φ_1 firms' early entry further.

Lemma 5

⁴⁴ $L(\varphi_1, \tau_1)$ is not the true net loss and $B(\varphi_1, \tau_2)$ and $G(\varphi_1, \tau_0)$ are not the true net gain since $Sdiff(\varphi_1, \tau_1)$ is proportional to $Diff(\varphi_1, \tau_1)$.

Good news principal: for φ_1 firms, a reduction in good state tariff τ_0 may decrease the relative profits of early entry if good news τ_0 is not sufficiently low and high belief b_H is not sufficiently high. However, for a sufficiently low τ_0 or high b_H , a decrease in τ_0 increases the relative profits of early entry.

Proof: from equation (31), $G(\varphi_1, \tau_0)$ is a decreasing function of τ_0 as long as $\tilde{\pi}(\varphi_1, \tau_0, b_L) > 0$, which holds given that $\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma > 0$. However, when $\tilde{\pi}(\varphi_1, \tau_0, b_L) = 0$ and $\frac{1}{2}b_H^\sigma - b_M^\sigma < 0$, $G(\varphi_1, \tau_0)$ is an increasing function of τ_0 .

A counterintuitive result here is that good news can make early entry less appealing for φ_1 firms. When $\tilde{\pi}(\varphi_1, \tau_0, b_L) = 0$, conditional on entering under τ_1 in period t , in future periods under τ_0 , φ_1 firms only make positive profits in the best case scenario where they hold high belief b_H , which happens with probability $\frac{1}{2}$. Considering the risk of having a low belief b_L afterward and a relatively lower cost of entering under τ_0 , if high belief b_H is not high enough, waiting in period t and entering in future periods under τ_0 can be a more appealing choice. In this case, a smaller τ_0 (better news) can favor waiting more. Recall that early entry allows firms to benefit from the extra profit of learning one period earlier. When $\tilde{\pi}(\varphi_1, \tau_0, b_L) = 0$ and $\frac{1}{2}b_H^\sigma - b_M^\sigma < 0$, this extra benefit is not profitable enough and cannot compensate for the loss under τ_1 . Since good news may deter φ_1 firms' early entry, for given τ_2 and τ_0 , the effect of λ_2 can also be non monotone. Using a mean-preserving spread and substituting τ_2 by $\delta\tau_1$ and τ_0 by $\frac{1-\lambda_2\delta}{1-\lambda_2}\tau_1$, there is a following proposition and the intuition is similar to that of Proposition 1.

Proposition 4

In fixed cost learning model, if TPU measure δ is small, $Sdiff(\varphi_1, \tau_1) < 0$ and there will be fewer entrants under TPU. However, if δ is large enough, $Sdiff(\varphi_1, \tau_1)$ can be greater than 0 and there can be more entrants under TPU.

Proof: see Appendix K for more details.

Recall that in sunk cost learning model, when the variance measure of posterior beliefs $\varepsilon = 1$, there is no learning and $\frac{\varphi_{1u}}{\varphi_1}$ is H&L solution such that $\varphi_{1u} > \varphi_1$ and there are fewer entrants under TPU. However, in the case of a fixed cost model, when $\varepsilon = 1$, firms' entry decision is based only on profit in the current period and there is no state dependence. In this case, $\varphi_{1u} = \varphi_1$ which is equal to zero-profit cutoff of $\pi(\varphi, \tau_1, b_M)$. There is a following proposition.

Proposition 5

(1) As $\varepsilon = 1$, $Sdiff(\varphi_1, \tau_1) = 0$ and $\varphi_{1u} = \varphi_1$ which is equal to zero-profit cutoff of $\pi(\varphi, \tau_1, b_M)$.

(2) As ε is close to 1, $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} < 0$ and $\varphi_{1u} > \varphi_1$. There are fewer entrants under TPU as there is not much demand learning.

(3) As $\lambda_2\tau_2^{-\sigma} + (1 - \lambda_2)\tau_0^{-\sigma} < \tau_1^{-\sigma}$, $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} < 0$ and there are always fewer entrants under TPU.

(4) As $\lambda_2\tau_2^{-\sigma} + (1 - \lambda_2)\tau_0^{-\sigma} > \tau_1^{-\sigma}$, $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} > 0$ if ε is large enough. In this case, there can be more entrants under TPU. If ε is not large enough, the sign of $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon}$ is ambiguous.

Proof: see Appendix L.

Similar to the sunk cost learning model, if TPU process is unfavorable such that $\lambda_2\tau_2^{-\sigma} + (1 - \lambda_2)\tau_0^{-\sigma} < \tau_1^{-\sigma}$, there cannot be more entrants under TPU. Furthermore, in the case of fixed cost, entry firms only consider the post-learning scenarios with positive expected profits. Therefore, the marginal effect of ε only applies to these positive scenarios. Increasing the variance measure of posterior beliefs ε can be relatively less favorable for early entry under TPU even if TPU process is favorable.

In this section, I employ per period fixed cost instead of sunk entry cost. For both TPU and no TPU cases, entry cutoff firms incur a negative profit in the entry period and hope to receive a favorable demand signal afterward. Since per period export profit can be negative, there exist multiple kinks in the solution of $\frac{\varphi_{1u}}{\varphi_1}$ and the problem becomes less tractable. I use *Sdiff* (φ_1, τ_1) instead to study the relationship between φ_{1u} and φ_1 . Unlike sunk cost learning model, as exporters only take the scenarios with positive profit into account after learning, good news can deter firms' early entry in some cases. Some other results in sunk cost learning model are not robust in fixed cost learning model either.

5. Suggestive evidence of good news effect

I have shown that in H&L partial equilibrium model, there is no good news effect and TPU only deters firms' entry through the bad news τ_2 channel. However, my models suggest that good news τ_0 does matter, and the sunk cost learning model predicts that it encourages entry.⁴⁵ If I can empirically observe that good news has an effect, H&L's result may not be robust. To test this, I plan to shut down the bad news channel entirely and examine the effect of good news separately. However, it is difficult to distinguish between the bad news effect and the good news effect in practice, as they can operate simultaneously. For instance, if a trade agreement is established between two countries in the future, a potential exporter may expect that it is more (less) likely to face a lower (higher) tariff and both channels jointly affect the current export decision. Once I shut down the bad news channel, my model predicts that for potential exporters that face zero risk of future bad news (higher tariff), the future good news (lower tariff) will encourage their current entry into foreign markets.

When considering trade policy in WTO country pairs, bound tariffs can be approximately considered as the worst-case scenario, since they represent the maximal most-favoured-nation tariff (MFN) level that can be imposed for a given commodity line.⁴⁶ Therefore, for product lines in which the applied tariff is MFN tariff which equals bound tariff (BND), I consider there is no effect or little effect of bad news given that bound tariff is considered as the worst-case scenario. I take the future signature of trade agreements (TAs) as pure good news for those HS6 products of which MFN=BND>0. When a trade agreement is concluded between two or more countries, the applied MFN tariff can be replaced by a lower preferential tariff. Figures 6(a) and 6(b) illustrate the decision tree when the bad news channel is shut down ($\lambda_2 = 0$) in the sunk cost learning model and H&L model respectively.⁴⁷ The net difference between the upper and lower green terms captures the net effect on entry through the good news channel which is positive in sunk cost learning model and zero in H&L model. The state τ_1 represents the pre-trade agreement signature state where applied MFN tariff equals bound tariff and is positive. Good news state τ_0 is assumed to be the realization of a trade agreement signature where $\tau_0 \leq \tau_1$.⁴⁸

⁴⁵Although the fixed cost learning model predicts that the effect of good news on entry can be negative under some conditions, I believe it is less likely to occur.

⁴⁶I say approximately because, in reality, the applied tariff can occasionally be higher than the bound tariff, for example, due to temporary trade barriers and there can also exist some non-tariff barriers.

⁴⁷Bad news channel is also shut down as $\tau_2 = \tau_1$, which is equivalent to $\lambda_2 = 0$.

⁴⁸ τ_0 can be equal to τ_1 because there may exist some product lines that are not eligible for preferential tariff

the post-signature phase is assumed to be weakly better. During the post-signature phase, lower non-tariff barriers are allowed as they can also be considered good news.

As in Handley (2014), I use product entry as an indirect measure of firms' entry into foreign markets. Specifically, I use an indicator of positive HS6 bilateral trade flow which equals 1 if the nominal value of trade flow from exporting country i to destination country j in a given year t is not less than 1000 US dollars and 0 otherwise. The underlying assumption is that as more firms enter a foreign market, a product becomes more likely to be traded bilaterally (from the home country to that foreign country). The empirical test I conduct is similar to previous research on the effects of preferential trade agreements such as Egger et al. (2022) and Ptashkina (2022) where they find an anticipation effect of trade agreements. Nevertheless, I focus on product-level entry and a specific set of products. Furthermore, I utilize the recently developed two-way fixed effects estimator that allows for heterogeneous treatment effects and control for highly disaggregated exporting and importing side fixed effects.

Before presenting the data and the results of various regression specifications, I would like to mention some caveats. Firstly, it is important to be mindful of the general equilibrium effect. Using a general equilibrium model, H&L (2017) point out that if the current state is close to the bad state (i.e. bad news channel is shut down), TPU can induce exporters' entry into foreign markets. It is because good news for home exporters is bad news for foreign domestic firms. Foreign domestic firms exist, which pushes up the foreign price and induces more exporters' entry into foreign markets. Therefore, to control for the general equilibrium effect through aggregate price, adding destination-side fixed effects is necessary. Secondly, the good news effect is not specific to the learning model. Any model that creates age dependence is able to generate a good news effect under TPU, e.g., demand accumulation. However, the approach to the problem should be relatively similar to what has been discussed in the above theoretical part. The key element that makes good news relevant is age dependence. Thirdly, it is important to be cautious about the endogeneity of trade agreements. Baier and Bergstrand (2007) argue that introducing instrumental variables is not an effective way to deal with the endogenous problem of trade agreements. Instead, introducing exporting country-year and destination-year fixed effects is a better way to control for the endogenous problem. Therefore, I should include fixed effects for both the exporting side and the destination side. These fixed effects are also useful in controlling for the supply side and demand side characteristics. Like H&L, I only focus on the entry problem. However, the product-level bilateral trade indicator not only captures the entry margin but also the exit margin. Handley (2014) keeps silent about this issue and I would like to make some discussion here. As the bilateral indicator switches from 0 to 1, within a product line, only one firm is required to enter the corresponding foreign market. However, as the bilateral indicator switches from 1 to 0, within a product line, all firms are required to exit the corresponding foreign market. Consequently, the entry margin should have a relatively greater impact on the bilateral indicator compared to the exit margin and here I assume that the entry margin effect dominates.

5.1. Data

The data sets I use are the BACI database, the Gravity database, the WITS TRAINS/IDB database and the Design of Trade Agreements (DESTA) database. The BACI database is used to construct my dependent variable, i.e., bilateral HS6 product-level entry (positive trade flow indicator). The Gravity database provides information on WTO/GATT membership, EU membership, etc. The WITS TRAINS/IDB database contains information on MFN tariff and bound tariff at HS6 level. The DESTA database provides information on preferential trade

agreements.⁵¹ I only keep WTO/GATT country pairs and the bilateral HS6 tariff lines where MFN tariff equals the bound tariff and is greater than 0. Additionally, to distinguish between zero and missing flows, I keep those bilateral country pairs within which at least one of the two reports their disaggregated bilateral trade flows to the United Nations Statistical Division in a given year t .⁵² The sample period runs from 1996 to 2019 and it comprises 9406 exporting country-destination pairs.⁵³ An exporting country-destination pair is considered as treated from the first time they signed a preferential trade agreement.⁵⁴ Among the treated country pairs, I only include those that signed a trade agreement (for the first time) after the year 1996.⁵⁵ That is to say, I drop the always-treated country pairs within my sample period. The never treated country pairs are those that have no record of trade agreements in the DESTA database. The panel I use is unbalanced and the EU is treated as one country.⁵⁶ Table 3 gives the summary statistics of the sample. The average probability that a HS6 product is traded from one country to another is 7.4%; the average value of trade flow at HS6 level is 412 thousand US dollars; the average MFN and bound tariff is 13.37% and the share of treated observations is 9.6%.⁵⁷

| | Mean | St. Dev. | Min. | Max. | Obs. |
|---|-----------|-----------|-------|---------------|----------|
| product traded binary (≥ 1000 US dollars) | 0.0739755 | 0.261731 | 0 | 1 | 63711020 |
| product trade value (1000 US dollars) | 412.1615 | 32713.01 | 0 | $5.67 * 10^7$ | 63711020 |
| MFN/BND | 0.1336546 | 0.3613537 | 0.001 | 30 | 63711020 |
| treated (post signature) | 0.09623 | 0.2949064 | 0 | 1 | 63711020 |

Table 3: Summary statistics

5.2. Reduced-form analysis

In this subsection, I present the results obtained from both the classic regression-based event study specifications and the imputation-based specifications of Borusyak et al. (2022) where heterogeneous treatment effects are taken into account. i is exporting country; j is destination country and t is year. p denotes HS6 product and $hs2$ denotes HS2 sector. $positive_{ijpt} = 1$ if product-level trade flow from country i to j in a given year t is not less than 1000 US dollars in nominal value. Between two countries i and j , for years greater than or equal to the year of the signature of their first preferential trade agreement, treatment TA_{ijt} takes the value 1.⁵⁸

⁵¹One caveat is that the DESTA database doesn't include unilateral trade agreements which are one-sided, non-reciprocal trade preferences normally granted by developed countries to developing ones. As I control for time-varying exporting/importing side fixed effect and time invariant bilateral fixed effect, the impact of unilateral trade agreements can be at least partially taken into account.

⁵²This information is provided by the BACI database.

⁵³See Appendix M for more details on data construction. All of the regression results presented in this section are robust except for the specification with country-pair linear time trend, when I exclude the years 2018 and 2019 to mitigate the impact of the US-China trade war.

⁵⁴Between two countries, there can exist several different preferential trade agreements being signed in different years and I consider a country pair being treated from the year of signature of their first preferential trade agreement. Also, I disregard the cases where countries quit the trade agreement. One of my next steps is to exclude the country pairs that have a trade agreement currently under negotiation from the never-treated group. Another is to exclude the bilateral product lines that have been targeted by temporary trade/no trade barriers during the sample period.

⁵⁵See Appendix M for the trade agreements included in the sample.

⁵⁶Across different years, the EU member countries may change. For all EU member countries, I drop the observations before their accession to the EU.

⁵⁷Recall that in my sample, only observations that have $MFN=BND > 0$ are included. The US dollar is in nominal value. The results don't significantly change even if I exclude observations with low MFN/BND value, e.g., 5%(0.05).

⁵⁸The year of trade agreement enforcement may differ from the year of signature. However, the difference is not large and the mean difference across all DESTA observations is 1.8 years. Since I treat the EU as a single unit, the bilateral treatment value can be between 0 and 1. I attribute value 1 to those with a treatment value

Otherwise, the bilateral pair is not treated and $TA_{ijt} = 0$. Always-treated country pairs are excluded.

5.2.1. Regression-based specifications

In the first part, I conduct several classic event study regressions. I first regress bilateral positive trade flow indicator $positive_{ijpt}$ on time to event dummies $\mathbb{1}(time\ to\ event_{ijt} = t_to_e)$, exporting country-product-year fixed effect fe_{ipt} , destination-product-year fixed effect fe_{jpt} and exporting country-destination-product fixed effect fe_{ijp} . The coefficient of the year before the signature $\beta_{t_to_e=-1}$ is normalized to 0. The three sets of fixed effects are able to control for time-varying supply-side characteristics, time-varying demand-side characteristics and time-invariant bilateral characteristics at the product level.⁵⁹ Additionally, the three sets of fixed effects aim to at least partially address the endogeneity of trade agreements. t_to_e denotes time to event which is equal to the current year minus the year of signature. $t_to_e = -10$ if time to event is equal to or smaller than -10 and $t_to_e = 10$ if time to event is equal to or greater than 10 . Standard errors are clustered at HS6 product level and the confidence interval is at 95% level.⁶⁰ There are 63 711 020 observations included in the following three specifications. The equation below gives the regression function of specification 1 and Figure 7 shows the corresponding event plot.⁶¹

$$positive_{ijpt} = \sum_{\substack{t_to_e=10 \\ t_to_e=-10 \\ t_to_e \neq -1}} \beta_{t_to_e} \mathbb{1}(time\ to\ event_{ijt} = t_to_e) + fe_{ipt} + fe_{jpt} + fe_{ijp} + \epsilon_{ijpt}$$

greater or equal to 0.5 and value 0 to those with a treatment value less than 0.5. It is also very infrequent that the treatment value is near 0.5.

⁵⁹Ideally, I would also like to control for preferential tariffs during the post-trade agreement signature phase, in order to partially account for the heterogeneous effects of trade agreements. Due to the poor quality of preferential tariff data, I have chosen not to include them in my analysis. Instead, in the second part of the study, I have employed a more appropriate method to account for the heterogeneous treatment effects.

⁶⁰In Handley (2014), standard errors are clustered at the 8 digit tariff line by year level.

⁶¹Time 0 corresponds to the year of signature of the trade agreement. See Appendix M for the regression result of specification 1.

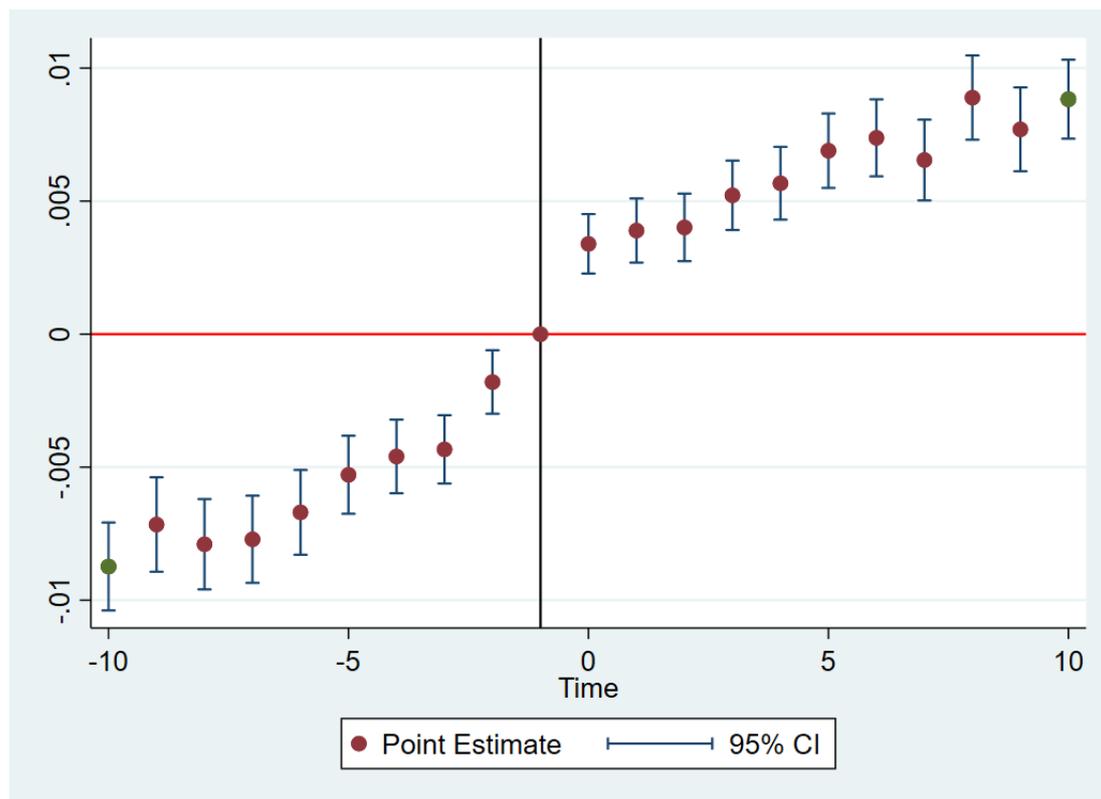


Figure 7: Regression-based specification 1 - baseline

The graph for specification 1 shows a clear upward trend beginning roughly 6 years prior to the year of signature. This trend indicates that the probability of a product being exported to the future trade agreement partner has increased prior to the signature of the trade agreement. This result remains robust for the rest of the specifications as well. Moser and Rose (2012) study 88 regional trade agreements from 1988 to 2009 and find that, on average, the gap between the day of an official announcement of the trade agreement negotiation and its conclusion is 28 months. Arroyo and Castillo-Ponce (2019) take a sample of 80 trade agreements that were initiated and concluded between 1980 and 2011 and find that the average duration of negotiations was 72 months.⁶² Given that there can exist some pre-negotiation event that triggers the negotiation of the trade agreements, it is possible that exporters can form some expectations about the future trade agreement as early as 6 years before the official signature of the agreement. As I focus on the product lines that only face potential good tariff news, these product lines are likely to react to the future realization of the trade agreement more intensively. In other words, even if the trade agreement failed, the worst-case scenario for these product lines would just be a return to the pre-trade agreement state. I also manually conduct some additional checks using Google Trends. Figure 8 below displays Google Trends indicators between 2008 and 2018 using "EU Canada trade agreement" as the keyword. In October 2013, Canada and EU announced agreement in principle and the agreement was signed in October 2016. The trends indicator is positive around the year 2010, suggesting that people could form some expectations/anticipations about this trade agreement several years before its realization.⁶³ Furthermore, this result is not limited

⁶²Unlike Moser and Rose (2012), they use the enforcement date as the end date.

⁶³"Google Trends - understanding the data: Google trends numbers reflect how many searches have been done for the particular term relative to the total number of searches done on Google. Numbers on the graph don't represent absolute search volume numbers, because the data is normalized and presented on a scale from 0-100, where each point on the graph is divided by the highest point, or 100. A line trending downward means that a search term's relative popularity is decreasing-not necessarily that the total number of searches for that term is decreasing, but that its popularity compared to other searches is shrinking." Source:

to the EU-Canada Trade Agreement.

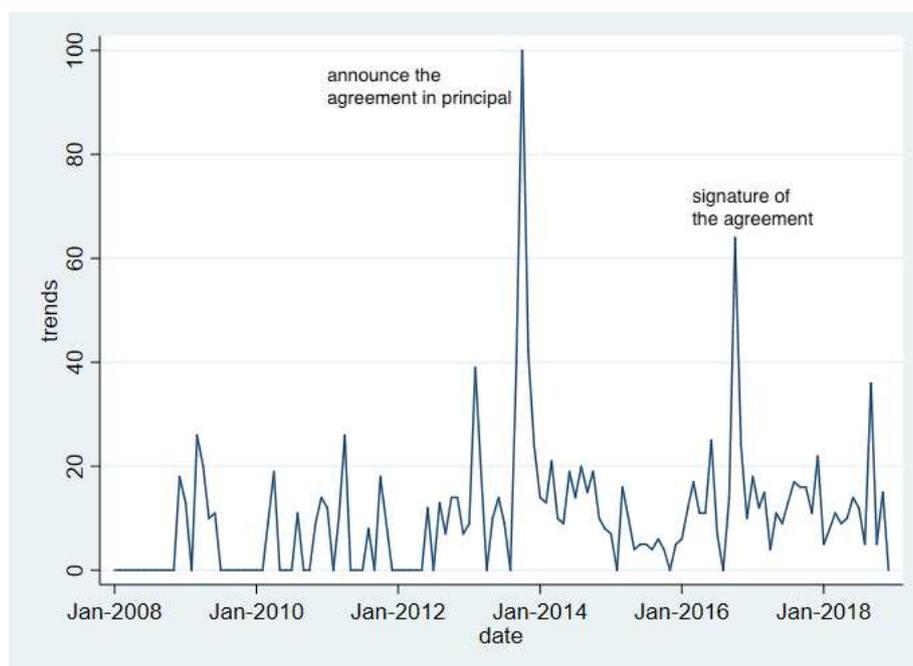


Figure 8: EU Canada Trade Agreement Google Trends

There may exist country-pair-specific time trends. To address this concern, in my second specification below, I add country-pair specific linear time trends of which the effect is captured by β_{ij} .⁶⁴

$$\begin{aligned}
 positive_{ijpt} = & \sum_{\substack{t_{to_e}=10 \\ t_{to_e}=-10 \\ t_{to_e} \neq -1}} \beta_{t_{to_e}} \mathbb{1}(time\ to\ event_{ijt} = t_{to_e}) + \sum_{ij} \beta_{ij} \mathbb{1}(country\ pair\ ij) * year \\
 & + fe_{ipt} + fe_{jpt} + fe_{ijp} + \epsilon_{ijpt}
 \end{aligned}$$

<https://newsinitiative.withgoogle.com/resources/lessons/google-trends-understanding-the-data/>

⁶⁴Country pair refers to exporting country-destination pair.

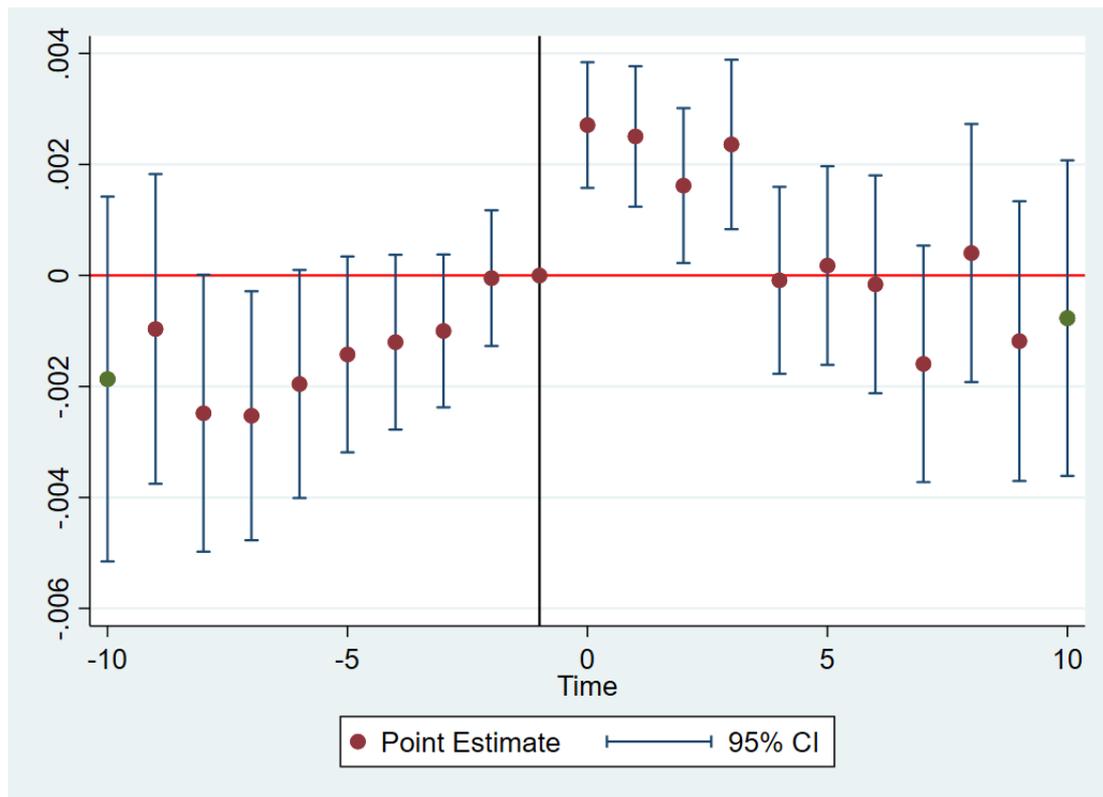


Figure 9: Regression-based specification 2 - country pair linear trend

Figure 9 illustrates the coefficient plot for specification 2.⁶⁵ Unsurprisingly, when the time trend is added, the confidence interval becomes wider and the effects of treatment become smaller. In the baseline specification 1, the treatment effect keeps increasing from about time-to-event -6 to time-to-event 6 in a relatively linear way. Therefore, on average, the linear trend artificially fits this increasing part and the estimated time-to-event coefficient far away from this increasing segment from the right-hand(left-hand) side shifts downward(upward) in specification 2. Even so, the overall shape of pre-treatment effects is similar to that in specification 1 and there is still an upward trend starting 6 years before the year of the signature. In my specification 3 below, I use lag 1 time-varying aggregate bilateral trade flow at HS Nomenclature section level to control for country-pair specific trends.⁶⁶ Olivero and Yotov (2012) argue that adding lagged trade flow as a covariate is able to control for trade persistence. Moreover, this variable partially controls for the time-varying bilateral elements other than trade agreements that can also affect trade.

$$\begin{aligned}
 positive_{ijpt} = & \sum_{\substack{t_{to.e}=10 \\ t_{to.e}=-10 \\ t_{to.e} \neq -1}} \beta_{t_{to.e}} \mathbb{1}(time\ to\ event_{ijt} = t_{to.e}) + \beta_s \ln(1 + section\ bilateral\ trade\ flow)_{ijst-1} \\
 & + f_{ept} + f_{ept} + f_{ejp} + \epsilon_{ijpt}
 \end{aligned}$$

⁶⁵Time 0 refers to the year of signature. See Appendix M for the full regression result.

⁶⁶There are 21 sections in total. The trade flow value is calculated using the universe of HS6 product lines. I take the log of $(1+\text{trade value})$. In the data, I observe that the mean of lag 1 aggregate bilateral section-level trade flow approximately keeps increasing before the year of signature.

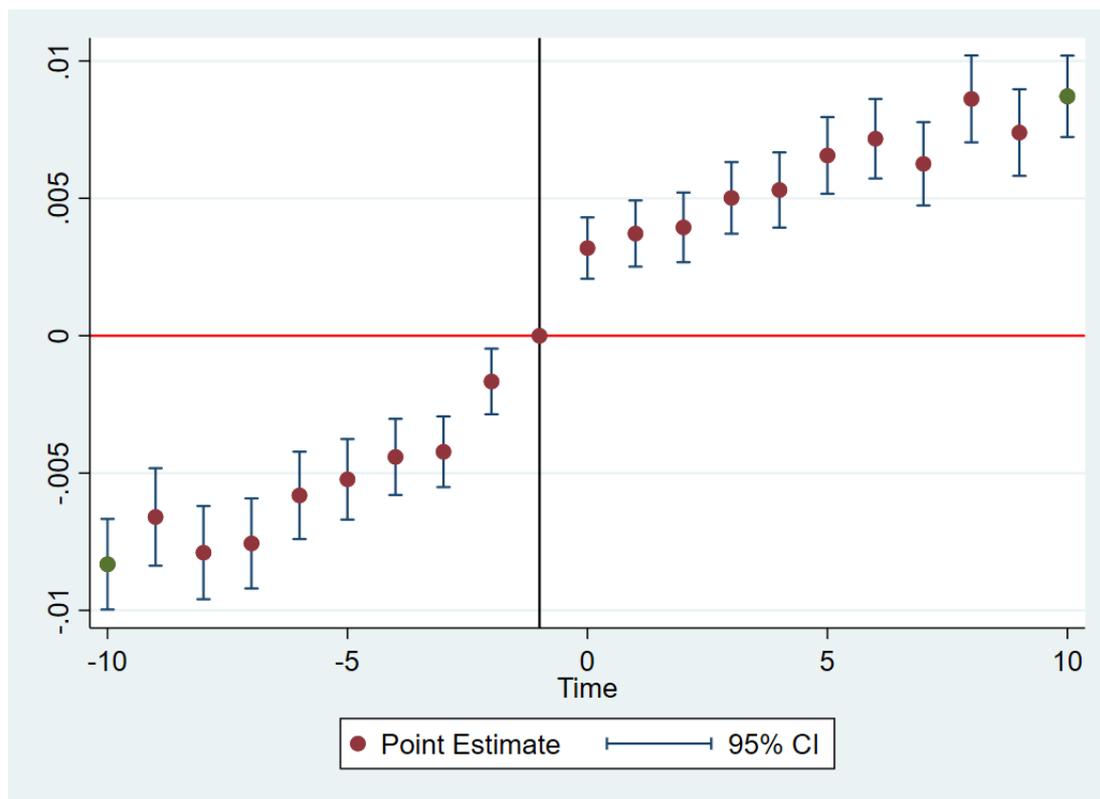


Figure 10: Regression-based specification 3 - controlling for section level trade flow

Figure 10 illustrates the coefficient plot for specification 3.⁶⁷ Adding the lag 1 aggregate bilateral trade flow at HS Nomenclature section level doesn't significantly alter the shape and the magnitude of coefficients in the event plot when compared to the baseline specification 1. Given that trade flow can capture the effect of some events other than the trade agreement that may have an impact on trade, the result of specification 3 suggests that it is highly likely that the increase in the probability of a product being traded during the pre-treatment phase is driven by trade agreement-related factors. Using the regression-based event study, treatment and anticipation effects are assumed to only vary by time to event horizon. In the subsection below, I use the imputation-based method proposed by Borusyak et al. (2022) and allow for heterogeneous treatment effects.

5.2.2. Imputation-based specifications

The above classic regression-based event study is non-robust when there are heterogeneous treatment effects. It is unlikely that different trade agreements will have homogeneous treatment effects across different units and periods. In order to examine the time-to-event effects in a more rigorous way, I apply the estimation method of Borusyak et al. (2022). I need to mention that Borusyak et al. (2022) is not the only paper that deals with heterogeneous treatment effects and there exist several other estimators that are robust to heterogeneous treatment effects. For example, Callaway and Sant'Anna (2021) impose a weaker parallel trend assumption and also allow for a conditional parallel trend. The reason for choosing Borusyak et al. (2022) estimator is that, among the various estimators I have tried, it is the only estimator that works well with a large dataset when including highly disaggregated time-varying export side and import side

⁶⁷Time 0 refers to the year of signature. See Appendix M for the full regression result.

fixed effects.⁶⁸

In Borusyak et al. (2022), the estimation process and the pretrend test process are separated. Regarding the estimation process, the non-treated observations including never-treated and not-yet-treated are used to impute non-treated potential outcomes for treated observations. More specifically, using the non-treated observations, the dependent variable is regressed on all fixed effects and controls except for time-to-event dummies. Then these estimated fixed effects and coefficients of the controls are used to build non-treated potential outcomes for the treated observations. The treatment effect for each treated observation is the difference between the observed outcome and the imputed potential outcome. The estimands are constructed by taking the average of individual treatment effects. Borusyak et al. (2022) assume that the parallel trend assumption should hold for the entire pre-treatment period. Regarding the pretrend test, a set of pre-treatment dummies should be specified ex-ante and all treated observations are excluded. The pretrend test process is similar to the estimation process except that the treated observations are assumed to be those with one of the pre-treatment dummies equal to 1.

The empirical evidence in the subsection above suggests that the treatment effect kicks in 6 years before the year of signature. Therefore, I assume that treatment starts artificially at time to event equal to -6 (6 years before the signature year). Borusyak et al. (2022) impose a relatively strong parallel trend assumption by assuming that the parallel trend should hold for all periods before the treatment. Empirically, this assumption is difficult to satisfy. After examining several different specifications, I choose to exclude all observations with time to event smaller than -11 . By doing so, the parallel trend holds approximately between time to event equal to -11 and -7 .⁶⁹ In other words, the parallel trend holds between 11 years and 7 years before the year of signature and the treatment effects start 6 years before the year of signature. I need to mention that the number of observations being used is 56 048 931 and is smaller than that in the regression-based results. This is because not all treated observations are imputable.

The event plot in Figure 11 below displays the estimation results after controlling for exporting country-HS2 sector-year fixed effects fe_{ihs2t} , destination-HS6 product-year fixed effects fe_{jpt} and exporting country-destination-HS6 product fixed effects fe_{ijp} .⁷⁰ The blue part shows the estimation process result for time to event equal to or greater than -6 . It is estimated by assuming that there is no treatment effect before time to event equal to -6 (between time to event -11 and -7). The red part shows the pretrend test result for time to event between -9 and -7 , which is done independently from the estimation process by assuming that there is no treatment effect between time to event -11 and -10 . Roughly speaking, it suggests that there are no/little treatment effects between time to event -11 and -7 .⁷¹

⁶⁸I have tried `did_multiplegt`, `eventstudyinteract` and `csdid` Stata packages. Either they cannot accommodate a large number of export side and import side fixed effects or there is a memory issue. I am currently using a server with 767 GB of memory.

⁶⁹I have also tried to include the observations with time to event smaller than -11 and cluster the standard errors at country pair ij level (the level of treatment assignment). The coefficients of pretrend dummies become insignificant while the coefficients of treatment dummies remain significantly positive and keep increasing.

⁷⁰I use fe_{ihs2t} in order to pass the degrees of freedom test. "Periods since the event = 0" corresponds to the 6th year before the signature (time-to-event -6). See Appendix M for the full regression result.

⁷¹The coefficient of `pre1` (time-to-event -7) is not significant at the 5% level, but it is significant at the 10% level when the standard errors are clustered at the HS6 product level. However, its magnitude is relatively low. Rambachan and Roth (2022) propose a robust inference approach by assuming that parallel trends do not hold exactly. Unfortunately, this approach is not applicable to the method used by Borusyak et al. (2022), as mentioned in the survey by De Chaisemartin and d'Haultfoeuille (2022). When I cluster the standard errors at country pair ij level, all pretrend coefficients become insignificant.

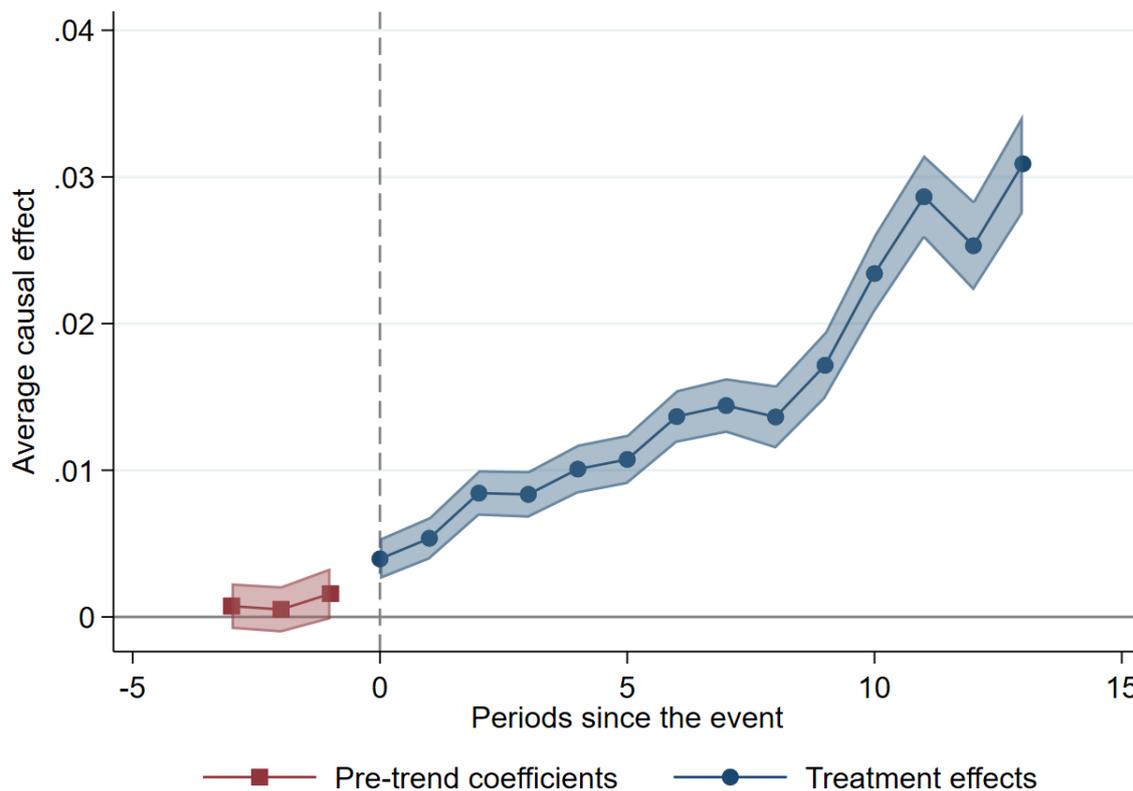


Figure 11: Imputation-based specification 1 - baseline

As I assume that treatment starts artificially 6 years before the year of the signature, "Periods since the event = 0" actually refers to the 6th year before the signature year (time-to-event -6). The overall treatment effect pattern is similar to that in regression-based specification 1 with treatment effects becoming stronger during the periods after the signature.⁷² From the 3rd year after the signature year ("Periods since the event = 9"), the treatment effects increase sharply, possibly due to the enforcement of the trade agreements. The positive pre-signature time-to-event coefficients are robust to heterogeneous treatment effects, suggesting the existence of a good news effect. Incorporating country pair ij linear time trend using Borusyak et al. (2022) Stata package is infeasible. As in the subsection above, I add the lag 1 aggregate bilateral trade flow at HS Nomenclature section level as an extra control to capture country-pair specific trends. The coefficient plot is illustrated in Figure 12 below.⁷³ The pattern of treatment effects in imputation-based specification 2 remains unchanged when the lag 1 aggregate bilateral trade flow is added, which again suggests that the treatment effects are driven by trade-agreement-related factors and the good news channel may be at work.

⁷²As not all treated observations are imputable, the results are not exactly comparable with the results in the regression-based specifications.

⁷³"Periods since the event = 0" corresponds to the 6th year before the signature (time-to-event -6). See Appendix M for the full regression result.

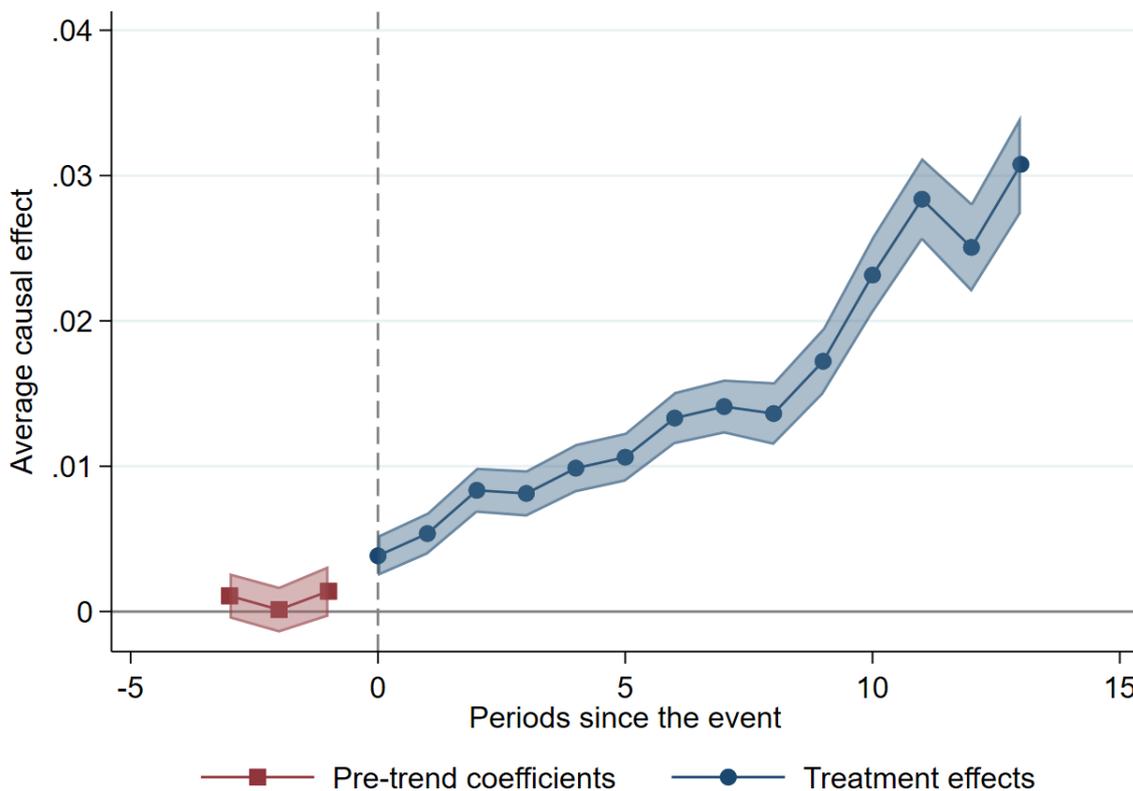


Figure 12: Imputation-based specification 2 - controlling for section level trade flow

To summarize, in this empirical section, I focus on a specific set of products of which the MFN tariff is positive and equals the bound tariff. I assume that the bad news channel is (approximately) shut down for those products. Recall that the good news channel doesn't work in H&L model but works in my learning model. Using this assumption, I am able to test the good news effect separately. I take the signature of trade agreements as the future good news and use the product level bilateral trade flow indicator as a measure of firms' entry. All my results suggest that the probability of a product being traded bilaterally starts to increase six years before the signature of the trade agreement. My empirical evidence is consistent with my model prediction. There exist some limitations regarding my empirical test. Despite my attempt to solve the endogeneity problem of the trade agreement signature by adding disaggregated exporting/importing side fixed effects, the endogeneity problem may still exist. In the literature, one way to deal with the endogeneity issue is through matching such as propensity score matching and covariate balance matching. In future work, I can incorporate the matching method to deal with the self-selection problem. Another work that should have been done but hasn't is the heterogeneous analysis. For example, intuitively, product lines with a higher MFN/bound tariff are expected to react more positively to the good news. Thus, one potential future work can be to investigate the heterogeneous treatment effects across different tariff levels.

6. Conclusion

In this paper, I present an extension to the partial equilibrium version of Handley and Limão (2017) model by introducing one-period demand learning. Their model predicts that TPU reduces exporters' entry due to *bad news principle* and gives a closed-form solution for entry

cutoff. I explore the impact of TPU on entry cutoff in the presence of demand learning using two models: sunk cost learning model and fixed cost learning model. Consistent with Handley and Limão (2017), bad news discourages firms' early entry. Moreover, good news matters in my model. My sunk cost learning model nests Handley and Limão model and provides a closed-form solution for entry cutoff. In sunk cost learning model, good news encourages firms' early entry. Future possible good news favors early entry over late entry because good news accompanied by more knowledge due to early learning brings additional profit to early entry. In the fixed cost learning model, per period export profit can be negative and there exists endogenous exit. The model becomes less tractable due to the existence of multiple kinks. Furthermore, good news can deter firms' early entry since entry cutoff firms take only the best learning outcome into account.

I also examine the impact of pure uncertainty by using a mean-preserving spread in tariff. For a sufficiently large uncertainty, there can be more entrants under TPU. In my models, firms' willingness to make early entry under TPU jointly depends on how profitable the learning is, namely the variance of posterior beliefs, and how favorable the TPU process is, namely the weighted inverted sum of high and low tariffs net of intermediate tariff. For an unfavorable TPU process, even though demand learning can bring extra profit to early entry, there are relatively fewer entrants under TPU compared to no TPU case. The variance of posterior beliefs is negatively correlated with firms' exporting ages. For new exporters, they learn more from exporting than old ones do and their variance of posterior beliefs is larger. Thus, my model suggests that the effect of TPU on exporters' entry decision is heterogeneous across exporters' age. Focusing on the product lines that don't face future bad news, my empirical findings indicate that the bilateral product-level entry starts to increase around 6 years before the signature of a trade agreement, which are consistent with my model prediction that good news can encourage entry. As both literature on export under TPU and literature on firm dynamics are recent, my paper combines the two pieces of literature and provides new insights into export decision-making under TPU. Additionally, my model can be applied to study other irreversible investment problems.

There are several limitations to my model. Firstly, I only consider TPU in a simplistic manner and it is not suitable for studying other types of trade barriers such as quota and sanitary measures. Secondly, trade policy uncertainty is assumed to be an exogenous process while tariff change can be an endogenous decision made by the government. Moreover, I assume that there is no correlation between the learning process and TPU process. There can still exist an endogenous treatment problem in my empirical test and some matching methods such as propensity score matching and covariate balance matching can be employed in the next step. Furthermore, a heterogeneous analysis should be included in the future version of this paper. I leave for future research the post-entry dynamics in the presence of TPU, multiple-periods demand learning, fixed cost, and sunk cost. Lastly, I suggest studying entry decisions under TPU using other export dynamics mechanisms.

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Appendix

A. Calculate the belief

(i) For a firm that starts to export in period t for the first time, the unconditional probability of her demand shock realization a_t will be:

$$Pr(a_t = \theta_H) = Pr(\theta = \theta_H, a_t = \theta_H) + Pr(\theta = \theta_L, a_t = \theta_H) = \frac{1}{2} \cdot p + \frac{1}{2} \cdot (1 - p) = \frac{1}{2} \quad (1)$$

$$Pr(a_t = \theta_L) = Pr(\theta = \theta_H, a_t = \theta_L) + Pr(\theta = \theta_L, a_t = \theta_L) = \frac{1}{2} \cdot (1 - p) + \frac{1}{2} \cdot p = \frac{1}{2} \quad (2)$$

Therefore, her belief (prior) of demand shock realization a_t in period t will be:

$$b_t = Pr(a_t = \theta_H) e^{\frac{\theta_H}{\sigma}} + Pr(a_t = \theta_L) e^{\frac{\theta_L}{\sigma}} = \frac{1}{2} e^{\frac{\theta_H}{\sigma}} + \frac{1}{2} e^{\frac{\theta_L}{\sigma}} = b_M, \quad (3)$$

(ii) For a firm that has exported in period $t - i$ with $i \geq 1$ for the first time and observed a realized demand shock $\bar{a}_t = a_{t-i} = \theta_H$, the conditional probability of her true underlying demand parameter θ will be

$$Pr(\theta = \theta_H | \bar{a}_t = \theta_H) = \frac{Pr(\bar{a}_t = \theta_H | \theta = \theta_H) \cdot Pr(\theta = \theta_H)}{Pr(\bar{a}_t = \theta_H, \theta = \theta_H) + Pr(\bar{a}_t = \theta_H, \theta = \theta_L)} = \frac{p \cdot \frac{1}{2}}{p \cdot \frac{1}{2} + (1 - p) \cdot \frac{1}{2}} = p \quad (4)$$

$$Pr(\theta = \theta_L | \bar{a}_t = \theta_H) = \frac{Pr(\bar{a}_t = \theta_H | \theta = \theta_L) \cdot Pr(\theta = \theta_L)}{Pr(\bar{a}_t = \theta_H, \theta = \theta_H) + Pr(\bar{a}_t = \theta_H, \theta = \theta_L)} = \frac{(1 - p) \cdot \frac{1}{2}}{p \cdot \frac{1}{2} + (1 - p) \cdot \frac{1}{2}} = 1 - p \quad (5)$$

Therefore, her posterior belief of a_t in period t will be

$$\begin{aligned} b_t(\bar{a}_t = \theta_H) &= Pr(\theta = \theta_H | \bar{a}_t = \theta_H) e^{\frac{\theta_H}{\sigma}} + Pr(\theta = \theta_L | \bar{a}_t = \theta_H) e^{\frac{\theta_L}{\sigma}} \\ &= p \cdot e^{\frac{\theta_H}{\sigma}} + (1 - p) \cdot e^{\frac{\theta_L}{\sigma}} = b_H, \end{aligned} \quad (6)$$

(iii) For a firm that has exported in period $t - i$ with $i \geq 1$ for the first time and observed a realized demand shock $\bar{a}_t = a_{t-i} = \theta_L$, the conditional probability of her true underlying demand parameter θ will be

$$Pr(\theta = \theta_H | \bar{a}_t = \theta_L) = \frac{Pr(\bar{a}_t = \theta_L | \theta = \theta_H) \cdot Pr(\theta = \theta_H)}{Pr(\bar{a}_t = \theta_L, \theta = \theta_H) + Pr(\bar{a}_t = \theta_L, \theta = \theta_L)} = \frac{(1 - p) \cdot \frac{1}{2}}{(1 - p) \cdot \frac{1}{2} + p \cdot \frac{1}{2}} = 1 - p \quad (7)$$

$$Pr(\theta = \theta_L | \bar{a}_t = \theta_L) = \frac{Pr(\bar{a}_t = \theta_L | \theta = \theta_L) \cdot Pr(\theta = \theta_L)}{Pr(\bar{a}_t = \theta_L, \theta = \theta_H) + Pr(\bar{a}_t = \theta_L, \theta = \theta_L)} = \frac{p \cdot \frac{1}{2}}{(1 - p) \cdot \frac{1}{2} + p \cdot \frac{1}{2}} = p \quad (8)$$

Therefore, her posterior belief of a_t in period t will be

$$\begin{aligned} b_t(\bar{a}_t = \theta_L) &= Pr(\theta = \theta_H | \bar{a}_t = \theta_L) e^{\frac{\theta_H}{\sigma}} + Pr(\theta = \theta_L | \bar{a}_t = \theta_L) e^{\frac{\theta_L}{\sigma}} \\ &= (1 - p) \cdot e^{\frac{\theta_H}{\sigma}} + p \cdot e^{\frac{\theta_L}{\sigma}} = b_L, \end{aligned} \quad (9)$$

Since p is assumed to be greater than $\frac{1}{2}$, $b_H \geq b_M \geq b_L > 0$ and $b_H + b_L = 2b_M$ ¹. b_H increases in p and b_L decreases in p . As $p = \frac{1}{2}$, $b_H = b_L = b_M$ and exporters learn nothing from their export

¹Using Jovanovic (1982) learning process, belief series is a martingale. Using our one period learning process, we can still capture the main idea of learning. Meanwhile, we are able to simplify our model as much as possible.

experience in the entry period. In this case, potential entrant is more like a very experienced exporter since receiving a new signal has no impact on her belief. As p increases, b_H and b_L diverge further from b_M and learning brings more information about exporters' type. In this case, potential entrant is more like a less experienced exporter since receiving a new signal has a large impact on her belief. The variance of belief sheds light on the age of exporter. However, we should keep in mind that more experienced incumbents are also highly selected. Therefore, their belief and productivity should be generally higher than that of fresh exporters. As $p = 1$ and $\theta_H \gg \theta_L$, b_H is close to $2b_M$, which also means that b_H cannot be greater than $2b_M$ by construction.

B. Recursive form of $\Pi_e(\varphi, \tau)$

In this section, I try to rewrite $\Pi_e(\varphi, \tau)$ using recursive formula like H&L. The expected value from exporting after entry under τ_1 is

$$\begin{aligned}
\Pi_e(\varphi, \tau_1) &= b_M^\sigma \tau_1^{-\sigma} \Phi + \gamma \lambda_2 \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + (1-\gamma) \beta \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_1^{-\sigma} \Phi + (1-\gamma) \beta \mathfrak{R}(\varphi, \tau_1) \\
&= b_M^\sigma \tau_1^{-\sigma} \Phi + \frac{\gamma \lambda_2}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \frac{\gamma (1-\lambda_2)}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + \frac{(1-\gamma)\beta}{1-(1-\gamma)\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_1^{-\sigma} \Phi
\end{aligned} \tag{10}$$

Where $\Phi = \varphi^{\sigma-1} k$. Firm φ enters under τ_1 with unconditional belief b_M . With probability $\gamma \lambda_2$, trade policy realization will be τ_2 in period 2 and it will be τ_2 forever. We have the term $\gamma \lambda_2 \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_2^{-\sigma} \Phi$. With probability $\gamma (1-\lambda_2)$, trade policy realization will be τ_0 in period 2 and it will be τ_0 forever. We have the term $\gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_0^{-\sigma} \Phi$. With probability $1-\gamma$, trade policy realization will be τ_1 in period 2 and we have the term $(1-\gamma) \beta \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_1^{-\sigma} \Phi$. $\mathfrak{R}(\varphi, \tau_1)$ is the recursive term which means if trade realization in period 2 is τ_1 , then in period 3, it will repeat the same process as that in period 2.² We have

$$\begin{aligned}
\mathfrak{R}(\varphi, \tau_1) &= \gamma \lambda_2 \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + (1-\gamma) \beta \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_1^{-\sigma} \Phi + (1-\gamma) \beta \mathfrak{R}(\varphi, \tau_1)
\end{aligned} \tag{11}$$

If the entry condition is τ_2 , we will have

$$\Pi_e(\varphi, \tau_2) = b_M^\sigma \tau_2^{-\sigma} \Phi + \frac{\beta}{1-\beta} \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \tag{12}$$

²It is because learning only lasts one period in my model.

Firm φ enters under τ_2 with unconditional belief b_M . As trade policy realization will be τ_2 forever, there is a term $\frac{\beta}{1-\beta} \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma \right) \tau_2^{-\sigma} \Phi$. If the entry condition is τ_0 , we will have

$$\Pi_e(\varphi, \tau_0) = b_M^\sigma \tau_0^{-\sigma} \Phi + \frac{\beta}{1-\beta} \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma \right) \tau_0^{-\sigma} \Phi \quad (13)$$

Firm φ enters under τ_0 with unconditional belief b_M . Trade policy realization will be τ_0 forever. Then we can write $\Pi_e(\varphi, \tau_1)$, $\Pi_e(\varphi, \tau_2)$, $\Pi_e(\varphi, \tau_0)$ recursively.

$$\begin{aligned} \Pi_e(\varphi, \tau_1) &= b_M^\sigma \tau_1^{-\sigma} \Phi + (1-\gamma)\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_1^{-\sigma} \Phi \\ &\quad + \gamma\lambda_2\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi \\ &\quad + \gamma(1-\lambda_2)\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi \\ &\quad + \beta E_{\tau_1} \Pi_e(\varphi, \tau') \\ &= f(\varphi, \tau_1) + \beta E_{\tau_1} \Pi_e(\varphi, \tau') \end{aligned} \quad (14)$$

Where $f(\varphi, \tau_1)$ is

$$\begin{aligned} f(\varphi, \tau_1) &= b_M^\sigma \tau_1^{-\sigma} \Phi + (1-\gamma)\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_1^{-\sigma} \Phi \\ &\quad + \gamma\lambda_2\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi \\ &\quad + \gamma(1-\lambda_2)\beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi \end{aligned} \quad (15)$$

$$\begin{aligned} \Pi_e(\varphi, \tau_2) &= b_M^\sigma \tau_2^{-\sigma} \Phi + \beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi + \beta E_{\tau_2} \Pi_e(\varphi, \tau') \\ &= f(\varphi, \tau_2) + \beta E_{\tau_2} \Pi_e(\varphi, \tau') \\ &= f(\varphi, \tau_2) + \beta \Pi_e(\varphi, \tau_2) \end{aligned} \quad (16)$$

Where $f(\varphi, \tau_2)$ is

$$f(\varphi, \tau_2) = b_M^\sigma \tau_2^{-\sigma} \Phi + \beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi \quad (17)$$

$$\begin{aligned} \Pi_e(\varphi, \tau_0) &= b_M^\sigma \tau_0^{-\sigma} \Phi + \beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi + \beta E_{\tau_0} \Pi_e(\varphi, \tau') \\ &= f(\varphi, \tau_0) + \beta E_{\tau_0} \Pi_e(\varphi, \tau') \\ &= f(\varphi, \tau_0) + \beta \Pi_e(\varphi, \tau_0) \end{aligned} \quad (18)$$

Where $f(\varphi, \tau_0)$ is

$$f(\varphi, \tau_0) = b_M^\sigma \tau_0^{-\sigma} \Phi + \beta \left(\frac{1}{2}b_H^\sigma + \frac{1}{2}b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi \quad (19)$$

The general expression of $\Pi_e(\varphi, \tau)$ is

$$\Pi_e(\varphi, \tau) = f(\varphi, \tau) + \beta E_\tau \Pi_e(\varphi, \tau') \quad (20)$$

$f(\varphi, \tau)$ captures the difference between the expected value from exporting after entry in the current period $\Pi_e(\varphi, \tau)$ and the expected value from exporting after entry in the next period $\beta E_\tau \Pi_e(\varphi, \tau')$.

C. The monotonicity of $V(\varphi, \tau)$

Ideally, we want $V(\varphi, \tau)$ to be a decreasing function of φ and increasing function of τ .

(A) For any given φ , $V(\varphi, \tau)$ is an increasing function of τ .

(i) $f(\varphi, \tau)$ is a decreasing function of τ . We can easily observe that $f(\varphi, \tau_0) > f(\varphi, \tau_1) > f(\varphi, \tau_2)$. Therefore, $-f(\varphi, \tau)$ is an increasing function of τ .

(ii) Because of the first-order dominance, $E_{\tau_0}V(\varphi, \tau') < E_{\tau_1}V(\varphi, \tau') < E_{\tau_2}V(\varphi, \tau')$ if $V(\varphi, \tau)$ is increasing in τ .

By property (i) and (ii), if we start with an increasing $V(\varphi, \tau)$ in τ , the fixed point to this iteration is also increasing τ .³

(B) For any given τ , $V(\varphi, \tau)$ is a decreasing function of φ .

In H&L (2017), they don't give such proof. But the logic should be like this: $f(\varphi, \tau)$ is an increasing function of φ , which means $-f(\varphi, \tau)$ is a decreasing function of φ . Then starting with a decreasing $V(\varphi, \tau)$ in φ , the fixed point to this iteration is also decreasing in φ .

Therefore, firm will be more willing to choose to wait in the current period if their productivity φ is low and the current trade policy realization τ is high.

D. Calculate $\frac{\varphi_{1u}}{\varphi_1}$ using sunk cost learning model

φ_{1u} is the entry threshold under TPU which satisfies the following equation

$$\beta E_{\tau_1} V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_1) + (1 - \beta) S = 0 \quad (21)$$

Recall that $V(\varphi_{1u}, \tau_0) = 0$, $V(\varphi_{1u}, \tau_1) = 0$ and $V(\varphi_{1u}, \tau_2) > 0$. $E_{\tau_1} V(\varphi_{1u}, \tau')$ will be

$$\begin{aligned} E_{\tau_1} V(\varphi_{1u}, \tau') &= \gamma \lambda_2 V(\varphi_{1u}, \tau_2) \\ &= \gamma \lambda_2 (\beta E_{\tau_2} V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_2) + (1 - \beta) S) \end{aligned} \quad (22)$$

We have

$$\begin{aligned} E_{\tau_2} V(\varphi_{1u}, \tau') &= V(\varphi_{1u}, \tau_2) \\ &= \beta E_{\tau_2} V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_2) + (1 - \beta) S \end{aligned} \quad (23)$$

From (23), we can solve $E_{\tau_2} V(\varphi_{1u}, \tau')$

$$E_{\tau_2} V(\varphi_{1u}, \tau') = S - \frac{f(\varphi_{1u}, \tau_2)}{1 - \beta} \quad (24)$$

Bring (24) into (22) and we have

$$E_{\tau_1} V(\varphi_{1u}, \tau') = \gamma \lambda_2 \left(S - \frac{f(\varphi_{1u}, \tau_2)}{1 - \beta} \right) \quad (25)$$

Bring (25) into (21) and we have

$$\beta \gamma \lambda_2 \left(S - \frac{f(\varphi_{1u}, \tau_2)}{1 - \beta} \right) - f(\varphi_{1u}, \tau_1) + (1 - \beta) S = 0 \quad (26)$$

³A difference between my model and that of H&L (2017) is that their $f(\varphi, \tau)$ is the per period profit which has the same form for different τ .

Arrange it as

$$f(\varphi_{1u}, \tau_1) + \frac{\beta\gamma\lambda_2}{1-\beta} f(\varphi_{1u}, \tau_2) = (1 - \beta + \beta\gamma\lambda_2) S \quad (27)$$

Recall that φ_1 is the entry threshold in a no TPU case and we have

$$b_M^\sigma \tau_1^{1-\sigma} \Phi_1 + \frac{1}{2} \frac{\beta}{1-\beta} (b_H^\sigma + b_L^\sigma) \tau_1^{1-\sigma} \Phi_1 = S \quad (28)$$

Where $\Phi_1 = \varphi_1^{\sigma-1} k$. Bring (28) into (27) and we have

$$\begin{aligned} & b_M^\sigma \tau_1^{1-\sigma} \Phi_{1u} + \beta \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma - b_M^\sigma \right) \left[(1 - \gamma) \tau_1^{1-\sigma} + \gamma \lambda_2 \tau_2^{1-\sigma} + \gamma (1 - \lambda_2) \tau_0^{1-\sigma} \right] \Phi_{1u} \\ & + \frac{\beta\gamma\lambda_2}{1-\beta} \left(b_M^\sigma \tau_2^{1-\sigma} \Phi_{1u} + \beta \left(\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma - b_M^\sigma \right) \tau_2^{1-\sigma} \Phi_{1u} \right) \\ & = (1 - \beta + \beta\gamma\lambda_2) \left(b_M^\sigma \tau_1^{1-\sigma} \Phi_1 + \frac{1}{2} \frac{\beta}{1-\beta} (b_H^\sigma + b_L^\sigma) \tau_1^{1-\sigma} \Phi_1 \right) \end{aligned} \quad (29)$$

Recall that $b_H = \varepsilon b_M$ and $b_L = (2 - \varepsilon) b_M$. The above equation can be simplified as

$$\begin{aligned} & \frac{\Phi_{1u}}{\Phi_1} \\ & = \frac{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2} \frac{\beta}{1-\beta} b(\varepsilon) \right)}{1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma \lambda_2 \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} + \gamma (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} \right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2} \frac{\beta}{1-\beta} b(\varepsilon) \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma}} \end{aligned} \quad (30)$$

Where $b(\varepsilon) = \varepsilon^\sigma + (2 - \varepsilon)^\sigma$ and $b(\varepsilon) - 2 \geq 0$.

E. Monotonicity of $\frac{\varphi_{1u}}{\varphi_1}$ regarding to λ_2

Recall that the monotonicity of $\frac{\varphi_{1u}}{\varphi_1}$ regarding to λ_2 is the same as that of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$ as σ is assumed to be greater than 1. Take the first derivative of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$ regarding to λ_2 and take the positive

denominator to the left hand side.

$$\begin{aligned}
& \frac{\partial \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \lambda_2} (\cdot)^2 \\
&= \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \beta\gamma \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \\
&\quad - \left(\frac{1}{2}\beta [b(\varepsilon) - 2] \left[\gamma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - \gamma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)\right) \\
&= \beta\gamma \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left[1 - \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right] \\
&\quad + \frac{1}{2}\beta [b(\varepsilon) - 2] \beta\gamma \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} - \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right] \\
&\quad + \frac{1}{2}\beta\gamma [b(\varepsilon) - 2] \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)\right) \left[\left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} - \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right] \\
&\geq 0
\end{aligned} \tag{31}$$

Where $(\cdot)^2$ is the denominator of the first derivative. The equality is taken as $\tau_2 = \tau_0 = \tau_1$. Therefore, $\frac{\varphi_{1u}}{\varphi_1}$ is an increasing function of λ_2 .

F. Proposition 2

Here, I would like to prove $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \gamma} \geq 0$ is equivalent to $\frac{\varphi_{1u}}{\varphi_1} \geq 1$ and vice versa. Recall that $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \gamma} \geq 0$ is equivalent to $\frac{\partial \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \gamma} \geq 0$ and $\frac{\varphi_{1u}}{\varphi_1} \geq 1$ is equivalent to $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} \geq 1$ as $\sigma > 1$. We have

$$\begin{aligned}
& \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}} \geq 1 \Leftrightarrow \\
& \frac{1}{2}\beta [b(\varepsilon) - 2] \left[-\gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left[\left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - 1\right] \\
& \leq 0
\end{aligned} \tag{32}$$

Take the first derivative of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$ regarding to γ and take the positive denominator to the left

hand side.

$$\begin{aligned}
& \frac{\partial \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \gamma} (\cdot)^2 \\
&= \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \beta\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \\
&\quad - \left(\frac{1}{2}\beta [b(\varepsilon) - 2] \left[-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)\right) \\
&= \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2]\right) \\
&\quad \cdot -\frac{1}{2}\beta [b(\varepsilon) - 2] \left[-\gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] - \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left[\left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - 1\right]
\end{aligned} \tag{33}$$

Where $(\cdot)^2$ is the denominator of the first derivative which is positive. The two above equations show that $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \gamma} \geq 0$ is equivalent to $\frac{\varphi_{1u}}{\varphi_1} \geq 1$. The proof of the other statement is trivial.

G. Proposition 3

Take the first derivative of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$ regarding to ε and take the positive denominator to the left hand side.

$$\begin{aligned}
& \frac{\partial \frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}}{\partial \varepsilon} (\cdot)^2 \\
&= \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \left(\frac{1}{2}\beta b'(\varepsilon) + \frac{1}{2}\frac{\beta}{1-\beta}\beta\gamma\lambda_2 b'(\varepsilon)\right) \\
&\quad - \left(\frac{1}{2}\beta b'(\varepsilon) \left[1 - \gamma + \gamma\lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right] + \frac{1}{2}\frac{\beta}{1-\beta}\beta\gamma\lambda_2 b'(\varepsilon) \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}\right) \\
&\quad \cdot \left(1 + \frac{1}{2}\beta [b(\varepsilon) - 2] + \beta\gamma\lambda_2 \left(1 + \frac{1}{2}\frac{\beta}{1-\beta}b(\varepsilon)\right)\right) \\
&= \frac{1}{2}\beta\gamma \left(\gamma\lambda_2 \frac{\beta}{1-\beta} + 1\right) b'(\varepsilon) \left[1 - \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}\right]
\end{aligned} \tag{34}$$

Where $b'(\varepsilon) = \sigma\varepsilon^{\sigma-1} - \sigma(2 - \varepsilon)^{\sigma-1} > 0$. Therefore, $\frac{\partial \frac{\varphi_{1u}}{\varphi_1}}{\partial \varepsilon} > 0$ as $\lambda_2\tau_2^{-\sigma} + (1 - \lambda_2)\tau_0^{-\sigma} < \tau_1^{-\sigma}$ and vice versa.

H. Calculate $\frac{\varphi_{1u}}{\varphi_1}$ using fixed cost learning model

In this section, I consider a model with fixed cost and learning but without sunk cost. Define $\Pi_e(\varphi, \tau)$ as the expected value from exporting conditional on entry (entry means first-time

exporting) with entry condition being τ and φ . $\Pi_e(\varphi, \tau_1)$ is

$$\begin{aligned}
\Pi_e(\varphi, \tau_1) &= b_M^\sigma \tau_1^{-\sigma} \Phi - f \\
&\quad + \gamma \lambda_2 \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \gamma \lambda_2 \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} \right) f \\
&\quad + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} \right) f \\
&\quad + (1-\gamma) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} b_L^\sigma \right) \tau_1^{-\sigma} \Phi \\
&\quad + (1-\gamma) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} \right) f \\
&\quad + (1-\gamma) \beta \mathfrak{R}(\varphi, \tau_1) \\
&= b_M^\sigma \tau_1^{-\sigma} \Phi - f \\
&\quad + \frac{\gamma \lambda_2}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \frac{\gamma \lambda_2}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} \right) f \\
&\quad + \frac{\gamma (1-\lambda_2)}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + \frac{\gamma (1-\lambda_2)}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} \right) f \\
&\quad + \frac{(1-\gamma)\beta}{1-(1-\gamma)\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} b_L^\sigma \right) \tau_1^{-\sigma} \Phi \\
&\quad + \frac{(1-\gamma)\beta}{1-(1-\gamma)\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} \right) f
\end{aligned} \tag{35}$$

Where $\Phi = \varphi^{\sigma-1} k$. $\mathbb{1}_{\varphi, \tau, b}$ is the indicator of per period profit conditional on productivity φ , current trade policy realization τ and current belief b . $\mathbb{1}_{\varphi, \tau, b} = 1$ if $\pi(\varphi, \tau, b) = b^\sigma \tau^{-\sigma} \varphi^{\sigma-1} k - f > 0$. $\mathbb{1}_{\varphi, \tau, b} = 0$ if $\pi(\varphi, \tau, b) < 0$. I introduce indicator function since using per period fixed cost, per period profit can be negative and firms won't export with a negative profit after learning.

Firm φ enters under τ_1 with unconditional belief b_M (line 1). With probability $\gamma \lambda_2$, trade policy realization will be τ_2 in period 2 and it will be τ_2 forever. Therefore, we have the term of line 2 and 3. With probability $\gamma (1-\lambda_2)$, trade policy realization will be τ_0 in period 2 and it will be τ_0 forever. Therefore, we have the term of line 4 and 5. With probability $1-\gamma$, trade policy realization will be τ_1 in period 2 and we have the term of line 6 and 7. $\mathfrak{R}(\varphi, \tau_1)$ is the recursive term which means if trade realization in period 2 is τ_1 , then in period 3, it will repeat the same

process as that in period 2. The recursive term $\mathfrak{R}(\varphi, \tau_1)$ is

$$\begin{aligned}
\mathfrak{R}(\varphi, \tau_1) = & \gamma \lambda_2 \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
& + \gamma \lambda_2 \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} \right) f \\
& + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
& + \gamma (1-\lambda_2) \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} \right) f \\
& + (1-\gamma) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} b_L^\sigma \right) \tau_1^{-\sigma} \Phi \\
& + (1-\gamma) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} \right) f \\
& + (1-\gamma) \beta \mathfrak{R}(\varphi, \tau_1)
\end{aligned} \tag{36}$$

$\Pi_e(\varphi, \tau_2)$ is

$$\begin{aligned}
\Pi_e(\varphi, \tau_2) = & b_M^\sigma \tau_2^{-\sigma} \Phi - f + \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma \right) \tau_2^{-\sigma} \Phi \\
& + \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} \right) f
\end{aligned} \tag{37}$$

Firm φ enters under τ_2 with unconditional belief b_M . Trade policy realization will be τ_2 forever. Similarly, $\Pi_e(\varphi, \tau_0)$ is

$$\begin{aligned}
\Pi_e(\varphi, \tau_0) = & b_M^\sigma \tau_0^{-\sigma} \Phi - f + \frac{\beta}{1-\beta} \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma \right) \tau_0^{-\sigma} \Phi \\
& + \frac{\beta}{1-\beta} \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} \right) f
\end{aligned} \tag{38}$$

Firm φ enters under τ_0 with unconditional belief b_M . Trade policy realization will be τ_0 forever. Then we can write $\Pi_e(\varphi, \tau_1)$, $\Pi_e(\varphi, \tau_2)$, $\Pi_e(\varphi, \tau_0)$ recursively.

$$\begin{aligned}
\Pi_e(\varphi, \tau_1) = & b_M^\sigma \tau_1^{-\sigma} \Phi - f + (1-\gamma) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} b_L^\sigma - b_M^\sigma \right) \tau_1^{-\sigma} \Phi \\
& + (1-\gamma) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_1, b_L} + 1 \right) f \\
& + \gamma \lambda_2 \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi \\
& + \gamma \lambda_2 \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} + 1 \right) f \\
& + \gamma (1-\lambda_2) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi \\
& + \gamma (1-\lambda_2) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} + 1 \right) f \\
& + \beta E_{\tau_1} \Pi_e(\varphi, \tau') \\
= & f(\varphi, \tau_1) + \beta E_{\tau_1} \Pi_e(\varphi, \tau')
\end{aligned} \tag{39}$$

$$\begin{aligned}
\Pi_e(\varphi, \tau_2) &= b_M^\sigma \tau_2^{-\sigma} \Phi - f + \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi \\
&\quad + \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_2, b_L} + 1 \right) f + \beta E_{\tau_2} \Pi_e(\varphi, \tau') \\
&= f(\varphi, \tau_2) + \beta E_{\tau_2} \Pi_e(\varphi, \tau') \\
&= f(\varphi, \tau_2) + \beta \Pi_e(\varphi, \tau_2)
\end{aligned} \tag{40}$$

$$\begin{aligned}
\Pi_e(\varphi, \tau_0) &= b_M^\sigma \tau_0^{-\sigma} \Phi - f + \beta \left(\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi \\
&\quad + \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi, \tau_0, b_L} + 1 \right) f + \beta E_{\tau_0} \Pi_e(\varphi, \tau') \\
&= f(\varphi, \tau_0) + \beta E_{\tau_0} \Pi_e(\varphi, \tau') \\
&= f(\varphi, \tau_0) + \beta \Pi_e(\varphi, \tau_0)
\end{aligned} \tag{41}$$

$\Pi_e(\varphi, \tau_1)$, $\Pi_e(\varphi, \tau_2)$, $\Pi_e(\varphi, \tau_0)$ can be summarized as a following equation

$$\Pi_e(\varphi, \tau) = f(\varphi, \tau) + \beta E_\tau \Pi_e(\varphi, \tau') \tag{42}$$

Define $\Pi(\varphi, \tau)$ as the expected value under trade policy τ for a potential exporter φ . We have

$$\Pi(\varphi, \tau) = \max \{ \Pi_e(\varphi, \tau), \beta E_\tau \Pi(\varphi, \tau') \} \tag{43}$$

$\Pi(\varphi, \tau)$ is the maximal value between entering in the current period $\Pi_e(\varphi, \tau)$ and waiting in the current period $\beta E_\tau \Pi(\varphi, \tau')$. Minus each side by $\Pi_e(\varphi, \tau)$ in (43) and bring (42) into (43), we have a following equation

$$\Pi(\varphi, \tau) - \Pi_e(\varphi, \tau) = \max \{ 0, \beta E_\tau [\Pi(\varphi, \tau') - \Pi_e(\varphi, \tau')] - f(\varphi, \tau) \} \tag{44}$$

$\Pi(\varphi, \tau) - \Pi_e(\varphi, \tau)$ is the value net of the profits of entering in the current period. If it's positive, firm φ will choose to wait in the current condition τ . If it's 0, firm φ will enter in the current period. Define $V(\varphi, \tau) = \Pi(\varphi, \tau) - \Pi_e(\varphi, \tau)$ which is the net value of waiting conditional on τ and φ and we have

$$V(\varphi, \tau) = \max \{ 0, \beta E_\tau V(\varphi, \tau') - f(\varphi, \tau) \} \tag{45}$$

I will focus on the entry threshold under $\tau_1 - \varphi_{1u}$. For φ_{1u} firms, following condition should be satisfied.

$$\beta E_{\tau_1} V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_1) = 0 \tag{46}$$

The above condition implies that $V(\varphi_{1u}, \tau_1) = 0$. Besides, I assume that $V(\varphi_{1u}, \tau_0) = 0$ and $V(\varphi_{1u}, \tau_2) > 0$ are satisfied, which means φ_{1u} firms prefer to enter under τ_0 and wait under τ_2 .

Ideally, we want $V(\varphi, \tau)$ to be a decreasing function of φ and increasing function of τ .

(A) For any given φ , $V(\varphi, \tau)$ is an increasing function of τ ?

(i) The problem is whether $f(\varphi, \tau)$ is a decreasing function of τ . We can easily observe that $f(\varphi, \tau_0) > f(\varphi, \tau_1)$. However, the relation between $f(\varphi, \tau_1)$ and $f(\varphi, \tau_2)$ is not obvious.

$f(\varphi, \tau_1) > f(\varphi, \tau_2)$ for any φ if and only if $\tau_1^{-\sigma} - (1 - \gamma)\beta\tau_1^{-\sigma} - \gamma\lambda_2\beta\tau_2^{-\sigma} - \gamma(1 - \lambda_2)\beta\tau_0^{-\sigma} > (1 - \beta)\tau_2^{-\sigma}$.

(ii) Because of first-order dominance, $E_{\tau_0}V(\varphi, \tau') < E_{\tau_1}V(\varphi, \tau') < E_{\tau_2}V(\varphi, \tau')$ if $V(\varphi, \tau)$ increases in τ .

So property (i) such that $f(\varphi, \tau)$ is a decreasing function of τ is not always satisfied. Assume that property (i) is satisfied. By property (i) and (ii), if we start with a $V(\varphi, \tau)$ increasing in τ , the fixed point to this iteration also increases in τ .

(B) For any given τ , $V(\varphi, \tau)$ is a decreasing function of φ ?

Using fixed cost, $f(\varphi, \tau_1)$ may not be an increasing function of φ . Therefore, we need to assume it. $f(\varphi, \tau_1)$ increases in φ if and only if $\tau_1^{-\sigma} - (1 - \gamma)\beta\tau_1^{-\sigma} - \gamma\lambda_2\beta\tau_2^{-\sigma} - \gamma(1 - \lambda_2)\beta\tau_0^{-\sigma} > 0$. We can easily observe that if $f(\varphi, \tau_1) > f(\varphi, \tau_2)$ for any φ is satisfied, then $f(\varphi, \tau_1)$ increasing in φ should also be satisfied.

If both (A) and (B) are satisfied, potential entrants will be more willing to choose to wait in the current period if their productivity φ is low and the current trade policy realization τ is high. In fact, we may be able to impose some weaker assumption. For example, $f(\varphi, \tau_1) > f(\varphi, \tau_2)$ for any φ is a too strong assumption. We don't need to consider the potential entrants that don't export in all three tariff states since their value is always 0. Therefore, a less restrictive condition is $\tau_1^{-\sigma} - (1 - \gamma)\beta\tau_1^{-\sigma} - \gamma\lambda_2\beta\tau_2^{-\sigma} - \gamma(1 - \lambda_2)\beta\tau_0^{-\sigma} + \frac{1}{2}\gamma(1 - \lambda_2)\beta\frac{b_H^\sigma\tau_0^{-\sigma}\varphi^{\sigma-1}k-f}{b_M^\sigma\varphi^{\sigma-1}} > (1 - \beta)\tau_2^{-\sigma}$ with $\varphi^{\sigma-1} \geq \frac{(1+\frac{1}{2}\frac{\beta}{1-\beta})f}{(b_M^\sigma + \frac{1}{2}\frac{\beta}{1-\beta}b_H^\sigma)k}\tau_0^\sigma$.

Following the above assumption, we can calculate $E_{\tau_1}V(\varphi_{1u}, \tau')$.

$$\begin{aligned} E_{\tau_1}V(\varphi_{1u}, \tau') &= \gamma\lambda_2V(\varphi_{1u}, \tau_2) \\ &= \gamma\lambda_2(\beta E_{\tau_2}V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_2)) \end{aligned} \quad (47)$$

We have

$$\begin{aligned} E_{\tau_2}V(\varphi_{1u}, \tau') &= V(\varphi_{1u}, \tau_2) \\ &= \beta E_{\tau_2}V(\varphi_{1u}, \tau') - f(\varphi_{1u}, \tau_2) \end{aligned} \quad (48)$$

From (48), we can solve $E_{\tau_2}V(\varphi_{1u}, \tau')$

$$E_{\tau_2}V(\varphi_{1u}, \tau') = -\frac{f(\varphi_{1u}, \tau_2)}{1 - \beta} \quad (49)$$

Bring (49) into (47) and we have

$$E_{\tau_1}V(\varphi_{1u}, \tau') = -\frac{\gamma\lambda_2}{1 - \beta}f(\varphi_{1u}, \tau_2) \quad (50)$$

Bring (50) into (46) and we have

$$f_{\tau_1}(\varphi_{1u}) + \frac{\beta\gamma\lambda_2}{1 - \beta}f(\varphi_{1u}, \tau_2) = 0 \quad (51)$$

Recall that φ_1 is the entry threshold in a no TPU case and we have

$$b_M^\sigma\tau_1^{-\sigma}\Phi_1 - f + \frac{1}{2}\frac{\beta}{1 - \beta}(b_H^\sigma\tau_1^{-\sigma}\Phi_1 - f) = 0 \quad (52)$$

Rearrange the above function and we have

$$f = \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \quad (53)$$

Bring (53) into (51) and we have

$$\begin{aligned} & b_M^\sigma \tau_1^{-\sigma} \Phi_{1u} - \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & + (1-\gamma) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_L} b_L^\sigma - b_M^\sigma \right) \tau_1^{-\sigma} \Phi_{1u} \\ & + (1-\gamma) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_L} + 1 \right) \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & + \gamma \lambda_2 \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_L} b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi_{1u} \\ & + \gamma \lambda_2 \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_L} + 1 \right) \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & + \gamma (1-\lambda_2) \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} b_L^\sigma - b_M^\sigma \right) \tau_0^{-\sigma} \Phi_{1u} \\ & + \gamma (1-\lambda_2) \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_H} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} + 1 \right) \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & + \frac{\beta \gamma \lambda_2}{1-\beta} b_M^\sigma \tau_2^{-\sigma} \Phi_{1u} - \frac{\beta \gamma \lambda_2}{1-\beta} \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & + \frac{\beta \gamma \lambda_2}{1-\beta} \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} b_H^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_L} b_L^\sigma - b_M^\sigma \right) \tau_2^{-\sigma} \Phi_{1u} \\ & + \frac{\beta \gamma \lambda_2}{1-\beta} \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_L} + 1 \right) \frac{\left(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma\right) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\ & = 0 \end{aligned} \quad (54)$$

$\pi(\varphi_{1u}, \tau_1, b_M) = b_M^\sigma \tau_1^{-\sigma} \Phi_{1u} - f < 0$ should be satisfied. If $\pi(\varphi_{1u}, \tau_1, b_M) > 0$, φ_{1u} firm will enter under τ_1 with a positive expected profit in the entry period and she will strictly prefer to enter under τ_1 which is a contradiction.⁴ Therefore, we have $\mathbb{1}_{\varphi_{1u}, \tau_2, b_L} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_1, b_L} = 0$. Moreover, since φ_{1u} firm is willing to enter under τ_0 , she should be able to make positive profit conditional on τ_0 and b_H and we have $\mathbb{1}_{\varphi_{1u}, \tau_0, b_H} = 1$. For now, the value of $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H}$, $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H}$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}$ cannot be determined. Recall that $b_H = \varepsilon b_M$ and $b_L = (2 - \varepsilon) b_M$. Simplify (54)

⁴Recall that $\frac{1}{2} b_H^\sigma + \frac{1}{2} b_L^\sigma \geq b_M^\sigma$. Therefore, we have $\frac{1}{2} \mathbb{1}_{\varphi, \tau, b_H} \pi(\varphi, \tau, b_H) + \frac{1}{2} \mathbb{1}_{\varphi, \tau, b_L} \pi(\varphi, \tau, b_L) \geq \pi(\varphi, \tau, b_M)$ for any given φ and τ . The unconditional expectation of post-learning per period profit is always greater than per period profit with prior belief and demand learning is advantageous. If $\pi(\varphi_{1u}, \tau_1, b_M) > 0$, φ_{1u} firms can benefit from learning while won't suffer from a negative entry-period expected profit. In this case, φ_{1u} firms will strictly prefer to enter under τ_1 , which is a contradiction.

and we have

$$\begin{aligned}
& \frac{\Phi_{1u}}{\Phi_1} - \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& + (1-\gamma)\beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} \varepsilon^\sigma - 1 \right) \frac{\Phi_{1u}}{\Phi_1} + (1-\gamma)\beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} + 1 \right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& + \gamma\lambda_2\beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} \frac{\Phi_{1u}}{\Phi_1} + \gamma\lambda_2\beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1 \right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& + \gamma(1-\lambda_2)\beta \left(\frac{1}{2} \varepsilon^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} (2-\varepsilon)^\sigma - 1 \right) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} \frac{\Phi_{1u}}{\Phi_1} \\
& + \gamma(1-\lambda_2)\beta \left(\frac{1}{2} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} \right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& + \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} \frac{\Phi_{1u}}{\Phi_1} - \frac{\beta\gamma\lambda_2}{1-\beta} \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& + \frac{\beta\gamma\lambda_2}{1-\beta} \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} \frac{\Phi_{1u}}{\Phi_1} + \frac{\beta\gamma\lambda_2}{1-\beta} \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1 \right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}} \\
& = 0
\end{aligned} \tag{55}$$

We can bring $\frac{\Phi_{1u}}{\Phi_1}$ on one side and bring the rest terms on the other side. Then we have

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{\text{numerator}}{\text{denominator}} \tag{56}$$

Where *numerator* is

$$\begin{aligned}
\text{numerator} = & \left(1 - (1-\gamma)\beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} + 1 \right) - \gamma\lambda_2\beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1 \right) \right. \\
& \left. - \gamma(1-\lambda_2)\beta \left(\frac{1}{2} - \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} \right) + \frac{\beta\gamma\lambda_2}{1-\beta} - \frac{\beta\gamma\lambda_2}{1-\beta} \beta \left(-\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} + 1 \right) \right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}
\end{aligned} \tag{57}$$

And *denominator* is

$$\begin{aligned}
\text{denominator} = & 1 + (1-\gamma)\beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_1, b_H} \varepsilon^\sigma - 1 \right) + \gamma\lambda_2\beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} \\
& + \gamma(1-\lambda_2)\beta \left(\frac{1}{2} \varepsilon^\sigma + \frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_0, b_L} (2-\varepsilon)^\sigma - 1 \right) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} \\
& + \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1} \right)^{1-\sigma} + \frac{\beta\gamma\lambda_2}{1-\beta} \beta \left(\frac{1}{2} \mathbb{1}_{\varphi_{1u}, \tau_2, b_H} \varepsilon^\sigma - 1 \right) \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma}
\end{aligned} \tag{58}$$

As we can see from the equations above, discussing if $\frac{\Phi_{1u}}{\Phi_1}$ is greater or less than 1 is not trivial. The formula of $\frac{\Phi_{1u}}{\Phi_1}$ depends on three indicators - $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H}$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H}$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}$. If we know the exact value of these three indicators, we can obtain a solution of $\frac{\Phi_{1u}}{\Phi_1}$ being expressed by exogenous parameters only. In order to obtain the exact solution of $\frac{\Phi_{1u}}{\Phi_1}$, we need to discuss the value of three indicators case by case. Moreover, we can start by discussing the value of $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H}$ firstly in order to simplify our discussion.

I. 6 possible solutions of $\frac{\varphi_{1u}^{\sigma-1}}{\varphi_1^{\sigma-1}}$

For the 3 undetermined indicators, I will show that there are 6 different combinations in total.

I.1. $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$

In this case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$. φ_{1u} firms cannot make positive profit under τ_1 conditional on good belief b_H . As $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ is also satisfied. Recall that $\mathbb{1}_{\varphi_1, \tau_1, b_H} = 1$ because φ_1 firms can make positive profit under τ_1 conditional on good belief b_H in the case without TPU. Therefore, if $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$, $\varphi_{1u} < \varphi_1$ and there will be more entrants. $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$ is equivalent to $b_H^\sigma \tau_1^{-\sigma} \varphi_{1u}^{\sigma-1} k - f \leq 0$. From equation (53), we have $f = \frac{(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}$. Substitute f by $\frac{(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma) \tau_1^{-\sigma} \Phi_1}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}$ and $b_H^\sigma \tau_1^{-\sigma} \varphi_{1u}^{\sigma-1} k - f \leq 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} \leq \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \varepsilon^\sigma} \quad (59)$$

Where $\Phi = \varphi^{\sigma-1} k$. We can easily observe that the right-hand side of the inequality $\frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \varepsilon^\sigma}$ is less than 1. Therefore, $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$ implies that $\frac{\Phi_{1u}}{\Phi_1} < 1$, which means there are more entrants in the uncertainty case. Assuming $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$ implies that $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and we only need to discuss the value of indicator $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L}$.

(1) $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$

$\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$ is equivalent to $b_L^\sigma \tau_0^{-\sigma} \varphi_{1u}^{\sigma-1} k - f < 0$. Substitute f using equation (53) and $b_L^\sigma \tau_0^{-\sigma} \varphi_{1u}^{\sigma-1} k - f < 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} < \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (60)$$

In this case, φ_{1u} firms cannot make positive profit under τ_0 conditional on bad belief b_L . Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$, the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$ is

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{[1 - (1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}}{1 - (1 - \gamma)\beta + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (61)$$

In order to guarantee that the above solution is feasible, two parametric constraints should be satisfied. The first constraint is obtained using (59) and (61) which is

$$\frac{[1 - (1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] \varepsilon^\sigma}{1 - (1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \leq 1 \quad (62)$$

The second constraint is obtained using (60) and (61) which is

$$\frac{[1 - (1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - (1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} < 1 \quad (63)$$

(2) $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$

$\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$ is equivalent to $b_L^\sigma \tau_0^{-\sigma} \varphi_{1u}^{\sigma-1} k - f > 0$. Substitute f using equation (53) and $b_L^\sigma \tau_0^{-\sigma} \varphi_{1u}^{\sigma-1} k - f > 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) (2-\varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (64)$$

In this case, φ_{1u} firms can make positive profit under τ_0 conditional on bad belief b_L . Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$, we can give the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{[1 - (1-\gamma)\beta] \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}}{1 - (1-\gamma)\beta + \gamma(1-\lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2-\varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (65)$$

In order to guarantee that the above solution is feasible, two parametric constraints should be satisfied. The first constraint is obtained using (59) and (65) which is

$$\frac{[1 - (1-\gamma)\beta] \varepsilon^\sigma}{1 - (1-\gamma)\beta + \gamma(1-\lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2-\varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \leq 1 \quad (66)$$

The second constraint is obtained using (64) and (65) which is

$$\frac{[1 - (1-\gamma)\beta] (2-\varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - (1-\gamma)\beta + \gamma(1-\lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2-\varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (67)$$

I.2. $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$

In this case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$. φ_{1u} firms can make positive profit under τ_1 conditional on good belief b_H . We cannot tell directly the relation between φ_{1u} and φ_1 and we need to discuss 4 different cases. $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$ is equivalent to $b_H^\sigma \tau_1^{-\sigma} \varphi_{1u}^{\sigma-1} k - f > 0$ which is also equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \varepsilon^\sigma} \quad (68)$$

(1) $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$

In the first sub case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$. φ_{1u} firms cannot make positive profit under τ_2 conditional on good belief b_H . Besides, they cannot make positive profit under τ_0 conditional on bad belief b_L either. $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} < \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (69)$$

And $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} < \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) (2-\varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (70)$$

Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$, we can give the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{[1 - \frac{1}{2}(1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}}{1 - \left[\frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] (2 - \varepsilon^\sigma)} \quad (71)$$

In order to guarantee that the above solution is feasible, three parametric constraints should be satisfied. The first constraint is obtained using (68) and (71) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] \varepsilon^\sigma}{1 - \left[\frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] (2 - \varepsilon^\sigma)} > 1 \quad (72)$$

The second constraint is obtained using (69) and (71) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 - \left[\frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] (2 - \varepsilon^\sigma)} < 1 \quad (73)$$

The third constraint is obtained using (70) and (71) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta - \frac{1}{2}\gamma(1 - \lambda_2)\beta] (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - \left[\frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] (2 - \varepsilon^\sigma)} < 1 \quad (74)$$

(2) $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$

In the second sub case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$. φ_{1u} firms can make positive profit under τ_2 conditional on good belief b_H while they cannot make positive profit under τ_0 conditional on bad belief b_L . $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (75)$$

$\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} < \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (76)$$

Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 0$, we can give the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{(1 - \frac{1}{2}\beta) \left(1 + \frac{\beta\gamma\lambda_2}{1-\beta}\right) \frac{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}{1 + \frac{1}{2} \frac{\beta}{1-\beta}}}{1 + \left[(1 - \gamma)\beta + \gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] \left(\frac{1}{2}\varepsilon^\sigma - 1 \right) + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (77)$$

In order to guarantee that the above solution is feasible, three parametric constraints should be satisfied. The first constraint is obtained using (68) and (77) which is

$$\frac{(1 - \frac{1}{2}\beta) \left(1 + \frac{\beta\gamma\lambda_2}{1-\beta}\right) \varepsilon^\sigma}{1 + \left[(1 - \gamma)\beta + \gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] \left(\frac{1}{2}\varepsilon^\sigma - 1\right) + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} > 1 \quad (78)$$

The second constraint is obtained using (75) and (77) which is

$$\frac{(1 - \frac{1}{2}\beta) \left(1 + \frac{\beta\gamma\lambda_2}{1-\beta}\right) \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 + \left[(1 - \gamma)\beta + \gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] \left(\frac{1}{2}\varepsilon^\sigma - 1\right) + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} > 1 \quad (79)$$

The third constraint is obtained using (76) and (77) which is

$$\frac{(1 - \frac{1}{2}\beta) \left(1 + \frac{\beta\gamma\lambda_2}{1-\beta}\right) (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 + \left[(1 - \gamma)\beta + \gamma(1 - \lambda_2)\beta \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \right] \left(\frac{1}{2}\varepsilon^\sigma - 1\right) + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} < 1 \quad (80)$$

(3) $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$

In the third sub case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$. φ_{1u} firms cannot make positive profit under τ_2 conditional on good belief b_H while they can make positive profit under τ_0 conditional on bad belief b_L . $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} < \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{\left(1 + \frac{1}{2}\frac{\beta}{1-\beta}\right) \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (81)$$

$\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{\left(1 + \frac{1}{2}\frac{\beta}{1-\beta}\right) (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (82)$$

Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$, we can give the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{[1 - \frac{1}{2}(1 - \gamma)\beta] \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{1 + \frac{1}{2}\frac{\beta}{1-\beta}}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (83)$$

In order to guarantee that the above solution is feasible, three parametric constraints should be satisfied. The first constraint is obtained using (68) and (83) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta] \varepsilon^\sigma}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (84)$$

The second constraint is obtained using (81) and (83) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta] \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} < 1 \quad (85)$$

The third constraint is obtained using (82) and (83) which is

$$\frac{[1 - \frac{1}{2}(1 - \gamma)\beta] (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (86)$$

(4) $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$

In the fourth sub case, we assume that $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$. φ_{1u} firms can make positive profit under τ_2 conditional on good belief b_H . Besides, they can also make positive profit under τ_0 conditional on bad belief b_L . $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{\left(1 + \frac{1}{2}\frac{\beta}{1-\beta}\right) \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}} \quad (87)$$

$\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$ is equivalent to

$$\frac{\Phi_{1u}}{\Phi_1} > \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{\left(1 + \frac{1}{2}\frac{\beta}{1-\beta}\right) (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (88)$$

Since we have assumed that $\mathbb{1}_{\varphi_{1u}, \tau_1, b_H} = 1$, $\mathbb{1}_{\varphi_{1u}, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_{1u}, \tau_0, b_L} = 1$, we can give the exact formula of $\frac{\Phi_{1u}}{\Phi_1}$

$$\frac{\Phi_{1u}}{\Phi_1} = \frac{\left[1 - \frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\frac{\beta\gamma\lambda_2}{1-\beta}\right] \frac{1 + \frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}{1 + \frac{1}{2}\frac{\beta}{1-\beta}}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} \quad (89)$$

In order to guarantee that the above solution is feasible, three parametric constraints should be satisfied. The first constraint is obtained using (68) and (89) which is

$$\frac{\left[1 - \frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\frac{\beta\gamma\lambda_2}{1-\beta}\right] \varepsilon^\sigma}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (90)$$

The second constraint is obtained using (87) and (89) which is

$$\frac{\left[1 - \frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\frac{\beta\gamma\lambda_2}{1-\beta}\right] \varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (91)$$

The third constraint is obtained using (88) and (89) which is

$$\frac{\left[1 - \frac{1}{2}(1 - \gamma)\beta + \frac{1}{2}\frac{\beta\gamma\lambda_2}{1-\beta}\right] (2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - \frac{1}{2}(1 - \gamma)\beta (2 - \varepsilon)^\sigma + \frac{1}{2}\varepsilon^\sigma \frac{\beta\gamma\lambda_2}{1-\beta} \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + \gamma(1 - \lambda_2)\beta \left(\frac{1}{2}\varepsilon^\sigma + \frac{1}{2}(2 - \varepsilon)^\sigma - 1\right) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}} > 1 \quad (92)$$

J. Lemma 3

J.1. φ_1 firms are willing to enter under τ_1

In this case, φ_1 firms are assumed to be willing to enter under τ_1 as TPU is imposed. The value of entering under τ_1 - $\Pi_e(\varphi_1, \tau_1)$ is

$$\begin{aligned} \Pi_e(\varphi_1, \tau_1) &= \pi(\varphi_1, \tau_1, b_M) + \frac{1}{2} \frac{(1-\gamma)\beta}{1-(1-\gamma)\beta} \pi(\varphi_1, \tau_1, b_H) \\ &\quad + \frac{1}{2} \frac{\gamma\lambda_2}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \tilde{\pi}(\varphi_1, \tau_2, b_H) \\ &\quad + \frac{1}{2} \frac{\gamma(1-\lambda_2)}{1-(1-\gamma)\beta} \frac{\beta}{1-\beta} \left(\pi(\varphi_1, \tau_0, b_H) + \tilde{\pi}(\varphi_1, \tau_0, b_L) \right) \end{aligned} \quad (93)$$

The value of waiting under τ_1 - $\beta E_{\tau_1} \Pi(\varphi_1, \tau')$ is

$$\begin{aligned} &\beta E_{\tau_1} \Pi(\varphi_1, \tau') \\ &= (1-\gamma)\beta \Pi_e(\varphi_1, \tau_1) + \gamma(1-\lambda_2)\beta \Pi_e(\varphi_1, \tau_0) \\ &= (1-\gamma)\beta \Pi_e(\varphi_1, \tau_1) + \gamma(1-\lambda_2)\beta \left[\pi(\varphi_1, \tau_0, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \left(\pi(\varphi_1, \tau_0, b_H) + \tilde{\pi}(\varphi_1, \tau_0, b_L) \right) \right] \end{aligned} \quad (94)$$

Recall that $\pi(\varphi_1, \tau_1, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \pi(\varphi_1, \tau_1, b_H) = 0$. Therefore, the net difference between the value of entering and the value of waiting under τ_1 - $Diff(\varphi_1, \tau_1) = \Pi_e(\varphi_1, \tau_1) - \beta E_{\tau_1} \Pi(\varphi_1, \tau')$ is

$$\begin{aligned} &Diff(\varphi_1, \tau_1) \\ &= \left(1 - (1-\gamma)\beta \right) \Pi_e(\varphi_1, \tau_1) - \gamma(1-\lambda_2)\beta \Pi_e(\varphi_1, \tau_0) \\ &= -\frac{1}{2} \gamma \frac{\beta}{1-\beta} \pi(\varphi_1, \tau_1, b_H) + \frac{1}{2} \gamma \lambda_2 \frac{\beta}{1-\beta} \tilde{\pi}(\varphi_1, \tau_2, b_H) \\ &\quad + \frac{1}{2} \gamma (1-\lambda_2) \beta \left(\pi(\varphi_1, \tau_0, b_H) + \tilde{\pi}(\varphi_1, \tau_0, b_L) - 2\pi(\varphi_1, \tau_0, b_M) \right) \\ &= \frac{1}{2} \gamma \beta Sdiff(\varphi_1, \tau_1) \end{aligned} \quad (95)$$

J.2. φ_1 firms are willing to wait under τ_1

In this case, φ_1 firms are assumed to be willing to wait under τ_1 as TPU is imposed. The value of waiting under τ_1 - $\beta E_{\tau_1} \Pi(\varphi_1, \tau')$ is

$$\begin{aligned} &\beta E_{\tau_1} \Pi(\varphi_1, \tau') \\ &= \frac{\gamma(1-\lambda_2)\beta}{1-\beta(1-\gamma)} \Pi_e(\varphi_1, \tau_0) \\ &= \frac{\gamma(1-\lambda_2)\beta}{1-\beta(1-\gamma)} \left[\pi(\varphi_1, \tau_0, b_M) + \frac{1}{2} \frac{\beta}{1-\beta} \left(\pi(\varphi_1, \tau_0, b_H) + \tilde{\pi}(\varphi_1, \tau_0, b_L) \right) \right] \end{aligned} \quad (96)$$

Therefore, the net difference between the value of entering and the value of waiting under τ_1 -

$Diff(\varphi_1, \tau_1) = \Pi_e(\varphi_1, \tau_1) - \beta E_{\tau_1} \Pi(\varphi_1, \tau')$ is

$$\begin{aligned} & Diff(\varphi_1, \tau_1) \\ &= \Pi_e(\varphi_1, \tau_1) - \frac{\gamma(1-\lambda_2)\beta}{1-\beta(1-\gamma)} \Pi_e(\varphi_1, \tau_0) \\ &= \frac{1}{2} \frac{\gamma\beta}{1-\beta(1-\gamma)} Sdiff(\varphi_1, \tau_1) \end{aligned} \quad (97)$$

K. $Sdiff(\varphi_1, \tau_1)$ as a function of δ

Substitute τ_2 by $\delta\tau_1$, τ_0 by $\frac{1-\lambda_2\delta}{1-\lambda_2}\tau_1$, b_H by εb_M , b_L by $(2-\varepsilon)b_M$ and $\varphi_1^{\sigma-1}$ by $\frac{(1+\frac{1}{2}\frac{\beta}{1-\beta})f}{(b_M^\sigma + \frac{1}{2}\frac{\beta}{1-\beta}b_H^\sigma)^k} \tau_1^\sigma$.

In addition, divide $Sdiff(\varphi_1, \tau_1)$ by f and we have

$$\begin{aligned} & \frac{Sdiff(\varphi_1, \tau_1)}{f} = \\ & - \frac{B\varepsilon^\sigma - 1}{1-\beta} + \frac{\lambda_2}{1-\beta} \max\{B\varepsilon^\sigma \delta^{-\sigma} - 1, 0\} \\ & + (1-\lambda_2) \left(B\varepsilon^\sigma \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} + \max\left\{ B(2-\varepsilon)^\sigma \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} - 1, 0 \right\} - 2B \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} + 1 \right) \end{aligned} \quad (98)$$

Where $B = \frac{(1+\frac{1}{2}\frac{\beta}{1-\beta})}{1+\frac{1}{2}\frac{\beta}{1-\beta}\varepsilon^\sigma}$. As $\delta \rightarrow 1$, $Sdiff(\varphi_1, \tau_1) \rightarrow 0$ and we go back to the case without TPU. There exist two zero profit cutoffs δ_{τ_2} and δ_{τ_0} . As $\delta < \delta_{\tau_2}$, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 1$ and $\max\{B\varepsilon^\sigma \delta^{-\sigma} - 1, 0\} = B\varepsilon^\sigma \delta^{-\sigma} - 1 > 0$. Otherwise $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 0$. As $\delta > \delta_{\tau_0}$, $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 1$ and $\max\left\{ B(2-\varepsilon)^\sigma \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} - 1, 0 \right\} > 0$. Otherwise $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. We have $\delta_{\tau_2} = B^{\frac{1}{\sigma}}\varepsilon$ and $\delta_{\tau_0} = \frac{1-\lambda_2}{\lambda_2} \left[\frac{1}{1-\lambda_2} - B^{\frac{1}{\sigma}}(2-\varepsilon) \right]$. In addition, since τ_0 cannot go below 1, there exists a maximum of $\delta - \delta_{max}$ which equals to $\frac{1-\lambda_2}{\lambda_2} \left(\frac{1}{1-\lambda_2} - \frac{1}{\tau_1} \right)$. Without loss of generality, I assume $f = 1$ in the current section.

K.1. $B(\varphi_1, \tau_2) = \frac{\lambda_2}{1-\beta} \max\{B\varepsilon^\sigma \delta^{-\sigma} - 1, 0\}$

$B(\varphi_1, \tau_2)$ is a function of δ and take the first derivative

$$\frac{\partial B(\varphi_1, \tau_2)}{\partial \delta} = -\mathbb{1}_{\varphi_1, \tau_2, b_H} * \sigma \frac{\lambda_2}{1-\beta} B\varepsilon^\sigma \delta^{-\sigma-1} \leq 0 \quad (99)$$

Take the second derivative

$$\frac{\partial^2 B(\varphi_1, \tau_2)}{\partial \delta^2} = \mathbb{1}_{\varphi_1, \tau_2, b_H} * \sigma(\sigma+1) \frac{\lambda_2}{1-\beta} B\varepsilon^\sigma \delta^{-\sigma-2} \geq 0 \quad (100)$$

As δ increases from 1 to $\delta_{\tau_2}^-$, $B(\varphi_1, \tau_2) = \frac{\lambda_2}{1-\beta} (B\varepsilon^\sigma \delta^{-\sigma} - 1)$ which is a decreasing function of δ . In this case, φ_1 firms can still make positive profit under τ_2 conditional on good belief b_H . However, as δ increases, this profit becomes smaller and smaller. As δ increases from $\delta_{\tau_2}^-$ to $\delta_{\tau_2}^+$, $\mathbb{1}_{\varphi_1, \tau_2, b_H}$ turns from 1 to 0 and $B(\varphi_1, \tau_2) = 0$. In this case, exporting under τ_2 conditional on good belief b_H turns to non-profitable and the profit is bounded at 0. Moreover, there will be an upward jump of the first derivative of $B(\varphi_1, \tau_2)$ (from negative to 0). As δ increases from $\delta_{\tau_2}^+$, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 0$ and $B(\varphi_1, \tau_2) = 0$. We can also see that the second derivative is always non-negative.

$$\mathbf{K.2.} \quad G(\varphi_1, \tau_0) = (1-\lambda_2) \left(B\varepsilon^\sigma \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} + \max \left\{ B(2-\varepsilon)^\sigma \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} - 1, 0 \right\} - 2B \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma} + 1 \right)$$

Take the first derivative

$$\frac{\partial G(\varphi_1, \tau_0)}{\partial \delta} = \sigma \lambda_2 B (\varepsilon^\sigma + \mathbb{1}_{\varphi_1, \tau_0, b_L} * (2-\varepsilon)^\sigma - 2) \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma-1} \quad (101)$$

Take the second derivative

$$\frac{\partial^2 G(\varphi_1, \tau_0)}{\partial \delta^2} = \sigma(\sigma+1) \frac{\lambda_2^2}{1-\lambda_2} B (\varepsilon^\sigma + \mathbb{1}_{\varphi_1, \tau_0, b_L} * (2-\varepsilon)^\sigma - 2) \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma-2} \quad (102)$$

As δ increases from 1 to $\delta_{\tau_0}^-$, $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. In this case, φ_1 firms cannot make positive profit under τ_0 conditional on bad belief b_L since τ_0 is not favorable enough. The sign of the first and second derivative depends on the relation between ε^σ and 2. If $\varepsilon^\sigma - 2 > 0$, $\frac{\partial G(\varphi_1, \tau_0)}{\partial \delta} > 0$ and $\frac{\partial^2 G(\varphi_1, \tau_0)}{\partial \delta^2} > 0$, which means $G(\varphi_1, \tau_0)$ is increasing and convex. Otherwise $\frac{\partial G(\varphi_1, \tau_0)}{\partial \delta} < 0$ and $\frac{\partial^2 G(\varphi_1, \tau_0)}{\partial \delta^2} < 0$. Therefore, as $\delta < \delta_{\tau_0}$, the monotonicity and convexity of $G(\varphi_1, \tau_0)$ depends on how good the good belief is. For a high value of good belief, good news can encourage φ_1 firms' early entry while for a low value of good belief, good news can even deter φ_1 firms' early entry. As δ increases from $\delta_{\tau_0}^-$ to $\delta_{\tau_0}^+$, $\mathbb{1}_{\varphi_1, \tau_0, b_L}$ turns from 0 to 1. In this case, exporting under τ_0 conditional on bad belief b_L becomes profitable and there will be an upward jump of the first and second derivative of $G(\varphi_1, \tau_0)$. Both first and second derivative turn to positive since $\varepsilon^\sigma + (2-\varepsilon)^\sigma - 2 > 0$. As δ increases from $\delta_{\tau_0}^+$, $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 1$ and $G(\varphi_1, \tau_0)$ is an increasing and convex function of δ .

K.3. Joint effect of bad and good news

Now we can write the first and second derivative of $Sdiff(\varphi_1, \tau_1)$ regarding to δ . The first derivative is

$$\begin{aligned} \frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \delta} &= -\mathbb{1}_{\varphi_1, \tau_2, b_H} * \sigma \frac{\lambda_2}{1-\beta} B \varepsilon^\sigma \delta^{-\sigma-1} \\ &\quad + \sigma \lambda_2 B (\varepsilon^\sigma + \mathbb{1}_{\varphi_1, \tau_0, b_L} * (2-\varepsilon)^\sigma - 2) \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma-1} \end{aligned} \quad (103)$$

And the second derivative is

$$\begin{aligned} \frac{\partial^2 Sdiff(\varphi_1, \tau_1)}{\partial \delta^2} &= \mathbb{1}_{\varphi_1, \tau_2, b_H} * \sigma(\sigma+1) \frac{\lambda_2}{1-\beta} B \varepsilon^\sigma \delta^{-\sigma-2} \\ &\quad + \sigma(\sigma+1) \frac{\lambda_2^2}{1-\lambda_2} B (\varepsilon^\sigma + \mathbb{1}_{\varphi_1, \tau_0, b_L} * (2-\varepsilon)^\sigma - 2) \left(\frac{1-\lambda_2\delta}{1-\lambda_2} \right)^{-\sigma-2} \end{aligned} \quad (104)$$

(1) δ is close to 1

In this case, we consider a small δ . Since δ is small, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. Exporting under τ_2 conditional on good belief b_H is profitable while exporting under τ_0 conditional on bad belief b_L is not profitable because both τ_2 and τ_0 are close to τ_1 . We have

$$\left. \frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \delta} \right|_{\delta \text{ small}} \approx -\sigma \frac{\lambda_2}{1-\beta} B \varepsilon^\sigma + \sigma \lambda_2 B (\varepsilon^\sigma - 2) < 0$$

Conditional on a small δ , as δ increases, for φ_1 firms, the increasing loss under τ_2 dominates the profit change under τ_0 because the loss under τ_2 is for multiple periods while the change

under τ_0 is just for one period. For a small δ , $Sdiff(\varphi_1, \tau_1) < 0$ and there are less entrants. If δ increases, the number of entrants will decrease.

(2) Monotonicity of $Sdiff(\varphi_1, \tau_1)$

i) $\varepsilon^\sigma - 2 > 0$

In this case, the second derivative of $Sdiff_u(\varphi_1)$ is always positive. In addition, at δ_{τ_0} and δ_{τ_2} , there is an upward jump of the first derivative. As $\delta > \delta_{\tau_0}$ and $\delta > \delta_{\tau_2}$, the first derivative is positive. Therefore, as δ increases from 1 to δ_{max} , there only exist 2 possibilities - either $Sdiff(\varphi_1, \tau_1)$ decreases always or $Sdiff(\varphi_1, \tau_1)$ decreases firstly then increases. For a sufficiently large δ , $Sdiff(\varphi_1, \tau_1)$ can be an increasing function of δ and pass above 0.

ii) $\varepsilon^\sigma - 2 < 0$

In this case, as $\delta < \delta_{\tau_0}$, the first derivative of $Sdiff(\varphi_1, \tau_1)$ is negative and $Sdiff(\varphi_1, \tau_1)$ decreases in δ . As $\delta > \delta_{\tau_0}$, the second derivative of $Sdiff(\varphi_1, \tau_1)$ is always positive, which means the first derivative increases in δ and can pass above 0 if δ is sufficiently large. As δ increases from 1 to δ_{max} , there only exist 2 possibilities - either $Sdiff(\varphi_1, \tau_1)$ decreases always or $Sdiff(\varphi_1, \tau_1)$ decreases firstly then increases.

L. $Sdiff(\varphi_1, \tau_1)$ as a function of ε

Assuming $f = 1$ and substituting b_H by εb_M , b_L by $(2 - \varepsilon)b_M$ and $\varphi_1^{\sigma-1}$ by $\frac{(1 + \frac{1}{2} \frac{\beta}{1-\beta})f}{(b_M^\sigma + \frac{1}{2} \frac{\beta}{1-\beta} b_H^\sigma)^k} \tau_1^\sigma$, $Sdiff(\varphi_1, \tau_1)$ is

$$\begin{aligned} Sdiff(\varphi_1, \tau_1) = & -\frac{B\varepsilon^\sigma - 1}{1 - \beta} + \frac{\lambda_2}{1 - \beta} \max \left\{ B\varepsilon^\sigma \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} - 1, 0 \right\} \\ & + (1 - \lambda_2) \left(B\varepsilon^\sigma \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} + \max \left\{ B(2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} - 1, 0 \right\} - 2B \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} + 1 \right) \end{aligned} \quad (105)$$

Where $B = \frac{(1 + \frac{1}{2} \frac{\beta}{1-\beta})}{1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma}$. $B\varepsilon^\sigma$ is an increasing function of ε ; B is a decreasing function of ε and $B(2 - \varepsilon)^\sigma$ is also a decreasing function of ε . Begin with the first and second derivative of $B\varepsilon^\sigma$, B and $B(2 - \varepsilon)^\sigma$ regarding to ε .

$$\frac{\partial B\varepsilon^\sigma}{\partial \varepsilon} = \frac{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \varepsilon^{\sigma-1}}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^2} > 0 \quad (106)$$

$$\frac{\partial B}{\partial \varepsilon} = -\frac{\frac{1}{2} \frac{\beta}{1-\beta} \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \varepsilon^{\sigma-1}}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^2} = -\frac{1}{2} \frac{\beta}{1-\beta} \frac{\partial B\varepsilon^\sigma}{\partial \varepsilon} < 0 \quad (107)$$

$$\begin{aligned} & \frac{\partial B(2 - \varepsilon)^\sigma}{\partial \varepsilon} \\ = & \frac{-\left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma (2 - \varepsilon)^{\sigma-1} - \frac{1}{2} \frac{\beta}{1-\beta} \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \varepsilon^\sigma (2 - \varepsilon)^{\sigma-1} - \frac{1}{2} \frac{\beta}{1-\beta} \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \varepsilon^{\sigma-1} (2 - \varepsilon)^\sigma}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^2} < 0 \end{aligned} \quad (108)$$

From (106), (107) and (108), there is a following inequality.

$$\frac{\partial B\varepsilon^\sigma}{\partial \varepsilon} + \frac{\partial B(2-\varepsilon)^\sigma}{\partial \varepsilon} - 2\frac{\partial B}{\partial \varepsilon} > 0 \quad (109)$$

From the first order conditions above, we know that $L(\varphi_1, \tau_1)$ is a decreasing function of ε . For φ_1 firms, greater is ε , greater is the net loss under τ_1 . $B(\varphi_1, \tau_2)$ is a non decreasing function of ε . For φ_1 firms, greater is ε , (weakly) greater is the gain under τ_2 . $G(\varphi_1, \tau_0)$ is an increasing function of ε . For φ_1 firms, greater is ε , greater is the gain under τ_0 . Moreover, $L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)$ is a decreasing function of ε . As ε increases, the increasing loss under τ_1 dominates the (weakly) increasing gain under τ_2 . However, for now, it's difficult to tell if $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon}$ is positive or not since both increasing and decreasing parts exist. Below, I also give the second derivative.

$$\frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} = \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \frac{(\sigma-1)\varepsilon^{\sigma-2} - \frac{1}{2} \frac{\beta}{1-\beta} (\sigma+1)\varepsilon^{2\sigma-2}}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^3} \quad (110)$$

$$\frac{\partial^2 B}{\partial \varepsilon^2} = -\frac{1}{2} \frac{\beta}{1-\beta} \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \frac{(\sigma-1)\varepsilon^{\sigma-2} - \frac{1}{2} \frac{\beta}{1-\beta} (\sigma+1)\varepsilon^{2\sigma-2}}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^3} = -\frac{1}{2} \frac{\beta}{1-\beta} \frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} \quad (111)$$

$$\begin{aligned} \frac{\partial^2 B(2-\varepsilon)^\sigma}{\partial \varepsilon^2} = & \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma \frac{(\sigma-1)(2-\varepsilon)^{\sigma-2} + \frac{1}{2} \frac{\beta}{1-\beta} (\sigma-1)\varepsilon^\sigma (2-\varepsilon)^{\sigma-2} + \frac{\beta}{1-\beta} \sigma \varepsilon^{\sigma-1} (2-\varepsilon)^{\sigma-1}}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^3} \\ & - \frac{1}{2} \frac{\beta}{1-\beta} \left(1 + \frac{1}{2} \frac{\beta}{1-\beta}\right) \sigma * \\ & \left[\frac{(\sigma-1) \left(\varepsilon^{\sigma-2} (2-\varepsilon)^\sigma - \varepsilon^\sigma (2-\varepsilon)^{\sigma-2}\right) + \frac{1}{2} \frac{\beta}{1-\beta} (\sigma-1) \left(\varepsilon^{2\sigma-2} (2-\varepsilon)^\sigma - \varepsilon^{2\sigma} (2-\varepsilon)^{\sigma-2}\right)}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^3} \right. \\ & \left. - \frac{\frac{\beta}{1-\beta} \sigma \left(\varepsilon^{2\sigma-1} (2-\varepsilon)^{\sigma-1} + \varepsilon^{2\sigma-2} (2-\varepsilon)^\sigma\right)}{\left(1 + \frac{1}{2} \frac{\beta}{1-\beta} \varepsilon^\sigma\right)^3} \right] > 0 \end{aligned} \quad (112)$$

From (110) and (111), it's easy to observe that if $\frac{1}{2} \frac{\beta}{1-\beta} \frac{\sigma+1}{\sigma-1} \varepsilon^\sigma > 1$, $\frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} < 0$ and $\frac{\partial^2 B}{\partial \varepsilon^2} > 0$. Otherwise $\frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} > 0$ and $\frac{\partial^2 B}{\partial \varepsilon^2} < 0$. We would expect $\frac{1}{2} \frac{\beta}{1-\beta} \frac{\sigma+1}{\sigma-1} \varepsilon^\sigma > 1$ is more likely to be satisfied because normally the discount factor β is not a very small number.⁵ However, even if we assume that $\frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} < 0$ and $\frac{\partial^2 B}{\partial \varepsilon^2} > 0$, the sign of the second derivative of $Sdiff(\varphi_1, \tau_1)$ is still ambiguous in some cases. There exist two zero profit cutoffs ε_{τ_2} and ε_{τ_0} . As $\varepsilon > \varepsilon_{\tau_2}$, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 1$ and $\max \left\{ B\varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - 1, 0 \right\} = B\varepsilon^\sigma \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} - 1 > 0$. Otherwise $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 0$. As $\varepsilon < \varepsilon_{\tau_0}$, $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 1$ and $\max \left\{ B(2-\varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} - 1, 0 \right\} > 0$. Otherwise $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. Below I will discuss $Sdiff(\varphi_1, \tau_1)$ as a function of ε part by part.

⁵In my model, there is an endogenous exit. Therefore, it is only necessary to set a β which is able to capture the exogenous death rate.

L.1. $L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)$

I start by discussing $L(\varphi_1, \tau_1)$ and $B(\varphi_1, \tau_2)$ together since the sum of these two terms has a good property of monotonicity.

$$L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2) = -\frac{B\varepsilon^\sigma - 1}{1 - \beta} + \frac{\lambda_2}{1 - \beta} \max \left\{ B\varepsilon^\sigma \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} - 1, 0 \right\} \quad (113)$$

Take the first derivative and we have

$$\frac{\partial L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)}{\partial \varepsilon} = \frac{-1 + \mathbb{1}_{\varphi_1, \tau_2, b_H} * \lambda_2 \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma}}{1 - \beta} \frac{\partial B\varepsilon^\sigma}{\partial \varepsilon} < 0 \quad (114)$$

Take the second derivative and we have

$$\frac{\partial^2 L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)}{\partial \varepsilon^2} = \frac{-1 + \mathbb{1}_{\varphi_1, \tau_2, b_H} * \lambda_2 \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma}}{1 - \beta} \frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} \quad (115)$$

As ε increases from 1 to $\varepsilon_{\tau_2}^-$, $L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2) = -\frac{B\varepsilon^\sigma - 1}{1 - \beta}$ which is a decreasing function of ε . The loss under τ_1 is greater since the value of good belief b_H is greater. As ε increases from $\varepsilon_{\tau_2}^-$ to $\varepsilon_{\tau_2}^+$, $\mathbb{1}_{\varphi_1, \tau_2, b_H}$ turns to 1 and $\frac{\lambda_2}{1 - \beta} \left(B\varepsilon^\sigma \left(\frac{\tau_2}{\tau_1} \right)^{-\sigma} - 1 \right)$ shows up in (113) whose first derivative is positive. Therefore, there is an upward jump of the first derivative of $L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)$. In this case, exporting under τ_2 starts to be profitable conditional on good belief. As ε increases from $\varepsilon_{\tau_2}^+$, $L(\varphi_1, \tau_1) + B(\varphi_1, \tau_2)$ is still a decreasing function. However, the loss under τ_1 is partially offset by the gain under τ_2 . If we assume $\frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} < 0$, $\frac{\partial^2 f_{\tau_1}(\varepsilon) + f_{\tau_2}(\varepsilon)}{\partial \varepsilon^2}$ will always be positive and there will be a downward jump at $\varepsilon = \varepsilon_{\tau_2}$.

L.2. $G(\varphi_1, \tau_0)$

We have

$$G(\varphi_1, \tau_0) = (1 - \lambda_2) \left(B\varepsilon^\sigma \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} + \max \left\{ B(2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} - 1, 0 \right\} - 2B \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} + 1 \right) \quad (116)$$

Take the first derivative and we have

$$\frac{\partial G(\varphi_1, \tau_0)}{\partial \varepsilon} = (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} \left(\frac{1}{1 - \beta} \frac{\partial B\varepsilon^\sigma}{\partial \varepsilon} + \mathbb{1}_{\varphi_1, \tau_0, b_L} * \frac{\partial B(2 - \varepsilon)^\sigma}{\partial \varepsilon} \right) > 0 \quad (117)$$

Take the second derivative

$$\frac{\partial^2 G(\varphi_1, \tau_0)}{\partial \varepsilon^2} = (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} \left(\frac{1}{1 - \beta} \frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} + \mathbb{1}_{\varphi_1, \tau_0, b_L} * \frac{\partial^2 B(2 - \varepsilon)^\sigma}{\partial \varepsilon^2} \right) \quad (118)$$

As ε increases from 1 to $\varepsilon_{\tau_0}^-$, $G(\varphi_1, \tau_0) = (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} B(\varepsilon^\sigma + (2 - \varepsilon)^\sigma - 2)$ which is an increasing function of ε . In this case, exporting under τ_0 is still profitable even conditional on bad belief b_L . As ε increases from $\varepsilon_{\tau_0}^-$ to $\varepsilon_{\tau_0}^+$, $\mathbb{1}_{\varphi_1, \tau_0, b_L}$ turns to 0 and $B(2 - \varepsilon)^\sigma \left(\frac{\tau_0}{\tau_1} \right)^{-\sigma} - 1$ will disappear in (116) whose first derivative is negative. Therefore, there will be an upward jump

of the first derivative of $G(\varphi_1, \tau_0)$. In this case, exporting under τ_0 starts to be unprofitable conditional on bad belief. As ε increases from $\varepsilon_{\tau_0}^+$, $G(\varphi_1, \tau_0)$ is an increasing function. If we assume $\frac{\partial^2 B \varepsilon^\sigma}{\partial \varepsilon^2} < 0$, $\frac{\partial^2 G(\varphi_1, \tau_0)}{\partial \varepsilon^2} < 0$ if $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. If $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 1$, we cannot tell the sign of the second derivative easily. In addition, for the second derivative, there will be a downward jump at $\varepsilon = \varepsilon_{\tau_0}$.

L.3. Joint effect of ε

The first derivative of $Sdiff(\varphi_1, \tau_1)$ is

$$\begin{aligned} \frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} = & \frac{-1 + \mathbb{1}_{\varphi_1, \tau_2, b_H} * \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} \\ & + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \left(\frac{1}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} + \mathbb{1}_{\varphi_1, \tau_0, b_L} * \frac{\partial B (2 - \varepsilon)^\sigma}{\partial \varepsilon} \right) \end{aligned} \quad (119)$$

And the second derivative is

$$\begin{aligned} \frac{\partial^2 Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon^2} = & \frac{-1 + \mathbb{1}_{\varphi_1, \tau_2, b_H} * \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma}}{1 - \beta} \frac{\partial^2 B \varepsilon^\sigma}{\partial \varepsilon^2} \\ & + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \left(\frac{1}{1 - \beta} \frac{\partial^2 B \varepsilon^\sigma}{\partial \varepsilon^2} + \mathbb{1}_{\varphi_1, \tau_0, b_L} * \frac{\partial^2 B (2 - \varepsilon)^\sigma}{\partial \varepsilon^2} \right) \end{aligned} \quad (120)$$

We can easily observe that as $\varepsilon \rightarrow 1$, $Sdiff(\varphi_1, \tau_1) \rightarrow 0$ and $\varphi_{1u} \rightarrow \varphi_1$. Moreover, in this case, since there is no learning, the entry threshold is just the zero profit cutoff conditional on τ_1 and b_M .

(1) ε is close to 1

As ε is close to 1, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 0$ and $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 1$. In this case, good belief is not too good and bad belief is not too bad. Therefore, exporting under τ_2 conditional on good belief is not profitable and exporting under τ_0 conditional on bad belief is profitable. The first derivative is

$$\left. \frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} \right|_{\varepsilon \text{ small}} = -\frac{1}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} \left(\frac{1}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} + \frac{\partial B (2 - \varepsilon)^\sigma}{\partial \varepsilon} \right) < 0 \quad (121)$$

As ε is small, $\frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} \approx \frac{\sigma}{1 + \frac{1}{2} \frac{\beta}{1 - \beta}}$ and $\frac{1}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} + \frac{\partial B (2 - \varepsilon)^\sigma}{\partial \varepsilon} \approx 0$. In this case, under τ_0 , as ε increases, the extra benefit from good belief will be offset by the extra loss from bad belief. Therefore, the loss under τ_1 dominates and we have $\left. \frac{\partial Sdiff_u(\varphi_1)}{\partial \varepsilon} \right|_{\varepsilon \text{ small}} < 0$. I don't make a further discussion on the second order condition here since it is not obvious.⁶

(2) $\varepsilon > \varepsilon_{\tau_2}$ and $\varepsilon > \varepsilon_{\tau_0}$

In this case, $\mathbb{1}_{\varphi_1, \tau_2, b_H} = 1$ and $\mathbb{1}_{\varphi_1, \tau_0, b_L} = 0$. The first derivative is

$$\left. \frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} \right|_{\varepsilon \text{ large}} = \frac{-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - \beta} \frac{\partial B \varepsilon^\sigma}{\partial \varepsilon} \quad (122)$$

⁶It's more likely to be positive.

And the second derivative is

$$\frac{\partial^2 Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon^2} \Big|_{\varepsilon \text{ large}} = \frac{-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}}{1 - \beta} \frac{\partial^2 B\varepsilon^\sigma}{\partial \varepsilon^2} \quad (123)$$

As $\tau_2 = \tau_0 = \tau_1$, $-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} = 0$. The sign of $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon} \Big|_{\varepsilon \text{ large}}$ depends on the sign of $-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma}$, which is similar to the result in sunk cost learning model. In this case, exporting under τ_2 conditional on good belief is profitable and exporting under τ_0 conditional on bad belief is unprofitable. The former term is an increasing function of ε and the later term is a decreasing function of ε . As $\varepsilon > \varepsilon_{\tau_2}$ and $\varepsilon > \varepsilon_{\tau_0}$, we introduce an increasing term and get rid of a decreasing term. Therefore, if $-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} < 0$, $\frac{\partial Sdiff(\varphi_1, \tau_1)}{\partial \varepsilon}$ will always be negative. However, if $-1 + \lambda_2 \left(\frac{\tau_2}{\tau_1}\right)^{-\sigma} + (1 - \lambda_2) \left(\frac{\tau_0}{\tau_1}\right)^{-\sigma} > 0$, as $\varepsilon < \varepsilon_{\tau_2}$ or $\varepsilon < \varepsilon_{\tau_0}$, the sign of the first derivative is not clear and we cannot tell the sign of the second derivative easily either. Therefore, we don't have a clear conclusion in this case.

M. Data construction and regression results

Recall that the data sets I use are the BACI database, the Gravity database, the WITS TRAINS/IDB database, and the Design of Trade Agreements (DESTA) database. HS6 product code is converted to the 1992 version. The detailed steps are as follows:

1. HS6 MFN and bound tariffs (BND) are collected using the WITS TRAINS/IDB database. By definition, the MFN and bound tariffs are applied to all WTO/GATT exporters. Both BND and MFN are simple averages at the HS6 level. I only keep HS6 tariff lines whose MFN=BND > 0 and are stable across years. Using the information on WTO/GATT membership from the Gravity database, I assign each destination-HS6 product-year all possible potential WTO/GATT exporting countries and obtain a bilateral MFN/BND tariff panel.
2. The signature year of the trade agreement is obtained from the DESTA database. Between two countries, there can exist several trade agreements and I consider the signature year as the one of the earliest agreement in the database. A country pair is treated from the signature year. A country can withdraw from the trade agreement and I disregard this problem. The sample period is from 1996 to 2019 and I only consider the trade agreements with a signature year greater than or equal to 1997 in my sample. Bringing the information on the year of signature in the data set of step 1, now I have a tariff-gravity data set.
3. The BACI database provides information on bilateral HS6 trade flows. I deal with missing values using the matrix of reporting countries provided by CEPII. I merge the BACI database with the above tariff-gravity data set. For the observations in the BACI database that cannot be merged, I just drop them. For the observations in the tariff-gravity data set that cannot be merged with the BACI observations, I assign 0 as the trade value. Then I can build a positive trade flow indicator at the exporting country-HS6-destination-year level. It takes 1 if the trade value is greater than 1 thousand US dollars in nominal value and 0 otherwise.

| Signature_year | Agreement | Signature_year | Agreement |
|----------------|--|----------------|--|
| 1997 | Greater Arab Free Trade Agreement | 2008 | Gulf Cooperation Council (GCC) Singapore |
| 1997 | African Economic Community South Africa accession | 2009 | Albania EFTA |
| 1997 | Association of Southeast Asian Nations (ASEAN) FTA | 2009 | EFTA Gulf Cooperation Council (GCC) |
| 1997 | Laos Myanmar accession | 2009 | Latin American Integration Association (ALADI LAIA) Panama accession |
| 1997 | EFTA Morocco | 2009 | Association of Southeast Asian Nations (ASEAN) |
| 1997 | Chad Morocco | 2009 | Australia New Zealand FTA (AANZFTA) |
| 1998 | Latin American Integration Association (ALADI LAIA) | 2009 | Association of Southeast Asian Nations (ASEAN) India |
| 1999 | Cuba accession | 2009 | Canada Jordan |
| 1999 | Central America Chile | 2009 | Canada Panama |
| 1999 | EC South Africa | 2009 | Japan Switzerland |
| 2000 | EFTA Mexico | 2009 | China Peru |
| 2000 | EC Mexico | 2009 | Jordan Turkey |
| 2000 | New Zealand Singapore | 2009 | Malaysia New Zealand |
| 2001 | Canada Costa Rica | 2009 | EFTA Peru |
| 2001 | EFTA Jordan | 2010 | EFTA Ukraine |
| 2002 | Chile EC | 2010 | China Costa Rica |
| 2002 | EFTA Singapore | 2010 | Egypt MERCOSUR |
| 2002 | Japan Singapore | 2010 | EC Korea |
| 2003 | Albania Moldova | 2010 | Hong Kong New Zealand |
| 2003 | Chile EFTA | 2010 | Costa Rica Singapore |
| 2003 | Chile US | 2011 | Costa Rica Peru |
| 2003 | China Pakistan | 2011 | Ecuador Guatemala |
| 2003 | China Thailand | 2011 | Guatemala Peru |
| 2003 | China Hong Kong | 2011 | EFTA Hong Kong |
| 2003 | Economic Cooperation Organization Trade Agreement (ECOTA) | 2011 | India Japan |
| 2003 | China Macao | 2011 | Japan Peru |
| 2003 | Australia Singapore | 2011 | Mauritius Turkey |
| 2003 | Singapore US | 2012 | Colombia EC Peru |
| 2004 | MERCOSUR Southern African Customs Union (SACU) | 2012 | Central America EC |
| 2004 | Australia Thailand | 2012 | Chile Hong Kong |
| 2004 | Australia US | 2012 | Asia Pacific Trade Agreement (Bangkok Agreement) |
| 2004 | Bahrain US | 2013 | amended Mongolia accession |
| 2004 | Association of Southeast Asian Nations (ASEAN) China | 2013 | Canada Honduras |
| 2004 | EFTA Tunisia | 2013 | China Switzerland |
| 2004 | Central American Free Trade Agreement (CAFTA) | 2013 | Central America EFTA |
| 2004 | Central American Free Trade Agreement (CAFTA) Dominican Republic | 2013 | China Iceland |
| 2004 | India MERCOSUR | 2013 | Colombia Israel |
| 2004 | Japan Mexico | 2014 | Australia Japan |
| 2004 | Morocco Turkey | 2014 | Australia Korea |
| 2004 | Morocco US | 2014 | Canada Korea |
| 2004 | Macedonia Moldova | 2014 | EC Georgia |
| 2004 | Jordan Singapore | 2014 | EC Moldova |
| 2005 | Brazil Suriname | 2014 | EC Ukraine |
| 2005 | Trans Pacific Strategic EPA | 2014 | Moldova Turkey |
| 2005 | EFTA Korea | 2015 | Australia China |

| Signature_year | Agreement | Signature_year | Agreement |
|----------------|--|----------------|---|
| 2005 | Chile China | 2015 | Central America EFTA Guatemala accession |
| 2005 | Japan Malaysia | 2015 | Honduras Peru |
| 2005 | New Zealand Thailand | 2015 | Japan Mongolia |
| 2006 | Albania EC SAA | 2015 | Korea New Zealand |
| 2006 | Albania Turkey | 2015 | Eurasian Economic Union (EAEU) Vietnam |
| 2006 | D8 PTA | 2015 | Singapore Turkey |
| 2006 | Association of Southeast Asian Nations (ASEAN) Korea | 2016 | Transpacific Partnership (TPP) |
| 2006 | EFTA Southern African Customs Union (SACU) | 2016 | Canada EC (CETA) |
| 2006 | Chile Panama | 2016 | EFTA Georgia |
| 2006 | Colombia US | 2016 | EFTA Philippines |
| 2006 | Japan Philippines | 2016 | Colombia EC Peru Ecuador accession |
| 2006 | Oman US | 2017 | Armenia EC |
| 2006 | Peru US | 2017 | Canada Ukraine |
| 2006 | Panama Singapore | 2017 | China Georgia |
| 2006 | African Customs Union (SACU) Venezuela accession | 2017 | China Maldives |
| 2007 | MERCOSUR Southern African Customs Union (SACU) | 2017 | Ecuador El Salvador |
| 2007 | Israel MERCOSUR | 2017 | Pacific Agreement on Closer Economic Relations (PACER) Plus |
| 2007 | Brunei Japan | 2018 | African Continental Free Trade Area (AfCFTA) |
| 2007 | EFTA Egypt | 2018 | Burundi Lesotho Namibia Sierra Leone South Africa accession |
| 2007 | Chile Japan | 2018 | African Continental Free Trade Area (AfCFTA) |
| 2007 | Georgia Turkey | 2018 | Ecuador EFTA |
| 2007 | Indonesia Japan | 2018 | EFTA Indonesia |
| 2007 | Japan Thailand | 2018 | Central America Korea |
| 2007 | Korea US | 2018 | EC Japan |
| 2007 | Mauritius Pakistan | 2018 | Association of Southeast Asian Nations (ASEAN) Hong Kong |
| 2007 | Panama US | 2018 | Georgia Hong Kong |
| 2008 | Australia Chile | 2018 | Israel Panama |
| 2008 | Canada Colombia | 2018 | EC Singapore (consolidated) |
| 2008 | Canada EFTA | 2019 | EC Vietnam (consolidated) |
| 2008 | Canada Peru | 2019 | African Continental Free Trade Area (AfCFTA) |
| 2008 | Colombia EFTA | 2019 | Botswana Guinea-Bissau Zambia accession |
| 2008 | China New Zealand | 2019 | Australia Hong Kong |
| 2008 | Association of Southeast Asian Nations (ASEAN) Japan | 2019 | Israel Ukraine |
| | | 2019 | China Mauritius |
| | | 2000 | Cotonou Agreement |

Table 1: Trade agreements included in the sample

| time to event | Specification 1 | Specification 2 | Specification 3 |
|---------------|------------------------|-----------------------|------------------------|
| ≤ -10 | -0.0087 (0.0008)*** | -0.0019 (0.0017) | -0.0083 (0.0008)*** |
| -9 | -0.0072 (0.0009)*** | -0.0010 (0.0014) | -0.0066 (0.0009)*** |
| -8 | -0.0079 (0.0009)*** | -0.0025 (0.0013)* | -0.0079 (0.0009)*** |
| -7 | -0.0077 (0.0008)*** | -0.0025 (0.0011)** | -0.0076 (0.0008)*** |
| -6 | -0.0067 (0.0008)*** | -0.0020 (0.0010)* | -0.0058 (0.0008)*** |
| -5 | -0.0053 (0.0007)*** | -0.0014 (0.0009) | -0.0052 (0.0007)*** |
| -4 | -0.0046 (0.0007)*** | -0.0012 (0.0008) | -0.0044 (0.0007)*** |
| -3 | -0.0043 (0.0007)*** | -0.0010 (0.0007) | -0.0042 (0.0007)*** |
| -2 | -0.0018 (0.0006)*** | -0.0000 (0.0006) | -0.0017 (0.0006)*** |
| 0 | 0.0034 (0.0006)*** | 0.0027 (0.0006)*** | 0.0032 (0.0006)*** |
| 1 | 0.0039 (0.0006)*** | 0.0025 (0.0006)*** | 0.0037 (0.0006)*** |
| 2 | 0.0040 (0.0006)*** | 0.0016 (0.0007)** | 0.0039 (0.0006)*** |
| 3 | 0.0052 (0.0007)*** | 0.0024 (0.0008)*** | 0.0050 (0.0007)*** |
| 4 | 0.0057 (0.0007)*** | -0.0001 (0.0009) | 0.0053 (0.0007)*** |
| 5 | 0.0069 (0.0007)*** | 0.0002 (0.0009) | 0.0066 (0.0007)*** |
| 6 | 0.0074 (0.0007)*** | -0.0002 (0.0010) | 0.0072 (0.0007)*** |
| 7 | 0.0065 (0.0008)*** | -0.0016 (0.0011) | 0.0063 (0.0008)*** |
| 8 | 0.0089 (0.0008)*** | 0.0004 (0.0012) | 0.0086 (0.0008)*** |
| 9 | 0.0077 (0.0008)*** | -0.0012 (0.0013) | 0.0074 (0.0008)*** |
| ≥ 10 | 0.0088 (0.0008)*** | -0.0008 (0.0015) | 0.0087 (0.0008)*** |
| ln_L1_vs_ijt | | | 0.0023 (0.0001)*** |
| _cons | 0.0736 (0.0001)*** | 0.0740 (0.0001)*** | 0.0653 (0.0002)*** |
| fixed effects | | ipt, jpt, ijp | |
| clustered SE | | HS6 product level | |
| N | 63711020 | 63711020 | 63711020 |
| r2 | 0.7881 | 0.7895 | 0.7882 |

Note: Time to event 0 is the year of signature. Specification 1 is the baseline specification; Specification 2 includes country-pair specific linear time trends and Specification 3 includes lag 1 aggregate bilateral trade flow at HS Nomenclature section level.

Table 2: Regression-based results

| | Specification 1 | Specification 2 |
|---------------|-----------------------|-----------------------|
| time to event | | |
| -9 | 0.0007 (0.0008) | 0.0011 (0.0008) |
| -8 | 0.0005 (0.0008) | 0.0001 (0.0008) |
| -7 | 0.0016 (0.0009)* | 0.0014 (0.0009) |
| -6 | 0.0040 (0.0007)*** | 0.0038 (0.0007)*** |
| -5 | 0.0054 (0.0007)*** | 0.0054 (0.0007)*** |
| -4 | 0.0084 (0.0008)*** | 0.0083 (0.0008)*** |
| -3 | 0.0084 (0.0008)*** | 0.0081 (0.0008)*** |
| -2 | 0.0101 (0.0009)*** | 0.0099 (0.0009)*** |
| -1 | 0.0107 (0.0009)*** | 0.0106 (0.0009)*** |
| 0 | 0.0137 (0.0009)*** | 0.0133 (0.0009)*** |
| 1 | 0.0144 (0.0010)*** | 0.0141 (0.0010)*** |
| 2 | 0.0136 (0.0011)*** | 0.0136 (0.0011)*** |
| 3 | 0.0172 (0.0012)*** | 0.0172 (0.0012)*** |
| 4 | 0.0234 (0.0014)*** | 0.0232 (0.0014)*** |
| 5 | 0.0286 (0.0015)*** | 0.0284 (0.0015)*** |
| 6 | 0.0253 (0.0016)*** | 0.0251 (0.0016)*** |
| 7 | 0.0309 (0.0017)*** | 0.0308 (0.0017)*** |
| ln_L1_vs_ijt | | 0.0021 (0.0001)*** |
| fixed effects | lhs2t, jpt, ijp | |
| clustered SE | HS6 product level | |
| N | 56048931 | 56048931 |

Note: Time to event 0 is the year of signature. I artificially assume that treatment starts at time to event -6 (6 years before the year of signature). Time to event -9, -8 and -7 are the pretrend test. Specification 1 is the baseline specification and Specification 2 includes lag 1 aggregate bilateral trade flow at HS Nomenclature section level.

Table 3: Imputation-based results

Chapter 2

Firm-Level Export and Import Survival over the Business Cycle

Note: This chapter is co-authored with Gregory Corcos, Silvano Esteve-Pérez and Salvador Gil-Pareja.

Abstract

This paper examines how the duration of new export and import spells depends on business cycle conditions, using micro-level data on trade spells initiated by French firms over the period 1998-2015. First, we find that exporters' and importers' hazard rates of leaving foreign markets are counter-cyclical. Second, new spells initiated during recessions face a lower hazard of exiting export/import markets (cohort effect), suggesting downturns have long-lasting effects on participation in foreign trade. Third, hazard rates are high at entry but fall sharply with spell age, both for cohorts 'born' at good and bad times. Fourth, approximately 2/3 (1/2) of aggregate negative age dependence in exports (imports) is related to "true" age dependence, and 1/3 (1/2) is related to sorting. Finally, the estimation of a bivariate duration model confirms these patterns and reveals a positive association between the duration of import and export spells. Overall, our results suggest that business cycle conditions affect trade participation both in the short- and long-run, with both 'cleansing' and 'scarring' effects of recessions at work.

Keywords: firm export and import survival; business cycle; inflow heterogeneity

1. Introduction

The extant literature concerning the relationship between the business cycle and trade dynamics has mostly focused on the short-run effects of recessions, especially the 2008-2009 Great Recession. The evidence suggests that the 2008-09 trade collapse¹ mainly occurred on the intensive margin (i.e., falling trade volumes among continuing exporters) with little impact on the extensive margin (i.e., exit out of exporting) of trade.² However, these studies have overlooked the important long-lasting implications of economic crises on trade due to effects channeled through the extensive margin. Indeed, despite high hazard rates suffered by new exporters (that typically start small), export survival is a key driver of long-run export dynamics.³ Likewise, Bellas and Vicard (2014) argue that the extensive margin is an important source of the large long-run response of trade volumes to the business cycle. Despite the importance of entry in and exit from foreign markets in trade fluctuations, little is known about the role of post-entry trade dynamics in the propagation of economic shocks over time.

Furthermore, the literature on business cycle and (domestic) firm dynamics has long emphasized the effects of recessions on resource allocation. On the one hand, recessions accelerate the elimination of obsolete techniques and out-of-date products, and thus free resources for more productive uses (i.e., cleansing effects).⁴ Hence, recessions change the composition of firms as entry and exit selection get tougher, thus raising the entry and exit productivity cutoffs. On the other hand, recessions also have long-lasting effects (i.e., scarring effects) through their effect on the tougher entry conditions.⁵ That is, conditions at birth have persistent effects, mainly driven through the extensive margin.

In this paper, we examine the effects of the business cycle conditions at entry on export/import survival. Our empirical analysis relies on customs data documenting annual disaggregated exports and imports, matched with data on firm characteristics. More specifically, we examine the hazard of exiting export/import markets, accounting for conditions at birth, age dependence (i.e., age-of-spell), and business cycle effects. That is, we consider inflow heterogeneity, which refers to the variation over the business cycle in the composition of the new export/import spells with respect to their survival chances.

First, we find that gross exit rates are higher than gross entry rates during downturns, leading to a fall in foreign market participation. In good times, both gross rates are rather similar, such that net entry rates are very small. Second, we assess whether some firm-level characteristics (namely, number of employees, total factor productivity, and total sales) of firms that start exporting/importing during recessions differ from those of firms that begin foreign market participation during expansions. We further make these comparisons for export/import exiters and continuers. The results suggest that entrants at bad times are smaller but more

¹World trade in manufactures abruptly fell about 30% in nominal terms between the first quarter of 2008 and the second quarter of 2009 (World Trade Organization, 2009), which was disproportionately higher than the drop in aggregate output, breaking a steady growth since WWII. Several scholars have pointed out the impact of the financial crisis on the shortage of trade finance (Amiti and Weinstein, 2011; Bricongne et al., 2012; Chor and Manova, 2012; Paravisini et al., 2015) and the disproportionate slowdown in demand for imported goods, in part due to the product composition of imports (Levchenko et al., 2010; Eaton et al., 2016; Bems et al., 2010; Abiad et al., 2014).

²Wagner (2016) provides an excellent survey of transaction-level data empirical studies. These studies confirm that short-run export dynamics are dominated by the intensive margin, that is, new exporters or firms that stop exporting are much less important for year-to-year changes in exports. For instance, Bernard et al., 2009, for US; Amador and Opromolla, 2013, for Portugal; Álvarez and Fuentes, 2011, for Chile; De Lucio et al., 2011, for Spain; Bricongne et al., 2012, and Behrens et al., 2013, for France; Wagner, 2014, for Germany; and Cebeci and Fernandes, 2015, for Turkey.

³See (among others) Besedes and Prusa (2011), Eaton et al. (2007), and Albornoz et al. (2012)

⁴See Caballero and Hammour (1994); Campbell (1998); Bilbiie et al. (2012); Clementi and Palazzo (2016); Gomis and Khatiwada (2016); Ayres and Raveendranathan (2021), among others

⁵See Haltiwanger et al. (2013); Moreira (2016); Sedlacek and Sterk (2017); Vardishvili (2022), among others.

productive. Besides, the productivity threshold for exiters is higher during recessions. Third, we dig deeper into the role of productivity (also employment and sales) in shaping the decision to export/import at good and bad times. The probit regressions on the transition to entry confirm the increase in the productivity cutoff during downturns. Fourth, relying on Moreira (2016) we estimate age-period-cohort regressions that allow us to assess the existence of persistent effects of conditions at birth. Hence, we find support for the cleansing hypothesis given that exit rates are counter-cyclical, entry rates pro-cyclical, and higher productivity entry and exit cutoffs during recessions. Besides, we find evidence of persistent effects of recessions on some firm-level characteristics over their export/import lifetimes.

Fifth, as the main novelty and contribution of the paper, we estimate survival models to assess whether and how the hazard of exiting export/import differs across cohorts that face different business cycle conditions at birth. To this end, we use annual information on firm-level export spells initiated (i.e., “fresh” spells) during the period 1998-2015 relying on both Customs Data (*Full Sample*) and a sample of firms with the full set of firm-level characteristics that results from merging French Customs Data and French Tax Authority data -FICUS- (*Restricted Sample*). This analysis allows us to uncover insights on how the business cycle conditions when firms begin to export and/or import affects their survival chances over their export/import lifetimes, accounting for spell-specific age-dependence (i.e., ongoing experience or duration dependence) and the state of the economy (overall business cycle effects).

In our context, there arise some concerns about the identification of individual contributions to the average survival probability of the baseline hazard, the unobserved heterogeneity, the covariates, and the business cycle. Following Cameron and Trivedi (2005), we deal with these issues through the estimation of several specifications of a flexible discrete time proportional hazards model (i.e., a Mixed Proportional Hazards Model equivalent to a piece-wise constant exponential hazards model) that includes a discrete mixture distribution with finite support to summarize unobserved exporter-level heterogeneity (Heckman and Singer, 1984). The export hazards are estimated by maximum likelihood. Furthermore, the identification of the parameters of interest (i.e., duration dependence, business cycle, and inflow heterogeneity effects) is improved due to both the presence in the dataset of multiple spells per firm (i.e., about 33.1% of firms in the data experience more than one spell -repeated spells, and 92.8% of these repeated spells are complete), and the use of business cycle and inflow heterogeneity indicators. Besides, our results are robust to several binary and continuous business cycle measures.

Furthermore, our methodology permits us to analyze the pattern and sources of duration dependence (i.e., sorting or “spurious dependence” vs genuine or “true” duration dependence), business cycle, and inflow heterogeneity effects, and whether and how the period of birth of export/import spells shapes both the pattern of duration dependence and the relationship between spell characteristics and export/import survival. That is, we examine whether spells initiated under different entry conditions face a one-off difference in their hazard rates and/or they further differ in their patterns of duration dependence.

Rather interestingly, we find that while the overall hazard of leaving export/import markets is higher during downturns, exporters/importers born at bad macroeconomics conditions have lower hazard of ending their export/import spells. That is, firms that start exporting and/or importing during downturns are intrinsically fitter to survive than those spells initiated during upturns. This finding is robust to the use of different business cycle measures (i.e., binary indicators, continuous variables, GDP-related and GDP-growth related dummy and continuous variables). Furthermore, we find negative duration dependence. Our results confirm the existence of “true” negative age-dependence effects that account for 2/3 (1/2) of the observed aggregate negative export (import) duration dependence using the *Full sample*. Besides, the pattern of negative duration dependence does not differ between firms that start exporting at bad and good times, suggesting the existence of a one-off drop in the hazard of leaving foreign

participation for firms that start exporting during recessions. However, the pattern differs between firms that start importing at bad and good times. Finally, we estimate bivariate duration models which suggest that the joint pattern of firm's export and import duration tends to be either long-long or short-short.

After reviewing the related literature in the next sub-section, the rest of the paper is organized as follows. Section 2 describes the data and presents some evidence on firm export/import dynamics and the business cycle. Section 3 briefly outlines the empirical methodology on duration models and presents the main results. Section 4 discusses our main results and related them to the existing literature on firm dynamics and business cycle. Finally, Section 5 concludes and sketches out some policy implications from our findings.

1.1 Background and related Literature Our paper contributes to the scarce empirical literature that relates the extensive margin of trade and macroeconomic conditions. The extant literature has mainly focused on the relationship between the number of exporters/importers and the business cycle (e.g., Alessandria and Choi, 2007, 2019). To the best of our knowledge, no previous studies have examined exporters' and/or importers' differences in long-run performance, namely survival, accounting for business cycle conditions at birth over their export/import lifetime.⁶

Our paper is related to two main strands of the literature. First, it is related to the empirical firm dynamics literature that examines the relationships between macroeconomic conditions at birth and firm characteristics over their lifetime (Caballero and Hammour, 1994; Campbell, 1998; Haltiwanger et al., 2013; Lee and Mukoyama, 2015, 2018; Moreira, 2016; Sedlacek and Sterk, 2017; Vardishvili, 2022). These studies find robust evidence of persistent effects of entry conditions. Second, our work is related to export participation dynamics (Dixit, 1989, 1991; Roberts and Tybout, 1997; Melitz, 2003; see also the survey by Alessandria et al., 2021). Our findings that hazard rates out of exporting/importing fall along an exporter/importer life cycle, are in line with existing work, e.g. Bernard and Jensen (2004, 2012); Volpe and Carballo (2007); Eaton et al. (2008); Lawless (2009) Iacovone and Javorcik (2010); Amador and Opromolla (2013); Esteve-Pérez et al. (2013, 2021); Albornoz et al. (2016); and Araujo et al. (2016). Yet, these studies do not examine the effect of macroeconomic conditions at birth in survival performance.

On one hand, the idea of strong and long-lasting effects of recessions on resource allocation has been long emphasized since Schumpeter (1934), who advances the concept of cleansing effect of recessions. They accelerate the elimination of outdated techniques and products, thus enhancing productivity through the exit of low-productivity firms and the entry of new ones. Both credit constraints and market fundamental forces (supply, productivity, demand) are suggested as the key drivers of reallocation. This literature has been strongly revived in the last decade when a number of studies have pointed out the important effects of macroeconomic conditions at birth on firm dynamics. Some studies find that firm/plant entry is pro-cyclical while exit is counter-cyclical (e.g., Bilbiie et al., 2012; Clementi and Palazzo, 2016; Gomis and Khatiwada, 2016; Tian, 2018; and Ayres and Raveendranathan, 2021) thus suggesting cleansing effects of recessions. Moreover, a number of studies (e.g., Caballero and Hammour, 1994; Haltiwanger et al, 2013; Lee and Mukoyama, 2015, 2018; Moreira, 2016; Sedlacek and Sterk, 2017; Vardishvili, 2022) point out that macroeconomic conditions at birth have persistent effects (i.e., scarring effects of recessions) that operate through the composition of newborn cohorts

⁶The few studies that have examined export survival under financial constraints (Berman and Hericourt, 2010; Besedes et al., 2014) conclude that credit constraints are an important barrier to start exporting, with a decreasing or even no effect as the duration in export markets increases. Yet, although these studies consider market dynamics, they do not account for re-entry possibility in a dynamic framework with more than two (either consecutive or distant) periods. In such dynamic setting, entry barriers become exit barriers so an option value of staying in arises.

(i.e., inflow heterogeneity). Interestingly, Ouyang (2009) points out the existence of a trade-off between cleansing and scarring effects of recessions in a model with demand fluctuations and learning about idiosyncratic productivity. The infant mortality of potentially good firms during recessionary periods may lead to lower productivity in the long run. We discuss below on the underlying propagation mechanisms related to export/import dynamics. In this vein, the Great Recession could have hampered the development of potentially good projects due to the lack of external financing or may have conditioned them (e.g., newborn projects of a smaller size).

On the other hand, the literature on export (and import) participation dynamics relies on Dixit-type framework (Dixit, 1989, 1991; Dixit and Pindyck, 1994). In this setting, firms make investment decisions under ongoing uncertainty about their future profitability and costly reversibility (sunk costs). That entails a range of the state variable where inaction (i.e., no entry, no exit) is optimal. Recently, Alessandria et al. (2021) present a canonical model considering that firms make dynamic decisions to participate in export markets that relies on Melitz (2003). Heterogeneous firms decide whether to enter to export markets in presence of sunk costs and uncertainty on their future benefit from exporting. A firm's uncertainty may arise due to its unawareness about destination markets regulations and legal requirements, the evolution of foreign demand, and the adequacy of its products to local tastes. Moreover, exporting is costly as it involves extra costs to enter foreign markets (e.g., for studying the foreign market; for setting up a distribution network; for product customization to foreign standards, regulations, or local tastes; for marketing and red tape) that often must be paid upfront and that, to a large extent, are sunk costs.

Our paper further contributes to the previous two strands through the discussion on the broad economic forces that can explain the observed differences in export/import survival across cohorts. We discuss them below.

First, profit flows tend to be pro-cyclical, which is commonly driven by demand fluctuations, leading to expect less entry and more exit at recessions. This mechanism is compatible with cleansing and stronger entrants. In this line, Caballero and Hammour (1994) develop a vintage model of creative destruction (of firms/plants) to consider the business cycle effect, which is proxied by demand fluctuations, which confirms the cleansing effects of recessions. By the same token, Moreira (2016)'s model that features demand fluctuations and high uncertainty at recessions, and a demand accumulation disadvantage for entrants, explains that establishments born during recessions are not only smaller than those born during booms but also remain smaller over long periods of time. In this model, persistent effects (i.e., differences in firm dynamics across cohorts) are related to selection at entry and demand-side channels. The former refers to the existence of systematic differences in the quality of business's entering during economic booms and recessions which could lead to differences in initial investments and growth patterns, while the economic constraints at recessions limit the ability of businesses to adjust their size following an initial investment (e.g., building a customer base). Hence, entrants at recessions are smaller and remain so after entry, while they are more productive due to the tougher selection at entry during recessions. Sedlacek and Sterk (2017) develop a general equilibrium model that shows that macroeconomic conditions at birth (rather than post-entry choices) have long-lasting effects on macroeconomic aggregate fluctuations, channelled through the differences in the composition of cohorts born at different stages of the business cycle. Ouyang (2009) argue that recessions create a scarring effect in addition to the conventional cleansing effect by interrupting businesses' learning of their unobservable idiosyncratic productivity. The lower demand during recessions reduces profitability in general so that firms exit younger, which creates two countervailing forces: cleansing effects as resources concentrate on younger and more productive forces; yet, it may truncate the learning process that leads resources toward firms with higher idiosyncratic productivity, creating a scarring effect that reduces average productivity.

Second, some studies on firm dynamics assume counter-cyclical sunk entry costs (Bilbiie et al,

2012; Clementi and Palazzo, 2016; Alessandria and Choi, 2019). Lee and Mukoyama (2018) make the same assumption but argue that this could be explained by both higher costs in equipment and structures and financial constraints during recessions. However, counter-cyclical sunk entry costs would lead to expect less entry and less exit at recessions, which is not compatible with cleansing effects as exit rates should be higher during recessions. Re-entry costs increase during recessions leading to expect less exit -even for ongoing spells.

Third, some authors emphasize the effects of financial constraints on firm and export dynamics. On one hand, Ayres and Raveendranathan (2021) report reduced firm entries and increased exits during the Great Recession (i.e., years 2008, 2009, and 2010), primarily concentrated among young firms (among them, new entrants). The mechanism is that the credit crisis constrained the ability of firms to borrow and accumulate capital, leading to a much slower process of capital accumulation and therefore a slower rate of growth for profits. It disproportionately affected potential entrants and young incumbents that are borrowing to accumulate capital. The negative shock reduces their value of operating, so that potential entrants choose not to enter, and young incumbents choose to exit. On the other hand, some authors argue that credit constraints lead to counter-cyclical sunk entry-to-export costs. Manova (2013), Manova et al. (2015), and Chaney (2016) point out that credit constraints raise entry barriers to foreign markets making the selection-into-exporting mechanism tougher. Thus, the productivity cut-off to enter export markets increases. Hence, credit constraints can hamper or even prevent exporting.⁷ In this line, Impullitti et al. (2013) extend Melitz (2003) setting relying on Dixit and Pindyck (1994) model of investment decisions under uncertainty. In this model, financial constraints increase entry barriers that turn into exit barriers when re-entry, which entails sunk entry costs, is a possibility and upfront investment in market access rapidly depreciates. This introduces an option value in the decision to enter or exit the export market leading to an increase of a firm's export status persistence. Current exporters wait longer to leave the export market to avoid re-paying the entry costs later on. Similarly, non-exporters wait for higher efficiency levels before entering the export markets. Therefore, during downturns we could expect a tougher selection mechanism leading to fitter-to-survive new exporters that survive longer in exporting after entering and overcoming the initial phase of high infant mortality. Yet, in this setting we would expect both less entry and less exit during bad times. The latter would be explained by the increased option value of waiting as re-entry costs increase.

Fourth, recently Vardishvili (2022) develops a model that embeds procyclical profit flows and demand accumulation disadvantage for entrants, as in Moreira (2016), and counter-cyclical cost of entry due to a value of delay that operates only for potential entrants (and not for ongoing firms). The value of waiting arises due to the higher overall failure risks during recessions. The effects operate through two channels. A direct channel through procyclical profit flows. And, an indirect (option value to delay) channel that arises because during recessions the risk of post-entry failure raises in line with the overall risk of failure, which creates a positive value of waiting and increases the relative cost of entry today. Thus, the model can simultaneously explain the observed lower entry and higher exit, together with fitter-to-survive (over their entire lifetime) entrants during recessions.

We argue that our results are compatible with a toughening of entry conditions during downturns as current macroeconomic conditions are worsened off. These traits are featured in Vardishvili (2022) model. In this line, we find that the overall risk of failure is higher during recessions. Both entry to export/import productivity thresholds rise, and the hazard rate of leaving export/import markets is persistently lower for export/import spells initiated during downturns. In Section 4, in light of our results, we provide a more targeted discussion of the related literature.

⁷Berman and Hericourt (2010), and Wagner (2014); Mûuls (2015); Jaud et al. (2018) find that credit constrained firms are less likely to become exporters.

2. Empirical evidence on firm export/import dynamics and business cycle

In this section, we present the dataset used in this paper, define some key variables for the analysis, and provide some evidence on the relationship between firm export/import dynamics and the business cycle.

2.1. Data and variables

Our analysis is carried out using two main datasets that span the period from 1997 to 2016.⁸ First, the *Full Sample* consists of annual firm-level export and import data from French Customs. This dataset includes detailed information on all transactions (in euros) by firm, HS6 product, destination country and year.⁹ To handle revisions of the HS classifications, we concord product categories using data from Van Beveren et al. (2012), who use a version of the Pierce and Schott (2012) algorithm. Our paper focuses on the study of export/import spells. A firm export (import) spell is defined as a set of years where firm exports (imports) consecutively. As most of our analyses are conditional on the initial characteristics of export/import spells, we exclude those export/import spells of which the information on main destination's gravity variables is missing in the first year of the spell.¹⁰ The resulting *Full sample* contains both left-censored (i.e., ongoing firm-level export/import spells in 1997) and non left-censored export/import spells. Regarding non left-censored export spells, the *Full sample* consists of 403,821 export spells (about 89.3% of them complete) from 307,498 firms corresponding to 994,199 (spell-year) observations between 1998 and 2015. Regarding non left-censored import spells, the *Full sample* consists of 365,865 import spells (about 86.0% of them complete) from 296,823 firms corresponding to 1,052,992 (spell-year) observations between 1998 and 2015.

The second dataset (*Restricted sample*, hereafter) has been built after matching the *Full sample* with balance sheet data from the French tax authority's (FICUS/FARE dataset) and financial linkage data (LIFI dataset). The FICUS/FARE dataset includes sales, value-added, employment, capital stock, cost of materials, its primary industry, foreign ownership, etc. for all French firms taxed under two main corporate tax regimes. We further exclude those firm-level export/import spells of micro firms (i.e., firms with less than 10 employees, which are not included in FICUS before 2008) or in distribution sectors in the first year of the spell. Regarding non left-censored export spells of which the first year observation can be matched with balance sheet data, the *Restricted sample* consists of 202,210 export spells (about 85.7% of them complete) from 157,027 firms corresponding to 485,652 (spell-year) observations between 1998 and 2015. Regarding non left-censored import spells, the *Restricted sample* consists of 190,311 import spells (about 82.3% of them complete) from 156,485 firms corresponding to 498,661 (spell-year) observations between 1998 and 2015. In some subsections, we rely on

⁸Year 1997 is used to identify left-censored export/import spells and year 2016 is used to identify whether export/import spells are right-censored or failed by the end of 2015.

⁹See Bergounhon et al. (2019) for a detailed presentation of this dataset. Following these authors, we keep valid firm identification numbers and valid destination countries. Moreover, we drop both special product codes and countries that account for a tiny share of all French exports (imports) over the sample period. We further drop "sporadic export and import relationships", which comprise firm-level export relationships with a value of sales abroad below 1500€ in a particular year. Yet, we correct for "accidental or false exits" that arise as a result of the previous threshold, which could lead to "false repeated spells" in our survival analysis. Therefore, if exports/imports of a firm-level export/import relationship in one year lie below 1500€ but both in t-1 and t+1 its value exceeds that level, then it is not considered as two different spells, one ending in t-1 and a second one starting at t+1, but as one ongoing spell from t-1 to t+1. That is, one-year-gaps due to our export/import threshold are not considered as exits and re-entry.

¹⁰For import spell, main destination refers to main sourcing country. For a given firm-year, main destination (sourcing country) is the one with the highest export (import) value.

subsamples of the *Restricted sample*, which will be explained therein in detail.¹¹

These two datasets depict two interesting features that make them particularly suitable for the analysis of the relationship between the business cycle and trade survival. First, on foreign market participation (either exporting or importing) they have been built using information on annual export transactions over the period 1997-2016. Hence, they comprise either the population of firms that entered or re-entered export/import markets (i.e., exporters/importers inflow), or a subset of it, over a long time span, including pre-recession years and recession years, and the initial years of the subsequent recovery. Second, their long time spans allow for examining a large number of new export/import spells (including repeated spells) over time with a long follow-up period (see section 3).

Furthermore, in the survival analysis we also include additional control variables relying on OECD country-risk data, COMTRADE and standard gravity variables from the CEPII Gravity dataset used in Head et al. (2010).¹²

Definition of variables We now turn to the definitions of some key variables for our analysis; namely, entry to export/import, exit from export/import, and business cycle indicators. First, a firm begins exporting (importing) in year t , when it had no exporting (importing) value in $t - 1$, but it has a positive value in year t . Second, a firm exits from exporting (importing) in year t , when it has a positive export (import) value in year t , but has no export (import) value in $t + 1$.

Our main interest lies in examining the hazard of exiting export/import markets accounting for both macroeconomic conditions at birth and current business cycle conditions, and controlling for age-of-spell effects. In the survival analysis, ideally, we would like to use both annual cohort dummies and year dummies so as to capture cohort effects and year effects of business cycle exhaustively. However, as spell age dummies are also included as covariates, the annual cohort dummies, year dummies and age dummies are perfectly collinear. Following Cameron and Trivedi (2005) and Heckman and Rob (1985), we start by grouping a sequence of adjacent years to proxy cohort effects and business cycle conditions. Hence, we start using two business cycle binary indicators to account for macroeconomic conditions at the time of entry (i.e., first year of a spell) and current business cycle conditions. First, aggregate conditions at entry are proxied with *birth2008_10*, which equals 1 if firm-level export/import spells were initiated in year 2008, 2009 or 2010. *birth2008_10* represents those export/import spells that were born during the financial crisis. Second, current macroeconomic conditions are proxied by *current2008_10*, which equals to 1 if the current year is 2008, 2009 or 2010. *current2008_10* aims to capture the effect of the financial crisis on all ongoing spells between 2008 and 2010. We made this choice relying on the World Bank, NBER and CEPR official recessions dates. For instance, Kose et al. (2020) date the trough in global activity in 2009, corresponding to a fall in annual real per capita global gross domestic product. The latter two institutions locate the trough in the second quarter of 2009, with the peak in late 2007 and recovery in early 2011. Moreover, Ayres and Raveendranathan (2021) and Vardishvili (2022) also consider years 2008, 2009 and 2010 as bad years.

In addition, in the survival analysis section, we present the results using an alternative GDP-based business cycle indicator, which defines a bad-time indicator (at-birth and current) equal to 1 if detrended GDP is smaller than 0. Interestingly, by utilizing business cycle indicators other than the previous crisis dummies, we can distinguish between the effects of France's at-entry/current business cycle and the effects of the main destination's at-entry/current business cycle. Furthermore, as robustness checks for our survival analysis (Appendix D), we use alternative business cycle proxies to account for both at-birth and current business cycle conditions.

¹¹Appendix A gives the summary statistics of some covariates of the *Restricted sample*.

¹²See Table 1b in Appendix A for variable definitions.

These include (1) a financial crisis and its aftermath dummy that covers a longer period (2008-2015), (2) a bad-times indicator that equals to 1 if the difference between country's GDP growth and world GDP growth is smaller than the mean of the difference across sample years, (3) log of country's TFP, (4) log of country's GDP and (5) the difference between country's GDP growth and world GDP growth.

In the remainder of Section 2, we will primarily discuss the results based on our *birth2008_10* business cycle binary indicator. Therefore, unless otherwise stated, "Bad" refers to year 2008, 2009 and 2010, whereas "Good" refers to the other years. In Section 3, we present the results for the 2008-10 dummy indicator and for the detrended GDP-based binary indicator.

2.2. Evidence: export/import entry and exit over the business cycle

In this section, we present some evidence on exporters' and importers' performance over business cycle from different perspectives.

2.2.1. Trade is cyclical & extensive margin importance in the long-run

This section provides evidence on the correlation between trade and the business cycle relying on the *Full sample*. Figure 1 plots total export and import values and GDP for France between 1997 and 2016. We observe a clear co-movement between trade values and the business cycle (GDP). The Great Recession prompted by the financial crisis of 2008 is associated with the Great Trade Collapse. Hence, this figure suggests that trade flows are highly cyclical.

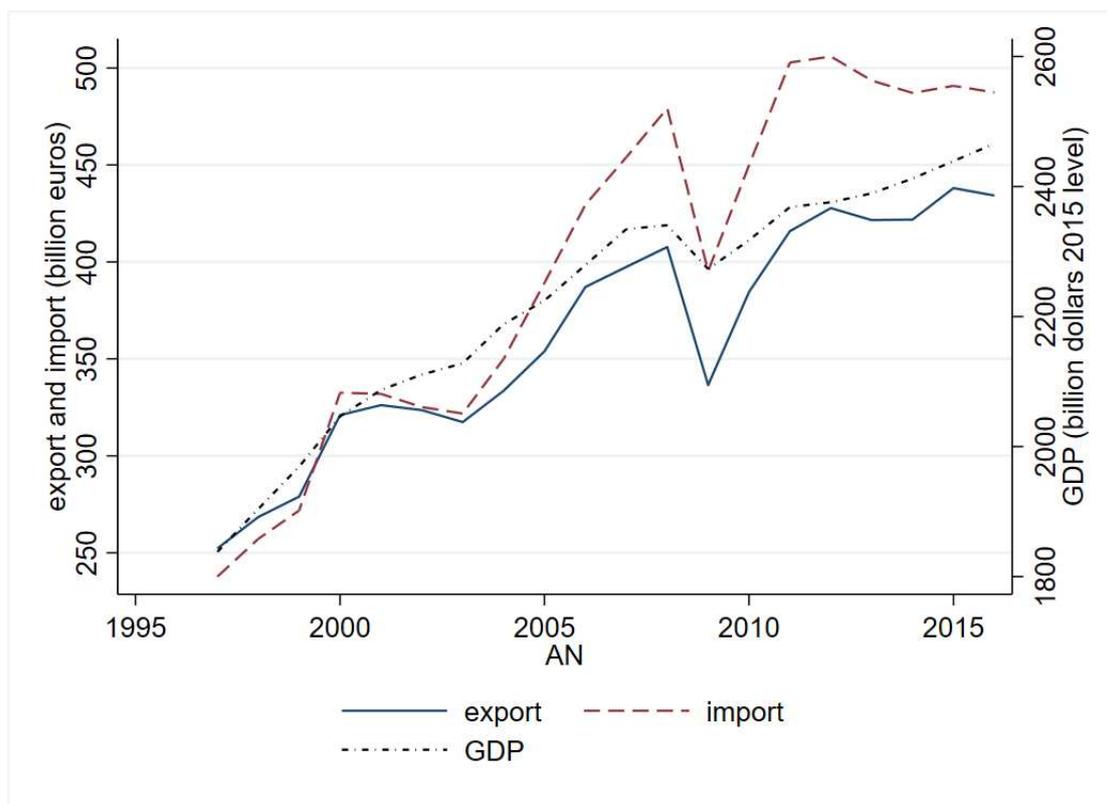


Figure 1: France total exports and imports, and GDP (1997-2016)

Figure 2a (2b) plots France's yearly total export (import) value and total export (import) value of cohorts that exported (imported) in 1997 (old). The vertical distance gives the export

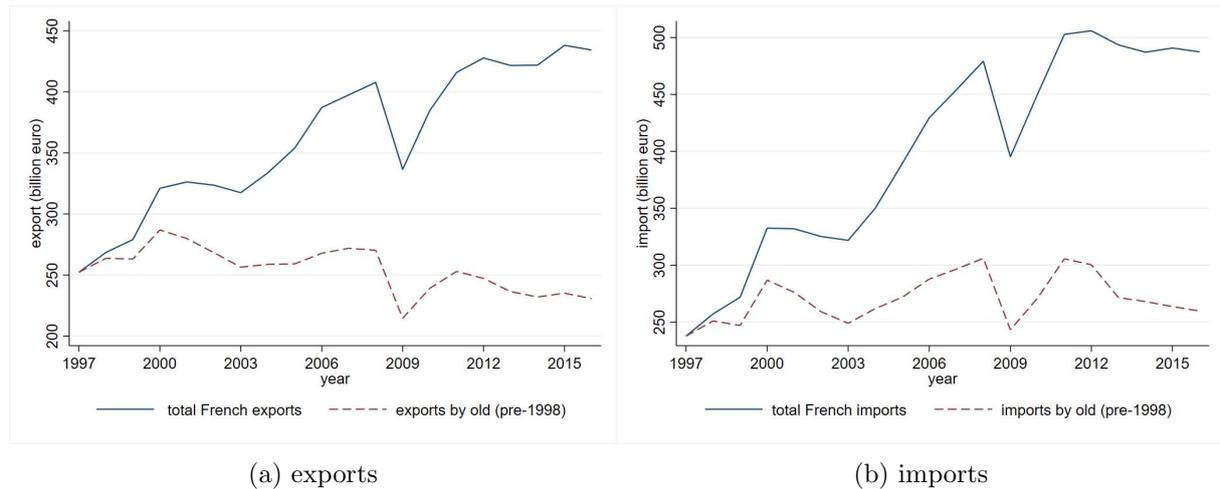


Figure 2: French total exports/imports and exports/imports by old (pre-1998) exporters (1997-2016)

(import) value of cohorts that did not export (import) in 1997 (new cohorts). In the long run, the export (import) value of new cohorts accounts for around 50% of yearly export (import) value. From these two figures, we can conclude the relevance of the extensive margin (i.e., the new exporters/importers and their survival and growth) in the long run. Therefore, the study of exporters' (importers') entry and exit is deemed essential to explain the dynamics of aggregate trade flows.

2.2.2. Entry/exit rates and the business cycle

Relying on the *Full sample*, Table 1 provides evidence on the relationship between entry and exit rates, and the business cycle. As previously explained, an entrant in year t means that a firm's exports (imports) are positive in t and zero in $t - 1$. An exit in year t occurs when the firm's exports (imports) are positive in t and zero in $t + 1$. For the calculation of the entry/exit rates, a firm that both enters and exits in a given year t is considered as 0.5 entrant and 0.5 exit.¹³ Furthermore, we define the entry (exit) rate at bad (good) times as the ratio between the mass of entrants (exits) and the mass of all exporters/importers at bad (good) times. For instance, export entry rate at bad times equals to the mass of entrants between 2008 and 2010 divided by the mass of exporters during this period.

We can observe that entry rates are pro-cyclical while exit rates are counter-cyclical. This pattern holds for both exports and imports. Thus, during bad times (i.e., years 2008, 2009, and 2010) entry rate is lower and exit rate is higher. In other words, during bad times, fewer firms are selected in and more firms are selected out of foreign markets, which suggests that there exists cleansing effect on both potential entrants and incumbents.

In addition, the last row of Table 1 suggests that the number of exporters/importers tends to fall during recessionary periods, with little change at good times. More specifically, during non-recessionary periods, there is a mild increase in the number of importers and a slight fall in the number of exporters.

¹³We use this definition of entrant and exit as it is consistent with that in survival analysis. Notice that, in a given year t , a one-year spell would be considered both as an entrant and an exit.

| | Exports | | Imports | |
|------------|----------|---------|----------|---------|
| | Good (%) | Bad (%) | Good (%) | Bad (%) |
| Entry rate | 18.6 | 17.4 | 16.2 | 15.2 |
| Exit rate | 18.6 | 19.7 | 16.0 | 19.2 |
| Net entry | -0.076 | -2.366 | 0.216 | -4.030 |

Note: Sample coverage is 1998 and 2015. Bad if year is 2008, 2009 or 2010. Entrant in year t means export (import) in t and not in $t - 1$. Exit in year t means export(import) in t and not in $t + 1$. A firm that both enters and exits in a given year is considered as 0.5 entrant and 0.5 exit.

Table 1: Entry and exit rates

2.2.3. Differences in firm-level characteristics of entrants, exiters and continuers over the business cycle

In this section, we explore whether there are differences in firm-level characteristics of entrants, continuers and exits between good and bad times. By doing so, we aim to gain insights into how the aforementioned selection mechanism works over the business cycle. For this end, we now rely on the *Restricted sample* given that it provides firm-level characteristics on exporters and importers that are not available in the *Full sample*.

Table 2 presents median values on firm-level characteristics, namely, number of workers - labor-, total factor productivity -TFP-, and total sales of entrants, continuers and exits for both exporters (Panel A) and importers (Panel B) across good and bad times.¹⁴ The last column of each panel indicates whether the differences for each variable within each group of firms between good and bad times are statistically significant.¹⁵

We follow our previous definitions of entrants (a firm with exports/imports in t but not in $t - 1$) and exits (a firm with exports/imports in t but not in $t + 1$) and business cycle (i.e., bad years include 2008, 2009, and 2010). Those exporters (importers) that are not classified as entrants or as exits are considered as continuers. For entrants, continuers and exits in year t , we use their characteristics in t . The sample coverage is from 1998 to 2015 and left-censored spells are included. It is important to bear in mind that exits and continuers include some left-censored export/import spells (i.e., firms that were already exporting/importing in 1997), which probably include a disproportionate share of well established experienced exporters/importers that might bias upwards some of these firm-level characteristics. By construction, these exporters and importers are not included in the group of entrants.¹⁶

The results of Table 2 indicate that, both for exporters and importers, entrants and exits have lower median labor force during bad times than in good times. The median labor force of continuers is similar across bad and good times. However, the share of observations with labor force greater than the median is lower during bad times and the difference is significant at 5% and 1% levels for exporters and importers, respectively. Regarding TFP, all types of exporters and importers have a significantly greater median performance during bad times (vs good times), yet the absolute difference is smaller for importers. This may suggest that selection becomes tougher for both entry and exit during recessionary periods. More productive firms are selected in and some relatively productive incumbents are selected out of foreign markets. In order to stay in their export/import markets during bad times, firms need to have a higher TFP. These findings are compatible with the hypothesis of the cleansing effects of recessions.

¹⁴TFP is calculated using the Levinsohn-Petrin method.

¹⁵We perform the default median test by group in STATA. When values for an observation are equal to the sample median, they are added to the group below the median.

¹⁶Notice that left-censored spells that we observe from 1997 onwards can only be classified as continuers or exits.

With regard to total sales, entrants have difficulty in achieving high total sales during bad times as market conditions are worse. Meanwhile, some relatively large exporters are selected out during recessionary periods and only large incumbents succeed in surviving in foreign markets. For importers, there is no difference for continuers and median total sales of exits are significantly smaller during bad times.

| | | Panel A. Exporters | | | Panel B. Importers | | |
|-------------|------------|--------------------|-----------|------|--------------------|---------|------|
| | | Good | Bad | Diff | Good | Bad | Diff |
| employment | entrants | 5 | 4 | *** | 5 | 3 | *** |
| | continuers | 18 | 18 | ** | 18 | 17,75 | *** |
| | exitors | 5 | 4 | *** | 5 | 4 | *** |
| TFP | entrants | 431.4 | 520.1 | *** | 412,3 | 427,5 | *** |
| | continuers | 959.5 | 1074.3 | *** | 1053,8 | 1163,7 | *** |
| | exitors | 414 | 515.8 | *** | 393,2 | 464,4 | *** |
| total sales | entrants | 742085 | 722535 | *** | 681314 | 512525 | *** |
| | continuers | 3191085 | 3367657.5 | *** | 3491160 | 3493380 | |
| | exitors | 713000 | 776455 | *** | 667000 | 649610 | ** |

Note: *Full sample* dataset over the period 1998-2015 (including left-censored spells). Bad if year 2008, 2009 or 2010. Entrant in year t means export (import) in t and not in $t - 1$. Exiter in year t means export (import) in t and not in $t + 1$. Continuer in year t is the one that exports (imports) in t and does belong to neither entrant nor exiter group. Units are number of employees for labor, and euros for total sales. TFP is calculated using the Levinsohn-Petrin method. Diff gives statistical significance of a test of equality of medians for good and bad groups. When values for an observation are equal to the sample median, they are added to the group below the median. * $p < 0.10$, ** $p < .05$, *** $p < .01$

Table 2: Exporters and importers firm-level characteristics (median values)

To sum up, we find that new exporters and importers during recessionary periods are smaller, but more productive. Firms quitting exporting and importing tend to be smaller in terms of employment, but have higher productivity.

2.2.4. Entry to export/import probability over the business cycle

In this subsection, we look at the correlation between export/import entry probability and some firm-level characteristics. More specifically, we analyze the relationship between business cycle conditions and entry probability in a period to gauge whether this relationship is shaped by firm-level characteristics. By doing so, we further examine changes in the composition of entrants over the business cycle.

We use a subset of our *Restricted sample*. In particular, we examine the association between firm-level characteristics and the probability of occurrence of a transition from being non-exporter (importer) in year $t - 1$ to become an exporter (importer) in year t . Therefore, an entrant in t is defined as a firm exporting (importing) in t but not in $t - 1$. Similarly, a non-entrant in t is defined as a firm not exporting (importing) neither in $t - 1$ nor in t .¹⁷ Notice that, by construction of the dataset in this subsection, there are no left-censored spells as they were already exporting in the first year of our sample period. In the regressions, we use the characteristics in $t - 1$ (i.e., one-year lagged values) to predict entry in t , which implies that firms must exist the year before they begin exporting (importing).

¹⁷For non entrants in t , we drop those which belong to micro firms and are in distribution sectors in $t - 1$. The results in this subsection are still robust to the use of our *Restricted sample* without any selection.

We estimate several specifications of the following probit model:

$$Pr(entry_{i,t} = 1|X_{i,t}) = \Phi(\beta_0 + \beta_1 birth2008_{10t} + \beta_2 birth2008_{10t} * characteristic_{i,t-1} + f_{enace}) \quad (1)$$

Table 3 presents the estimates of the probability of an entry transition to export (Panel A) and to import (Panel B) on the log of three measures of firm-level performance and our entry conditions dummy (i.e., macroeconomic conditions at birth of the export/import spell) with no other controls (cols. 1, 3, and 5); and including sector fixed effects (cols. 2, 4, and 6). The entry condition dummy is *birth2008_10*, which equals 1 if the export/import spell started in year 2008, 2009 or 2010. *L* stands for labor force and *catotal* is firm total sales.

Our specification is similar to Equation (6) in Moreira (2016) and includes the business cycle indicator and its interaction with each firm-level performance variable to examine the role of these performance indicators on the selection mechanism during bad times.¹⁸ A positive estimate of the interaction term suggests that an increase in that characteristic is positively associated with a higher probability of starting to export/import. For instance, a positive estimate for TFP suggests that the average productivity of entrants at bad times is higher (compared to that of non-entrants), suggesting that the average quality of entry cohorts is counter-cyclical.

The results of Table 3 show that bad macroeconomic conditions at birth reduce the expected probability of initiating an export/import relationship. That is, export/import entry becomes more difficult at bad times. Moreover, the correlation between export/import entry and TFP/labor force/total sales becomes stronger at bad times, which suggests that, to start export/import, firms' TFP, labor size and total sales become more crucial at bad times. Therefore, the entry selection mechanism is associated with firm-level characteristics.

¹⁸Moreira (2016) regresses the demeaned log change in the number of entrants in market segment in a given year on the change of business cycle indicator and the interaction between the change of business cycle indicator and market characteristics.

| Panel A: export entry probability | | | | | | |
|--|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | lnTFP | lnTFP_nace | lnL | lnL_nace | lncatotal | lncatotal_nace |
| birth2008_10 | -1.832 (0.014)*** | -1.753 (0.016)*** | -0.275 (0.004)*** | -0.243 (0.004)*** | -2.968 (0.018)*** | -2.669 (0.019)*** |
| birth2008_10.lnTFP | 0.334 (0.002)*** | 0.32 (0.003)*** | | | | |
| birth2008_10.lnL | | | 0.214 (0.002)*** | 0.200 (0.002)*** | | |
| birth2008_10.lncatotal | | | | | 0.241 (0.001)*** | 0.216 (0.001)*** |
| nace | | yes | | yes | | yes |
| N | 14538981 | 14538981 | 15910467 | 15910467 | 32710594 | 32710594 |
| ll | -755550.22 | -702375.096 | -789599.462 | -729708.113 | -1055181.861 | -969290.194 |
| Panel B: import entry probability | | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | lnTFP | lnTFP_nace | lnL | lnL_nace | lncatotal | lncatotal_nace |
| birth2008_10 | -1.571 (0.015)*** | -1.528 (0.016)*** | -0.227 (0.004)*** | -0.206 (0.005)*** | -2.574 (0.019)*** | -2.326 (0.020)*** |
| birth2008_10.lnTFP | 0.294 (0.003)*** | 0.287 (0.003)*** | | | | |
| birth2008_10.lnL | | | 0.198 (0.002)*** | 0.187 (0.002)*** | | |
| birth2008_10.lncatotal | | | | | 0.213 (0.001)*** | 0.192 (0.002)*** |
| nace | | yes | | yes | | yes |
| N | 14495221 | 14495221 | 15865605 | 15865605 | 32659403 | 32659403 |
| ll | -665629.29 | -632858.824 | -697497.441 | -660557.069 | -940615.138 | -882926.349 |

Note: Probit estimation of export/import entry probability (Eq. (1)). The sample coverage is between 1998 and 2015. $birth2008_10 = 1$ if entry year is 2008, 2009 or 2010. For exporters (importers), entry in year t means export (import) in t and not in $t-1$ and no entry in t means not export (import) in $t-1$ and t . See appendix A for the definition of TFP, L, catotal and nace. $f_{e_{nace}}$ is nace sector fixed effect and we use firm's sector in $t-1$. We use a subset of our *Restricted sample*, which consists of two-year observations for entrants and non-entrants. For consistency, we drop those non entrants in t that are micro firms or in distribution sectors in $t-1$. The number of observations varies across different specifications as many firms have 0 labor force and their lnTFP and lnL are missing. The unit of total sales is euro. Standard errors are clustered at the firm level. * $p < 0.10$, ** $p < .05$, *** $p < .01$

Table 3: Export and import entry probability

2.2.5. Persistent effects of conditions at birth

In this subsection, using the *Restricted sample*, we examine whether there exist persistent effects of conditions at birth on firm-level characteristics, namely export/import value, TFP, and labor force. More specifically, we examine whether there are persistent differences in firm-level characteristics (over the export/import spells' lifetime) between exporters (importers) starting to export (import) at different stages of the business cycle. Thus, we test for the existence of scarring effects of conditions at birth.

Relying on Moreira (2016), we estimate several specifications of the following age-period-cohort equation:

$$\ln(\text{firm characteristics}_{it}) = \beta_{b0} \text{birth2008.10}_{i0} + \sum_{a=1}^{8+} \beta_a \mathbb{1}_{age=a+t} + \beta_c \text{charac}_{i0} + f_{e_{nace}} + f_{e_{year}} \quad (2)$$

where t is firm's export/import age (duration) within each firm spell and $charac_{i0}$ is firm

spell's full initial (age 1) characteristics. We bin age 8 or more into age 8.¹⁹

The results are presented in Table 4 and Table 5 for exports and imports, respectively. Three important comments are in order. First, columns (1), (4), (7), and (10) of these two tables report the results from the OLS regressions of the log of firm time-varying (over the spell's lifetime) performance on their (export/import spell) birth business cycle conditions *birth2008_10*, age-of-spell dummies, sector dummies at entry (*baseline specification*). Second, columns (2), (5), (8), and (11) display the results when adding year fixed effects to the previous specification. Third, column (3), (6), (9), and (12) show the results when we add full initial control variables, which include trade-related, main-destination specific and firm-characteristics, measured at the onset of the spell (i.e., at entry).²⁰ While the first two sets of columns study the effect of birth macro conditions at an aggregate level as firm-export-spell level covariates are not controlled for, except for age-of-export-spell effects, the third set examines the effect of birth macro conditions once we take into account a number of firm-export/import-spell level covariates. We analyze the results for exporters and importers separately.

(1) Exporters

We first look at persistent effects for exporters. Columns (1)-(3) of Table 4 illustrate the effect of macro condition at birth *birth2008_10* on firm's export value over the spell's lifetime. Without controlling year dummies, column (1) examines the persistent effect of birth macro conditions across the 2 cohorts - those born during the crisis years 2008-2010 and those born in other years. Year dummies in column (2) capture the effect of current macro conditions across entrants, continuers and exiters within the current year. In this case, *birth2008_10* only captures the effect of birth macro conditions net of the effect of current macro conditions. For instance, between 2008 and 2010, all export entrants, continuers and exiters experienced tougher market conditions. Therefore, their export value fell. The year dummies 2008, 2009 and 2010 in column (2) capture the average decrease of export value among all three groups. A comparison between the *birth2008_10* estimate in columns (1) and (2), shows that this coefficient is more negative (i.e., higher absolute value) in column (2), which suggests that the percentage fall of export value for entrants between 2008 and 2010 is higher compared to that for continuers and exiters that were born before 2008. Column (1) and (2) examine the effect of birth conditions at the "macro" level as we compare the performance across cohort-age-sector-(year) groups.

As we add very disaggregated covariates in column (3), we examine the effect of birth conditions at the "micro" level. More precisely, we try to compare two similar export spells with the difference that one was born during the crisis period while the other was born in a different period. Hence, we aim to compare between two export spells with similar initial characteristics (e.g., labor force) except for their period of birth. In column (3), we find *birth2008_10* non-significant. Does it mean that there is no scarring effect for cohorts that were born during crisis at a "macro" level? The answer is no. For instance, during the financial crisis, the entrants are more likely to start with lower labor force compared to their level of employment at normal times. Thus, the result of column (3) is conditional on this initial disadvantage for cohorts at bad times. Column (3) in Table 4 tells us that conditional on all these disadvantages, there would be no extra difference between cohorts born at bad times and the ones born at good times. Taken together, the results reported in Column (1), (2) and (3) suggest that, on average, bad birth macro conditions have a persistent negative effect over the firm export lifetime.

Columns (4)-(6) of Table 4 demonstrate the correlation between macro conditions at birth and persistent effects on a firm's TFP (over their export spell lifetime). Column (4) shows that exporters born at bad birth times tend to have a higher TFP that persists over time.

¹⁹Since *birth2008_10* = 1 if export (import) spells start in 2008, 2009 or 2010, one caveat is that the maximum age of cohort 2008, cohort 2009 and cohort 2010 are 8, 7, and 6, respectively.

²⁰See appendix B for variable definition.

Nevertheless, when we add year dummies, the estimate capturing the birth effect turns into negative. In Section 2.2.3 we found that entrants, continuers and exiters have higher TFP during bad times. Therefore, the year dummies in our specification capture the joint upward movement of TFP during bad times due to tougher selection criteria across these three groups (i.e., export starters, continuers, and exiters). Hence, in column (5), the bad birth condition dummy only captures the birth effect net of this upward co-movement and the negative coefficient for *birth2008_10* implies that, compared to continuers and exiters, the selection on entrants are relatively looser, which is consistent with our previous results.²¹ Once full control is introduced, the effect of bad birth conditions becomes positive, which suggests that cohorts born at bad times are intrinsically and persistently stronger (i.e., more productive).

Columns (7)-(9) of Table 4 depict the correlation between macro conditions at birth and persistent effects on a firm's labor force. Columns (7) and (8) suggest that the cohorts of exporting relationships initiated during bad macro conditions have a lower level of labor force. However, as full control is introduced in column (9), the birth effect becomes insignificant. It does not mean that cohorts born at bad times catch up with cohorts born at good times in terms of labor force performance. It just implies that conditioning on certain initial conditions other than business cycle, the effect on labor of business cycle condition at birth vanishes.

Finally, columns (10)-(12) of Table 4 illustrate the correlation between macro condition at birth and firm's total sales accounting for the possibility of persistent effects of this firm-level characteristic. Columns (9) and (10) provide evidence on the existence of scarring effect when we do not control for other export-spell characteristics. Yet, column (12) shows that the net effect of bad birth conditions are positive once we account for export-spells characteristics. As we have mentioned above, the latter results of column (12) do not involve that cohorts born at bad times catch up with cohorts born at good times.

(2) Importers

Table 5 presents the results for the effect of the initial aggregate conditions (i.e., business cycle conditions when the import spell was initiated) on the firm's persistent characteristics (over its import spell's lifetime).

First, columns (1)-(3) of Table 5 show the effect of bad birth conditions on import value over the spell's lifetime. Unlike exporters born at bad times, importers born at bad times tend to have a higher import value during their lifetime. Hence, we find no evidence of scarring effect on import value.

Second, in columns (4)-(6) of Table 5 we report the correlation between bad birth conditions and differences in importers' TFP performance over their spells' lifetimes. The first two columns provide the estimates when we only control for age-of-spell, industry and year effects. Our results suggest that importers born at bad times persistently have lower TFP. It is possible that low productivity firms rely more on external suppliers. During the financial crisis, they had difficulty in finding domestic suppliers as some of the domestic suppliers could have struggled and exit. Therefore, they had to look for suppliers in foreign markets and rely more on foreign markets. In addition, the above results on import value give suggestive evidence that importers born at bad times rely more on foreign markets. Column (6) provides results when we control for the full set of covariates (measured at entry). Conditional on other importer's initial characteristics, importers born at bad times actually have a higher TFP.

Third, columns (7)-(9) demonstrate the correlation between bad birth conditions and importers' labor force performance over time. In all three specifications (with and without the full set of control variables) we find that the cohorts born at bad times have fewer employees

²¹It is also because the effect of bad birth conditions keeps decreasing as age increases using the specifications without year dummy.

persistently. They do not catch up with cohorts born at good times even when many different firm-level characteristics are controlled for.

Fourth, the results for firms' total sales are displayed in columns (10)-(12) of Table 5. The results indicate that the cohorts born (i.e., import spells initiated) at bad times have persistently lower total sales over the export spell lifetime. However, this effect turns positive once we control for the full set of import-spell level initial characteristics. That is, those spells initiated at bad times persistently outperform those that were born at good times, once we restrict the comparison to spells with similar initial firm-level characteristics. Recall that the cohorts born at bad times have persistently higher import value. Although the cohorts born at bad times rely more on import markets, they do not really have an extra advantage in terms of total sales side.

| | Export value (lnv_ex) | Total factor productivity (lnTFP) | Labor (lnL) | Total sales (lncatotal) | | | | | | | | |
|----------------------|-----------------------|-----------------------------------|-------------|-------------------------|------------|------------|------------|------------|---------|------------|------------|------------|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| birth2008_10 | -0.032 | -0.07 | -0.007 | 0.022 | -0.043 | 0.025 | -0.149 | -0.147 | -0.006 | -0.041 | -0.069 | 0.075 |
| | (0.014)** | (0.018)*** | (0.015) | (0.010)** | (0.011)*** | (0.008)*** | (0.012)*** | (0.014)*** | (0.011) | (0.013)*** | (0.015)*** | (0.007)*** |
| age dummy | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| nace | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| year | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| full initial control | | | yes | | yes | | | yes | | | | yes |
| N | 485651 | 485651 | 386267 | 389081 | 389081 | 373666 | 398115 | 398115 | 372452 | 471807 | 471807 | 379253 |
| ll | -1031625 | -1031489 | -720622 | -616469 | -615787 | -436477 | -718793 | -718128 | -528487 | -947385 | -947000 | -363961 |
| r2 | 0.964 | 0.964 | 0.979 | 0.968 | 0.968 | 0.986 | 0.731 | 0.732 | 0.879 | 0.984 | 0.984 | 0.998 |

Note: The estimation method is OLS without constant. We use *Restricted sample* over the period 1998-2015. Left-censored spells are excluded. *birth2008_10* = 1 if export spells started in year 2008, 2009 or 2010. For the specification of total factor productivity (labor), total factor productivity (labor) at age 1 is not included in the full initial control. See appendix A for the definition of v_ex, TFP, L, catotal, nace, and the full initial control. The number of observations varies across different specifications as many firms have 0 labor force and their lnTFP and lnL are missing. The unit of export value is euro. Standard errors are clustered at the firm level. * p<0.10, ** p<.05, *** p<.01

Table 4: Persistent effects of business cycle conditions at entry to export

| | Import value (lnv_im) | Total factor productivity (lnTFP) | Labor (lnL) | Total sales (lncatotal) | | | | | | | | |
|----------------------|-----------------------|-----------------------------------|-------------|-------------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| birth2008_10 | 0.128 | 0.101 | 0.080 | -0.051 | -0.064 | 0.027 | -0.266 | -0.219 | -0.045 | -0.142 | -0.100 | 0.077 |
| | (0.014)*** | (0.017)*** | (0.014)*** | (0.010)*** | (0.011)*** | (0.008)*** | (0.013)*** | (0.014)*** | (0.011)*** | (0.013)*** | (0.015)*** | (0.007)*** |
| age dummy | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| nace | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| year | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| full initial control | | | yes | | yes | | | yes | | | | yes |
| N | 498661 | 498661 | 387117 | 393489 | 393489 | 374128 | 403403 | 403403 | 372578 | 481195 | 481195 | 379444 |
| ll | -1069567 | -1068037 | -705951 | -630881 | -630502 | -455710 | -728809 | -726790 | -547186 | -974676 | -972802 | -397988 |
| r2 | 0.965 | 0.966 | 0.982 | 0.967 | 0.967 | 0.985 | 0.741 | 0.743 | 0.872 | 0.983 | 0.984 | 0.998 |

Note: The estimation method is OLS without constant. We use *Restricted sample* over the period 1998-2015. Left-censored spells are excluded. *birth2008_10* = 1 if import spells started in year 2008, 2009 or 2010. For the specification of total factor productivity (labor), total factor productivity (labor) at age 1 is not included in the full initial control. See appendix A for the definition of v_ex, TFP, L, catotal, nace, and the full initial control. The number of observations varies across different specifications as many firms have 0 labor force and their lnTFP and lnL are missing. The unit of export value is euro. Standard errors are clustered at the firm level. * p<0.10, ** p<.05, *** p<.01

Table 5: Persistent effects of business cycle conditions at entry to import

2.3. Remarks on trade dynamics and business cycle

To sum up, we have uncovered the following results:

1. *(Export/Import) entry rates are pro-cyclical and exit rates are counter-cyclical.*

Moreover, the number of exporters and importers tends to fall during recessions, with (relatively) less variation during upturns.

2. *Recessions change the composition of exporters and importers.*

New, continuing and quitting exporters/importers tend to be smaller in size (labor force), but more productive during bad times than during good times. This suggests tougher selection both at entry and at exit.

3. *The entry selection mechanism gets tougher during bad times.*

We find a higher entry productivity threshold at bad times. This result is consistent with the view that new entrants during bad times must overcome the overall/general negative macroeconomic conditions.

4. *Persistent effects of macro conditions at birth.*

The results indicate that there are persistent differences (over export/import spells' lifetimes) in firm-level characteristics between exporters (importers) starting to export (import) at different stages of the business cycle.

Taken altogether, our results are consistent with the hypothesis on the cleansing effect of recessions given that both entry and exit productivity cutoff levels are higher during recessions. We further find evidence consistent with the existence of scarring effects of conditions at export/import entry. Therefore, our results points out the importance of accounting for inflow heterogeneity to better understand the dynamics of trade flows over the business cycle. In the next section, we explore how the state of the economy when firms start exporting and/or importing is associated with their the post-entry survival performance.

3. The hazard rate of exiting export/import markets

This section is devoted to examine the relationship between the business cycle and the hazard of leaving export/import markets, accounting for age-of-spell effects (i.e., duration dependence) and individual (observed and unobserved) heterogeneity. More specifically, we investigate whether and how the macro conditions at birth of spells (i.e., when firms start exporting and/or importing) is associated with their post-entry survival performance controlling for current business cycle conditions.

3.1. Empirical methodology

This section presents the empirical methods and includes a brief discussion of some identification issues. We use survival models that examine the association between risk factors and time-to-an event since the onset of the spell (i.e., duration until the end of a new firm-level export/import spell). Survival models depict some interesting features that make them suitable for our analysis. First, they account for whether and when an event takes place, so it allows controlling for both the evolution of hazard rate with spell age (i.e., duration dependence) and business cycle conditions. Second, these methods appropriately deal with right-censored observations, which arise when export/import spells are incomplete (i.e., spells that are ongoing at the end of the sample period). These methods use the information on the time of survival up to

the censoring point but do not make inference about the subsequent survival time of the spell. Third, the long-time span of our dataset allows us to examine a large number of new spells over time with a long follow-up period, which permits us to overcome some drawbacks of previous studies on trade and firm survival that examine a few cohorts over short follow-up periods after entry.²²

We proceed by estimating flexible semi-parametric survival models that allow us to uncover long-run effects of different stages of the business cycle, accounting for entry, exit and re-entry of export/import spells. Our empirical methodology permits us to disentangle the pattern of duration dependence, overall business cycle effects, and whether and how the general macro conditions at birth of export/import spells shape both the pattern of duration dependence and the relationship between spell characteristics and export survival. Furthermore, we also make an attempt to empirically disentangle the relative importance of genuine/"true" negative duration dependence and sorting (i.e., unobserved heterogeneity, such as managerial capabilities) in driving the observed (aggregate) duration dependence and to analyse whether the pattern of "true" duration dependence differs for spells born during an upswing and a downturn.²³

We apply survival models using both the *Full dataset* and the *Restricted dataset* described in Section 2.1. The unit of observation is an export/import flow by firm i in year t . From the annual data, we define a new firm-level export/import spell relying on the number of periods t (years) of consecutive exporting/importing activity (i.e., transactions) by a firm since it started or re-started to export/import (i.e., "fresh" export/import spell). Since the focus of this section lies on survival in export/import markets of new exporting/importing firms, a clear definition of when both entry and exit occur is required. A firm's export/import spell starts in year t (i.e., birth year t) if the firm did not export/import in year $t - 1$ but it does export/import in year t . Therefore, the information in 1997 is only used to identify new export/import spells in 1998. A spell ends in year t when the firm was engaged in exporting/importing in year t but not in year $t + 1$. Hence, information in year 2016 is only used to determine whether ongoing spells in year 2015 end in that year or are right-censored (i.e., they continue beyond 2015). The duration of a firm's export/import spell is defined as the number of consecutive years in which a firm is exporting (since it started).

In the survival analysis, we exclude left-censored spells (i.e., export/import spells that were running at the start of the sample period - initiated on or before 1997) given that we do not know their exact entry-date.²⁴ That is, we do not know whether the first observed year of the spell (start of sample period) is in fact the first year of the relationship or the trade relationship had begun in some prior year. If we overlook that, duration estimates would be biased. Therefore, we focus on "fresh spells" (i.e., those spells born from 1998 onwards). Yet, we will add a dummy variable to control for those trade relationships that existed in 1997.

Therefore, the *Full sample* consists of all firm-level export (import) spells initiated over the period 1998-2015 (i.e., population of "fresh spells"). The maximum length of a spell is eighteen

²²In such studies, the robustness of their results critically depends on the representativeness of the few cohorts considered. In this line, Audretsch (1991) points out that the determinants of entrants' survival crucially depend on the length of the follow-up period. Besides, Wagner (1994) underlines the need to investigate several entrant cohorts given that the year of birth of a particular cohort may be an important factor that shapes its survival fates.

²³The commonly observed (aggregate) negative duration dependence in exporting/importing can be related to either sorting or "true" age dependence. The former refers to the selection mechanism that leads to an over-representation of "fitter-to-survive" spells as a given cohort ages. The latter refers to an intrinsic fall in the hazard of leaving export/import markets with the spell's age, commonly related to sunk costs, learning, or success-breeds-success effects (Roberts and Tybout, 1997; Clerides et al., 1998; Rauch and Watson, 2003; Das et al., 2007; Albornoz et al., 2012; Albornoz et al., 2016).

²⁴Notice that the sample with export/import relationships in 1997 is left-truncated because we only observe those firm-level export/import spells born before 1997 that have survived long enough to be ongoing in 1997, therefore excluding high-risk export/import spells initiated before 1997.

years.²⁵ After cleansing the data, the dataset consists of 403,821 export spells (about 89.3% of them complete) that correspond to 307,498 firms leading to 994,199 (spell-year) observations. The number of import spells is 365,865 (about 86.05% of them complete) that correspond to 296,823 firms leading to 1,052,992 (spell-year) observations. Hence, the dataset includes sporadic, regular, as well as multi-spell exporters/importers.

The *Restricted sample* includes firm-level characteristics such as sales, value-added, TFP, employment, the primary industry, foreign ownership, etc. We exclude those firm-level export/import spells of micro firms (i.e., firms with less than 10 employees, which are not included in FICUS before 2008) or in distribution sectors in the first year of the spell. Regarding non left-censored export spells of which the first year observation can be matched with balance sheet data, the *Restricted sample* consists of 202,210 export spells (about 85.7% of them complete) that correspond to 157,027 firms leading to 485,652 (spell-year) observations between year 1998 and 2015. Regarding non left-censored import spells, the *Restricted sample* consists of 190,311 import spells (about 82.3% of them complete) that correspond to 156,485 firms leading to 498,661 (spell-year) observations between 1998 and 2015.

The non-parametric Kaplan-Meier estimates of the export/import survivor functions²⁶ confirm the commonly found pattern of aggregate negative duration/age dependence. That is, the hazard rate is very high immediately after entry, and it drops off quickly with the duration of the flow.

To analyze the relationship between business cycle conditions (both current and at birth) and the hazard of exiting export/import markets, we estimate the following discrete-time proportional hazards model specification with a non-parametric characterization of the frailty distribution.

$$h_{zt} = 1 - \exp \left(-\exp \left(m_z + \beta_{b0} bad_0 + \beta_b bad_t + \sum_{a=1}^{8+} \beta_a \mathbb{1}_{age\ a=t} + \beta_c controls_{i0} \right) \right) \quad (3)$$

where the dependent variable is the hazard rate, which is the probability of leaving export markets at a given duration/age conditional upon survival up to that age. t is current year and a is the value of age of the spell. Moreover, the model includes a discrete mixture distribution with finite support to summarize unobserved exporter/importer level heterogeneity. The distribution is characterized by two mass points m_z , where $z = 1, 2$ refers to mass points that characterized the two unobserved types.²⁷ We assume there exist 2 unobserved types. With probability $p1$, a spell belongs to type 1 with mass point value equal to $m1$. With probability $1 - p1$, a spell belongs to type 2 with mass point value equal to $m2$. $m1$ is normalized to 0. The unobserved heterogeneity (or frailty) parameter is assumed to be constant over time (across spells of the same firm) and independent of observed characteristics. It controls for both omitted variable bias (i.e., unobserved individual heterogeneity not fully accounted for after including the full set of explanatory variables) and measurement errors in observed survival times and regressors (Jenkins, 2005). The estimation of Equation (3) allows us both to mitigate the bias associated with overlooking unobserved heterogeneity and to disentangle the relative importance of genuine duration dependence and sorting in driving the observed (aggregate) duration dependence.

²⁵While the data source is comprehensive, our sample ends in 2015 for all export and import relationships, regardless of their starting time, which involves that the maximum potential age that individual spells can reach is different across cohorts. Whereas a spell initiated in 1998 can reach a maximum of 18 years of life, those initiated since 2008 can reach, at most, 8 years of service.

²⁶Not reported for brevity, but available from the authors upon request.

²⁷We follow a non-parametric frailty distribution (Heckman and Singer, 1984). The model is estimated using Stephen Jenkins' *hshaz* program (Jenkins, 1995).

Business cycle indicators There is an important concern related to the identification of the link between the business cycle conditions (both at-birth and current) and the hazard of leaving export/import markets. More specifically, in a survival model we cannot include annual cohort dummies and year effects to account for macro conditions at birth and current economic conditions at once. As discussed by Imbens and Angrist (1994), the identification of duration and calendar effects is problematic. Following Kalwij (2010), we use either binary indicators or continuous variables to account for business cycle effects and for conditions at birth effects to identify these time effects.²⁸

In the tables in the next sub-sections (i.e., tables 6,7 and 8) we use two different binary indicators to account for both current and at-birth macroeconomic conditions. First, as in previous sections and as included in equation (1), we use the dummy variable bad_0 that takes value 1 when the export/import spell was initiated in 2008, 2009, or 2010, and the dummy variable bad_t that takes value if the current year is either 2008, 2009, or 2010. That is, we exogenously capture the Great Recession period. Second, we also use a more sophisticated measure applied to the origin (i.e., France) and destination country to proxy both current and at-birth business cycle conditions. We create four dummy variables based on these countries' detrended GDP using HP filter following the Ravn-Uhlig rule. Thus, $birth\ bad\ fr$ ($birth\ bad\ des$) takes value one if France's (destination country's) detrended GDP is negative when the spell is initiated. Besides, $current\ bad\ fr$ ($current\ bad\ des$) takes value one if France's (destination country's) detrended GDP is negative in the current year.²⁹

Other control variables In all our estimations we control for age-of-spell effects as well as for a large set of control variables denoted by $controls_{i0}$, which include spell-specific (time-invariant) initial conditions other than business cycle and i represents an individual spell index.³⁰ Using the *Full sample*, $controls_{i0}$ includes trade-related (initial size of the spell, product comparative advantage, firm's previous export/import experience, whether the firm is a two-way trader, multi-product, multi-country exporter/importer) and main destination/sourcing country specific characteristics (OECD country risk; gravity controls) for export/import spells. Using the *Restricted sample*, we further control for additional firm-level characteristics (namely, a firm's TFP, age, labor force, wage per labor force, foreign-owned, foreign affiliate, sector, region).³¹

In the next section, we present our main results that allow us to investigate the association between macroeconomic conditions at birth of an export/import spell and its expected duration, accounting for overall risk associated with the current state of the economy. We estimate the hazard of exiting export, import, and jointly for export-import spells controlling for age-of-spell, business cycle and inflow heterogeneity (i.e., cohort) effects using frailty survival models. In all the specifications, our results point to the existence of unobserved heterogeneity given that we reject the null hypothesis that mass point 2 is equal to zero (i.e., equal to mass point 1 that is normalized to 0). All tables report the estimated hazard ratios ($exp(\beta)$). The reported coefficients indicate the effect on the hazard for a shift from 0 to 1 for a dummy variable or a one-unit increase in a continuous variable. Thus, a hazard ratio smaller (greater) than 1 indicates a reduction (increase) in the hazard and a longer (shorter) duration. A hazard ratio of 1 indicates that the corresponding covariate has no effect the baseline hazard. The percentage

²⁸Heckman and Robb (1985) also discuss potential solutions to the age-period-cohort effect identification problem in earning equations. They argue that one possibility is to group a sequence of adjacent years (e.g., recessive period) to proxy "cohort" effects and/or year effects.

²⁹As robustness checks, we further estimate several specifications of equation (3) using: a common dummy of bad macro conditions for origin and destination; several dummies distinguishing between origin and destination; and also continuous measures of current and at-birth macro conditions for origin and destination countries. Appendix D provides the main results using these alternative measures of business cycle.

³⁰The use of time-invariant covariates measured at the onset of the spells helps to mitigate the potential simultaneity problem between a firm's export/import status and the explanatory variables that may arise in survival analysis (Van den Berg, 2001).

³¹See Table 1b in Appendix A for detailed variable definitions.

change in the hazard produced by a change in a covariate by one unit (or from 0 to 1 for dummy variables) is obtained as $(\exp(\beta) - 1) \times 100$. We discuss our main results in turn.

3.2. Export duration: entry conditions and business cycle

In this section, we examine the link between the business cycle and the hazard of leaving export markets, accounting for duration dependence and individual heterogeneity. More specifically, we examine the role on these relationships of inflow heterogeneity or cohort effects, which refers to the variation over the business cycle in the composition of the new export spells with respect to their survival chances.

Table 6 presents the results obtained from the estimation of equation (3). Columns (1)-(4) report the results for firm-level export spells, while columns (5)-(8) display the results for firm-country export spells. In the former, we consider the main product and main destination characteristics (including business cycle indicators) at the time of starting exporting. The firm-country level analysis allows us to consider product and country characteristics specific to the firm-country spell. As discussed in previous section, we use two different binary indicators to account for both current and at-birth business cycle conditions: a common dummy for the years 2008-2009-2010 and a origin and destination specific GDP-related dummy. Moreover, we carry out the analysis for the population of export spells using customs data (*Full sample*) and the sample resulting from merging customs data with FICUS data (*Restricted sample*), which allows using a larger set of control variables in our analysis.³²

The estimates for *current bad* and *birth bad* constitute our main results and uncover the differential effect on survival of current macroeconomic conditions and macroeconomic conditions at birth of new firm-level export spells. On the one hand, general macroeconomic conditions of the economy (i.e., business cycle effects) are driven by aggregate demand and supply shocks that are common to all exporters in a particular year and lead to a higher risk of failure of all ongoing export spells. On the other hand, new exporters may be especially affected by business cycle conditions at entry, which may lead to tougher selection-at-entry mechanisms shaping the entry decisions of potential entrants and their subsequent survival probability after entry.

The results from our preferred specification are reported in column (2) given that it provides results for firm-level export spells using our binary indicators for the Great Recession (current, *current2008_2010*; and at-birth, *birth2008_2010*) and the *Restricted sample*, which includes a larger set of control variables.³³

Failing to control for the heterogeneous effects of these business cycle conditions (i.e., current vs. at-birth general economic conditions) would result in a mixing up of their effects. When we disentangle the role of these two factors, some interesting results stand out. First, the risk of failure, that is, the risk of leaving export markets is significantly higher during downturns, once we control for age-of-spell effects, and unobserved heterogeneity. More specifically, the results in the first two columns indicate that the overall hazard rate during recessions is about 20.4-21.0% higher than the overall risk during upturns. Second, firms that begin to export during bad times endure better survival prospects, *ceteris paribus*, than those faced by new exporters at good times. In particular, the cohorts of new exporters during recessionary periods endure a 9.8-10.7% lower hazard of leaving export markets, once we control for age-effects, as well as for observed and unobserved heterogeneity. Rather importantly, our results are robust across the

³²For brevity, in the tables included in the main text (i.e., Tables 6, 7, 8), we only report the estimates of the main coefficients of interests. Tables with the full results are in Appendix C. See Section 2.1 for the definition of *Full sample* and *Restricted sample*.

³³We have also estimated all the specifications for export and import transitions using random effects logit models and the results are fully consistent to those reported in Tables 6 and 7. Not reported for brevity, but available from the authors upon request.

different specifications of Table 6 to: the use of our *Full sample* or *Restricted sample*; whether we consider firm-level or firm-country export spells; the use of more sophisticated measures of the business cycle; and, the use alternative business cycle indicators (for instance, the results of *Birth2008_10* are still robust when we use year dummies instead of *current2008_10* to control for current macroeconomic conditions).

| | Firm level | | | | Firm country level | | | |
|-----------------|------------|------------|--------------------------|------------|--------------------|------------|--------------------------|------------|
| | 2008_10 | | Binary: detrended GDP <0 | | 2008_10 | | Binary: detrended GDP <0 | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | | | 1.022 | 1.024 | | | 1.028 | 1.019 |
| | 1.204 | 1.210 | (0.006)*** | (0.009)*** | 1.220 | 1.185 | (0.002)*** | (0.003)*** |
| current bad des | (0.009)*** | (0.014)*** | 1.022 | 1.019 | (0.003)*** | (0.004)*** | 1.010 | 1.014 |
| | | | (0.006)*** | (0.009)** | | | (0.002)*** | (0.003)*** |
| birth bad fr | | | 0.974 | 0.963 | | | 0.978 | 0.981 |
| | 0.893 | 0.902 | (0.006)*** | (0.010)*** | 0.893 | 0.930 | (0.002)*** | (0.003)*** |
| birth bad des | (0.008)*** | (0.012)*** | 0.955 | 0.963 | (0.003)*** | (0.004)*** | 0.949 | 0.943 |
| | | | (0.006)*** | (0.010)*** | | | (0.002)*** | (0.003)*** |
| N | 994199 | 386267 | 910753 | 354616 | 5834330 | 3503367 | 5514500 | 3338078 |

Note: Sample coverage is between 1998 and 2015. *birth2008_10* = 1 if export spells started in year 2008, 2009 or 2010. *current2008_10* = 1 if current year is 2008, 2009 or 2010. *current bad fr*, *current bad des*, *birth bad fr*, *birth bad des* take value 1 when the current or at-birth detrended GDP is negative for France or the destination country. The number of observations is smaller in the specifications of detrended GDP because, for some country-years, GDP data is missing. Left-censored spells are excluded. See appendix A for the definition of all the covariates. * p<0.10, ** p<.05, *** p<.01

Table 6: Hazard of exiting export markets

Moreover, Table 6 also provides some interesting insights about the relationship between the explanatory variables and export survival.³⁴ The initial size of the spell, as well as the number of products and destination markets are negatively related with the hazard rate of leaving export markets. Experience in international markets, acquired either through simultaneous involvement in import activities, or by having exported previously also are positively related with survival. Several features of destination markets also matter for survival. Export spells initiated with neighboring countries are expected to be shorter. In particular, starting to export to high-risk countries is positively related with the risk of ending an export spell. Finally, exporting a product for which France holds comparative advantage is positively associated with survival.

In addition, our results confirm the existence of aggregate negative duration dependence or negative age-effects. That is, as a cohort ages, the hazard rate falls. Yet, as previously discussed, this result may arise from two different mechanisms that have different important implications. First, it could arise due to a dynamic selection mechanism (i.e., sorting) that as a cohort ages leaves a disproportionately large share of those spells that are intrinsically fitter to survive (due to factors not observed by the researcher) as the more "frail" spells are cleaned off. The second mechanism is related to a true feature of the process at work. That is, there may be factors leading to improve the survival prospects of exporters as they accumulate experience ("learning by exporting" or "success-breeds-success" effects), due to the presence of sunk entry costs that become exit barriers when re-entry is a possibility (Roberts and Tybout, 1997; Clerides et al., 1998; Rauch and Watson, 2003; Alborno et al., 2012; Alborno et al., 2016; Araujo et al., 2016). Following Kalwij (2010), we make an attempt to disentangle the relative importance of individual genuine duration dependence and sorting in driving the observed negative duration dependence. Our results suggest that 2/3 of the observed negative duration dependence is related to "true" age-dependence (1/3 due to unobserved heterogeneity) using the *Full sample*. See appendix E for more details.

Finally, we further explore whether the observed pattern of "true" negative age dependence

³⁴Notice that the association between the explanatory variables and the hazard of leaving export markets remain almost unchanged throughout the different specifications estimated as robustness checks (see Appendix D).

differs across cohorts born under different business cycle conditions. That is, we investigate whether in addition to having a direct association with export survival, birth-during-downturn also has an indirect effect by shaping the pattern of genuine duration dependence. We do so by interacting the inflow-heterogeneity dummy with the age-of-spell dummies. Our preliminary findings suggest that there are no significant differences in how this mechanism operates across cohorts of exporters born under different macroeconomic conditions. This is an interesting finding given that it suggests that the better survival prospects of cohorts of exporters born at bad times consist of a one-off fall in the hazard without affecting the pattern of "true" negative age-dependence (i.e., it would be an intercept effect with little impact on the slope of the hazard over a spell's lifetime).

3.3. Import duration: entry conditions and business cycle

In this section, we examine the hazard of exiting import relationships. The variable *current bad* captures the common risk of leaving an export market that all ongoing spells endure at recessionary periods. The variable *birth bad* tries to capture the role of conditions at birth of import relationships for subsequent survival of these relationships. More specifically, we wish to assess if import spells initiated during downturns are intrinsically fitter to survive than those born in good times.

| | Firm level | | | | Firm country level | | | |
|-----------------|---------------------|---------------------|--------------------------|---------------------|---------------------|---------------------|--------------------------|---------------------|
| | 2008_10 | | Binary: detrended GDP <0 | | 2008_10 | | Binary: detrended GDP <0 | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | | | 0.995 (0.006) | 1.014 (0.010) | | | 1.023 (0.003)*** | 1.023 (0.004)*** |
| current bad des | 1.241 (0.008)*** | 1.272 (0.015)*** | 1.015 (0.006)** | 1.02 (0.010)** | 1.249 (0.004)*** | 1.249 (0.006)*** | 0.998 (0.003) | 1.005 (0.004) |
| birth bad fr | | | 0.946 (0.007)*** | 0.945 (0.012)*** | | | 0.975 (0.003)*** | 0.997 (0.005) |
| birth bad des | 0.991 (0.009) | 0.952 (0.013)*** | 0.967 (0.007)*** | 0.961 (0.012)*** | 0.944 (0.004)*** | 0.955 (0.005)*** | 0.951 (0.003)*** | 0.950 (0.004)*** |
| N | 1052992 | 387117 | 958019 | 352174 | 4530367 | 2324943 | 4117952 | 2124759 |

Note: Sample coverage is between 1998 and 2015. *birth2008_10* = 1 if export spells started in year 2008, 2009 or 2010. *current bad fr*, *current bad des*, *birth bad fr*, *birth bad des* take value 1 when the current or at-birth detrended GDP is negative for France or the destination country. The number of observations is smaller in the specifications of detrended GDP because, for some country-years, GDP data is missing. Left-censored spells are excluded. See appendix A for the definition of all the covariates. * p<0.10, ** p<.05, *** p<.01

Table 7: Hazard of exiting import markets

The structure of Table 7 is the same as that of Table 6. It displays the results for firm-level and firm-country level import spells, using a Great Recession dummy common to all countries and a binary indicator based on detrended GDP for France and the destination country, and for the *Full sample* and *Restricted sample*.

The results indicate that bad current conditions increase the hazard of ending import relationships. Once we account for this overall higher failure rate, new import (both at firm- and firm-country level) face a significant lower hazard. In this case, we find some non-significant coefficients, but no estimate goes against these results.³⁵

Finally, we make an attempt to disentangle the relative importance of genuine/"true" duration dependence and sorting in driving the observed aggregate negative duration dependence. For imports, we find that unobserved heterogeneity accounts for 1/2 of the observed aggregated

³⁵The results of *birth2008_10* are still robust when we use year dummies instead of *current2008_10* to proxy current macroeconomic conditions. In addition, we provide additional robustness checks using alternative business cycle indicators in Appendix D. The results are broadly consistent with those reported in Table 7.

negative duration dependence using the *Full sample*. The latter may help explain why our results for imports are less accurate and it might suggest that there may be some important variables to understand import survival that are not fully accounted for in our specification. See appendix E for more details.

We further check whether inflow heterogeneity, that is, cohort effects associated with the different macroeconomic conditions at entry, shapes both the pattern and the relative importance of these two sources of duration dependence. After controlling for frailty, there exists negative age-dependence for cohorts born at good times while the negative age-dependence is slightly weaker for cohorts born at bad times.

3.4. Bivariate duration

This section analyzes the dependence of the exit from export and import on the length of time in an export or import spell and on other explanatory variables through the estimation of bivariate duration model. That is, we jointly estimate the hazard of leaving export and import markets. In this section, we account for unobserved firm-specific factors (constant across both spells and the transitions considered, i.e., exporting and importing) that affect the hazard of an event for all spells and transitions (e.g., managerial capabilities of firms not captured by the included explanatory variables). In this setting, we allow for correlation between time-invariant factors that influence each transition.

We briefly sketch out the methodology in next subsection.

3.4.1. A multilevel two-state logit model

At any time t , a firm i may be in one of the two states indexed by s ($s = \text{exporting}$, importing), and S_{tji} denotes the state occupied by firm i during interval t of episode j (i.e., firms may show more than one export and/or import spell). We estimate the probability that a firm exits from exporting or importing during period t , given that it has been either exporting or importing for $t-1$ previous periods. Since we have yearly information, we treat duration as a discrete variable and estimate a bivariate discrete-time duration model. Let us define y_{tji} as a binary variable indicating whether any transition (i.e., an exit from the spell of exporting or importing) has occurred during interval t . The discrete-time hazard function for state s , that is, the probability of a transition from state s during interval t , given that no transition has occurred before the start of t , is defined as follows:

$$h_{stji} = Pr(y_{tji} = 1 | y_{t-1,j,i} = 0, S_{tji} = s), \quad s = \text{exporting}(EXP), \text{importing}(IMP) \quad (4)$$

We estimate the following multilevel two-state logit model:

$$\log \left(\frac{h_{stji}}{1 - h_{stji}} \right) = \alpha_s D_{stji} + \beta_s X_{stji} + u_{si} \quad (5)$$

where D_{stji} is a vector of dummy variables that capture the age effects of a specific spell in state s by firm i . In particular, we report models in which D_{stji} includes eight dummy variables to control for age-of-spell effects as in the previous section. X_{stji} is the vector of explanatory variables that affects the transition from state s .

Finally, u_{si} allows for unobserved heterogeneity between firms in their probability of exiting from state s . There may exist unobserved firm-specific factors (constant across both episodes and states) that affect the hazard of an event for all episodes and states (e.g., firm managerial skills

not captured by the included explanatory variables). We assume that $u_{si} = (u_{EXPi}, u_{IMPi})$ follows a bivariate normal distribution, which allows for correlation between time-invariant factors that influence each transition.

While in Section 3.2 and 3.3 we implicitly assumed that the two transitions (i.e., exiting export and import markets) are independent, in this section we estimate the equations for the two transitions jointly. That is, we allow for $cov(u_{EXPj}, u_{IMPj}) \neq 0$, given that the firms move in and out of different states over time. We model a firm's exit from exporting jointly with exiting from importing using a two-state duration model. The state-specific unobserved heterogeneity components of these transition processes are allowed to be correlated across the two states. There may be time-invariant individual-specific unobservable factors that affect each type of transition. This correlation may be either positive or negative. On the one hand, if this correlation is positive, firms with a high (low) likelihood of exiting exporting may also have a high (low) hazard of exiting importing, that is, a tendency toward either long episodes of exporting and importing or short export and import spells. This would correspond to a positive random effect correlation, which splits firms into the following two groups: (i) firms with short export and import spells; and (ii) firms with long export and import spells. On the other hand, when the correlation between the two transitions is negative, firms with a high (low) likelihood of exiting export markets may have a low (high) hazard of leaving importing. That would lead to two groups of firms: (i) firms with short export spells but long import spells; and (ii) firms with long export spells, but short import spells.

In next section, we present the results when we jointly estimate two equations as follows: (i) the hazard of exiting export markets and (ii) the hazard of exiting import markets. Both equations include a firm-level random effect. We estimate it as a bivariate model.

3.4.2. Results

Our results indicate that the two processes are positively correlated. This suggests that we can split firms into two groups. Firms experiencing both long episodes of exporting and importing, and firms more prone to experience short spells of both exporting and importing (i.e., high churn).

Our findings are confirmed when we carry out the estimation for firm-country export and import spells (columns (2) and (4) of Table 8). In this case, we account for unobserved firm-specific factors (constant across both spells and the transitions considered), and allow for correlation between time-invariant factors that influence each transition.³⁶

³⁶For computational reasons, we cannot use firm-country random effects in the bivariate estimation for firm-country spells when using the restricted sample.

| | firm level | | | | firm country level | | | |
|-----------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | Full | | Restricted | | Full | | Restricted | |
| | export | import | export | import | export | import | export | import |
| <i>current2008_10</i> | 1.272 (0.011)*** | 1.363 (0.011)*** | 1.283 (0.017)*** | 1.386 (0.018)*** | 1.298 (0.004)*** | 1.354 (0.005)*** | 1.228 (0.005)*** | 1.293 (0.006)*** |
| <i>birth2008_10</i> | 0.861 (0.009)*** | 0.988 (0.010) | 0.881 (0.014)*** | 0.951 (0.016)*** | 0.873 (0.004)*** | 0.940 (0.004)*** | 0.904 (0.004)*** | 0.939 (0.005)*** |
| cov(ex,im) | 2.165 (0.024)*** | | 1.880 (0.030)*** | | 1.665 (0.009)*** | | 1.370 (0.005)*** | |
| N | 2047191 | | 773384 | | 10364697 | | 5828310 | |

Note: Sample coverage is 1998 to 2015. *birth2008_10* = 1 if export spells started in year 2008, 2009 or 2010. *current2008_10* = 1 if the current year is 2008, 2009 or 2010. Firm-level/firm-country level results are obtained using firm-level/firm-country-level random effects except for the firm-country-level restricted sample. We use firm-level random effects for the firm-country-level restricted sample as there is an issue of lack of memory. Left-censored spells are excluded. See appendix A for the definition of all the covariates.

* $p < 0.10$, ** $p < .05$, *** $p < .01$

Table 8: Hazard of exiting export and import markets - joint estimation

Interestingly, our main results are broadly consistent with those obtained in sections 3.2 and 3.3. Some interesting findings stand out. First, during recessionary periods, the overall hazard of leaving export and import markets is significantly higher than during expansionary periods. More specifically, for the firm-level analysis, we find that the higher risk is about 27.2-28.3% and 36.3-38.6% for exports and imports, respectively. Second, conditions at birth matter and have long-lasting effects. Firms that start exporting at bad times face a 11.9-13.9% lower hazard of leaving export markets, while those firms that start importing during recessionary periods also seem to endure a lower hazard (between 1.2-4.9% lower, yet not statistically significant when we use our *Full sample*). The results obtained from the firm-country level analysis clearly support these findings.

3.5. Summary of results

To sum up, this section has uncovered the following results:

1. *The exporters' (importers') hazard rate of exiting foreign markets is higher at bad times [overall business cycle effects].*

2. *The (Export/Import) new spells born during recessions face a lower hazard of exiting export/import markets than those initiated during good times over their lifetime [cohort effect].*

That is, exporters/importers born during bad times survive longer than those born during good times. That is, conditions at entry have long-lasting effects on expected duration (i.e., scarring effects).

Therefore, new exporters that are born during downturn have an intrinsically lower hazard of exiting export markets, despite the (overall) higher hazard rate during bad times. The evidence on new importers is less compelling.

3. *The hazard rate is high at entry and drops off quickly with the spell's age for cohorts born at good and bad times [aggregate negative duration dependence].*

4. *Approximately 2/3 (1/2) of aggregate negative age dependence in exports (imports) is related to "true" age dependence, and 1/3 (1/2) is related to sorting.*

For export spells, there are no significant differences in the pattern of "true" negative age dependence (the hazard of quitting exporting falls with ongoing experience) between cohorts born at good times and cohorts born at bad times. We find a one-off fall in the hazard of leaving exporting for spells initiated at bad times, with no additional effect on the slope of the

hazard over a spell's lifetime. For import spells, there are some differences in the pattern of "true" negative age dependence between cohorts born at good times and cohorts born at bad times.

5. *The bivariate duration model allows us to identify two groups of firms according to the expected duration of their export and import spells: either long-long or short-short.*

The results of the estimations of a bivariate duration model are broadly consistent with our results from the separate analysis of the hazard of exporting and importing. During recessionary periods, the overall macroeconomic conditions raise the overall risk of failure, although new export/import spells initiated during these difficult times are intrinsically "fitter-to-survive" compared to those born at expansionary periods. Yet, the positive and statistically significant covariance suggests a positive firm-level association in the duration of export and import episodes. Hence, firms can be split into two types, such that firms' export and import duration tend to be either long-long or short-short.

This results adds to the previously found complementarity in export and import participation (Kasahara and Lapham, 2013; Bernard et al., 2018). Our results point towards strong positive complementary effects in export/import duration.

4. Discussion of results

The findings of this paper support the view that export/import spells born at bad times face tougher entry conditions (associated with an overall higher risk of failure during recessions). That is, the selection mechanism at entry is tougher, so that only "stronger/fitter to survive" initiate export/import relations during bad times.

Confronting our results to existing models of firm trade dynamics and firm dynamics and business cycles some interesting insights stand out. First, we find less entry and more exit during bad times (i.e., entry rates are pro-cyclical and exit rates are counter-cyclical). This finding fits well the cleansing hypothesis (Caballero and Hammour, 1994). Moreover, the higher entry productivity (also higher exit productivity) cutoff point suggests a tightening of market conditions during recessionary periods. Our regression analysis further confirms an overall higher risk of ending ongoing trade relationships during bad times. However, we find that cohorts of new exporters/importers born during recessionary periods endure better survival prospects. These findings are compatible with studies that point out the existence of scarring effects of recessions (Ouyang, 2009; Moreira, 2016; Sedlacek and Sterk, 2017; Vardishvili, 2022), particularly during financial crisis which may have hindered the entry of new (small) entrants given that they tend to be more financially constrained (Foster et al., 2016; Ayres and Raveendranathan, 2021).

Second, our results (both for exports and imports) are compatible with the mechanisms emphasized by Vardishvili (2022). The overall risk of failure is higher during bad times and even dominates the cohort effect (e.g., in col. 2 of Table 6 and 7, 1.210 is larger than 0.902 and 1.272 is larger than 0.952 for exports and imports, respectively), but export/import relationships initiated by firms during recessionary periods are intrinsically fitter-to-survive than those born during expansionary periods, that is, they face a (persistent) lower hazard rate given that they are likely to face harsher entry conditions. Hence, the entry selection-into exporting/importing gets tougher. In her model, entrants are stronger due to the existence of an option value to wait (i.e., value of delay) to enter during recessions. In fact, Vardishvili (2022) points out an asymmetry between potential entrants and incumbent exporters/importers at bad times. First, the worsening of overall economic conditions has a negative effect on the net present value of flow profits for all firms (incumbent exporters/importers and potential entrants), labeled as *direct effect*. Second, an *indirect effect* arises as firms making a decision on whether or not to start

exporting or importing have a value of delay during bad general conditions so that only the best firms decide to start an export/import spell, increasing the inaction zone for intermediate (productive) firms. These predictions are fully compatible with our results in section 2 and section 3. On the one hand, in the former section, we found an increase to the productivity cutoff points for entrants and exiters during bad periods. The recessionary period may have led to a stronger self-selection into export leading to fitter-to-survive new exporters, which is in line with the predictions in the firm export dynamics literature (e.g., Manova, 2013; Impullitti et al., 2013; and Chaney, 2016). On the other hand, we also find persistent effects of entry conditions at birth in section 2, and especially in section 3 we obtain that new export/import spells born at bad times have better survival prospects than those born at good times. Therefore, we confirm the existence of scarring effects of recession on trade dynamics, which is consistent with previous studies (Ouyang, 2009; Moreira, 2016; Sedlacek and Sterk, 2017; Vardishvili, 2022).

However, our findings are at odds with the models of sunk entry costs to export/import (Roberts and Tybout, 1997; Melitz, 2003; Impullitti et al., 2013). Likewise, our results do not provide support to the predictions of studies that point towards asymmetric sunk entry costs that are higher during recessions (Bilbiie et al., 2012; Clementi and Palazzo, 2016; Lee and Mukoyama, 2018; Alessandria and Choi, 2019). As long as sunk entry costs depreciate shortly after, these models would lead to expect less entry but also less exit after entry, leading to less churning during bad times (vs good times). In addition, our results do not provide support to the predictions in Ayres and Raveendranathan (2021) model of firm dynamics with procyclical profit flows and financial constraints hindering capital accumulation of new entrants. They expect less entry and more exit in bad times, but they expect exit to be disproportionately concentrated among potential entrants and young firms.

Furthermore, and rather interestingly, our results suggest that after entry, for exporters, the “true” negative age dependence effects operate similarly independently of the macro-conditions at birth while they are different for importers. Hence, our findings (especially for exports) fit well with the models that point towards learning effects to explain genuine negative duration through the accumulation of ongoing experience in foreign markets (Clerides et al., 1998; Albornoz et al., 2012; Albornoz et al., 2016).

5. Conclusions

This paper examines the relationship between the business cycle and the firms’ export/import survival, accounting for duration dependence, individual heterogeneity and inflow heterogeneity (i.e., cohort effects).

Our findings confirm that recessionary periods have important and long-lasting effects for aggregate trade. In contrast to most previous studies that have analyzed these periods through the lens of the intensive margin, we focus on the extensive margin. We argue that our approach adds new insights that are relevant to get a better understanding of aggregate trade dynamics over long periods.

More specifically, our results confirm that recessions change the composition of exporters/importers. These recessionary periods trigger cleansing effects through the rise in entry to and exit from foreign markets productivity cutoffs. The worsening of overall economic conditions may lead to tougher selection at entry. Thus, entrants (i.e., firms starting to export and/or import) during recessionary periods tend to be more productive than entrants during expansionary periods, despite the fact that they may be smaller due to weaker demand conditions or capital accumulation constraints, and remain so over long periods after entry. Thus, the composition of exporters and importers changes over the business cycle. The average quality of the pool of entrants to

exporting/importing is found to be counter-cyclical. Hence, recessions have permanent effects on trade dynamics through the extensive margin. The estimation of frailty duration models confirms that conditions at entry are relevant and have persistent effects. In particular, we find that firms that start to export/import during recessionary periods fare better survival prospects than their counterparts born during expansionary periods, despite the overall higher risk at bad times. Moreover, our results suggest that the better survival prospects of cohorts born at bad times result from a one-off drop in the hazard of leaving export markets for all spell ages. The results are less compelling on the import side.

Rather tentatively, we discuss two main policy implications of our findings. First, if entry selection is *excessively* strong at bad times, there may be some potential export(import) relationships that cannot be created when they should be. This may be particularly true in the event of financial crises given that new export/import spells are disproportionately smaller and tend to be more financially constrained (regardless of their productivity). This could hinder the relevance of traditional reallocation mechanisms based on market fundamentals (productivity, demand and costs). Thus, unexpected shocks may hamper the development of potentially superior import/export new projects. Therefore, while in the event of "productivity-driven" cleansing, counter-cyclical policies may hinder economic growth, in presence of "counter-productive" cleansing, counter-cyclical policies may be particularly relevant during recessions, especially due to the long-run implications of the extensive margin of trade. In the latter case, young exporters (or export-country spells) should be supported because they may be intrinsically good, but they may either die young or grow old but never become large due to the persistent effects of the aggregate conditions at birth (e.g., Moreira, 2016; Sedlacek and Sterk, 2017 in the case of firm dynamics). This is particularly important in presence of "true" negative duration dependence and during recessionary periods, especially if the latter are brought about by sudden, unexpected and transitory negative shocks (e.g., credit crunch; COVID-19), that depart from traditional "efficiency/productivity-enhancing cleansing" associated with recessionary periods. In this setting, there may arise an argument for short-lived support for new potential exporters/importers during downturns.

Therefore, our marginal contribution is the need of policy measures related to the business cycle. We tentatively argue that subsidies should be related to business cycle. When shocks are orthogonal to productivity, then there is scope for subsidies because exit is less informative on firm's efficiency than in normal times. Moreover, our finding that the impact of recessions on new entrants is a one-off fall in the hazard of exiting foreign markets (especially for exports) without altering the pattern of "true"/genuine negative duration dependence also provides support for the use of age-dependent subsidies to help young firms and/or export spells to overcome the early high exit risk as proposed by Arkolakis, Papageorgiou, and Timoshenko (2018).

Another policy implication of our results from the bivariate duration estimation is related to the existence of two types of firms according to their expected export and import duration: either short-short or long-long. Therefore, from a policy standpoint, it may be interesting to make an effort to identify those firms' characteristics that make firms more likely to "belong" to either group. The short import/export spells are related to more churn and foreign experimentation, which may be more related to certain firm and/or product, or even market characteristics. Likewise, firms characterized by long export/import spells involve persistent trade relationships associated with specific firm-, product-, and/or destination market-level characteristics.

Finally, We plan to extend the analysis along several dimensions. First, we want to carefully explore the case of two-way traders. For these firms, the business cycle of the import source country can affect export survival and vice versa. Second, we aim to further explore the product-country dimension. So far, we have primarily focused on the export/import decisions at the firm level looking at characteristics at the time of firm-level entry, while there may be important considerations related to the product and country dimensions. By doing so, we could better

control for co-movement of economic conditions between France and the destination/source country to explain export/import survival. Third, we will further consider the inclusion of lead and lags on business cycle indicators to account for anticipation and lagged effects on export/import decisions.

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Appendix

A. Variable definitions and descriptive statistics

A.1. Variable definitions

| business cycle indicators | |
|----------------------------------|--|
| bad dummy | |
| birth2008_10 | =1 if export/import spells started in 2008, 2009 or 2010 |
| current2008_10 | =1 if current year is 2008, 2009 or 2010 |
| birth2008_15 | =1 if export/import spells started between 2008 and 2015 |
| current2008_15 | =1 if current year is between 2008 and 2015 |
| b_dgdp0_fr | =1 if France detrended GDP < 0 at age 1 |
| b_dgdp0_d | =1 if main destination detrended GDP < 0 at age 1 |
| b_dgdpt_fr | =1 if France detrended GDP < 0 in the current year |
| b_dgdpt_d | =1 if main destination detrended GDP < 0 in the current year |
| bad0_fr | =1 if (France GDP growth - world GDP growth) at birth < mean (France GDP growth - world GDP growth) between 1998 and 2015 |
| bad0_d | =1 if (main destination GDP growth - world GDP growth) at birth < mean (main destination GDP growth - world GDP growth) between 1998 and 2015 |
| badt_fr | =1 if (France GDP growth - world GDP growth) in current year < mean (France GDP growth - world GDP growth) between 1998 and 2015 |
| badt_d | =1 if (main destination GDP growth - world GDP growth) in current year < mean (main destination GDP growth - world GDP growth) between 1998 and 2015 |
| continuous | |
| ln_tfp0_fr | ln(France TFP) at age 1 |
| ln_tfp0_d | ln(main destination TFP) at age 1 |
| ln_tfp_t_fr | ln(France TFP) in current year |
| ln_tfp_t_d | ln(main destination TFP) in current year |
| ln_gdp0_fr | ln(France GDP) at age 1 |
| ln_gdp0_d | ln(main destination GDP) at age 1 |
| ln_gdp_t_fr | ln(France GDP) in current year |
| ln_gdp_t_d | ln(main destination GDP) in current year |
| diff0_fr | France GDP growth - world GDP growth at age 1 |
| diff0_d | main destination GDP growth - world GDP growth at age 1 |
| diff_t_fr | France GDP growth - world GDP growth in current year |
| diff_t_d | main destination GDP growth - world GDP growth in current year |

Note: For import spells, main destination refers to main sourcing country. Main destination(sourcing country) is the one with the highest export(import) value at age 1 and it's unvarying within export(import) spell. GDP price is at 2015 level (billion dollars). Detrended GDP is obtained using HP filter following the Ravn-Uhlig rule and a sample between 1998 and 2015. GDP growth is obtained from the World Bank data. Country-level TFP is obtained from Penn World Table and TFP is at constant national prices (2017=1).

Table 1a: Business cycle indicators: at-birth and current

| age dummies | |
|---|---|
| age1 - age7 | year 1 - year 7 of a spell |
| age 8 | year 8 or after |
| trade related characteristics | |
| initial size | initial export/import value at age 1. We define three binary variables by terciles (dini1, dini2, dini3) |
| comparative advantage | comparative advantage quantile (tierce) of France product (main product at age 1) dpto1, dpto2, dpto3 |
| dimp | = 1 if import at age 1 for export spell |
| dexp | = 1 if export at age 1 for import spell |
| d_lc1997_fpc_ex | = 1 if firm exported in year 1997 (export left censored) |
| d_lc1997_fpc_im | = 1 if firm import in year 1997 (import left censored) |
| lnpre_ex_exp | ln(firm previous export experience at age 1 + 1) |
| lnpre_im_exp | ln(firm previous import experience at age 1 + 1) |
| n_pre_spell_ex | number of previous completed export spells at age 1 |
| n_pre_spell_im | number of previous completed import spells at age 1 |
| repeated_spell | if the current spell is a repeated spell within a firm |
| gap_spell | number of year gap between the current spell and the last spell |
| r_lngap_spell | repeated_spell * ln(gap_spell) |
| dpto | = 1 if multiple products at age 1 |
| dcou | = 1 if multiple destinations at age 1 |
| main destination characteristics | |
| country risk | 1 high risk(dcou1), 2 medium risk(dcou2) and 3 low risk(dcou3) (main destination at age 1) based on OECD country risk classification |
| border | = 1 if main destination at age 1 shares border with France |
| french | = 1 if language of main destination at age 1 is french |
| eu.eea | = 1 if main destination at age 1 in EU/EEA |
| euro | = 1 if main destination at age 1 in euro |
| firm characteristics | |
| lnTFP | ln(TFP) at age 1 |
| ln(age+1) | ln(firm age) = ln(current year - firm creation year +1) at age 1 |
| lnL | ln(labor force) at age 1 |
| lnwpL | ln(wage per labor force) at age 1 |
| FO | owned by foreign at age 1 |
| FA | have foreign affiliate at age 1 |
| nace | 1-digit NACE sector at age 1 |
| region | geographic region at age 1 |

Note: For import spells, destination means sourcing country. Trade related characteristics, main destination characteristics and firm characteristics refer to characteristics at age 1 for each export/import spell. For export(import) spells, initial value is firm export(import) value at age 1. Quantile (tierce) is taken among all age 1 observations including left-censored spells. Main product/destination/sourcing country is determined based on value. *dimp*(*dexp*) is export(import) spell specific covariate. Previous export(import) experience is the number of years of exporting(importing) from 1997. *gap_spell* is not included as a covariate. There are 17 sectors which include Agriculture, Fishing, Mining, Manufacturing, Energy and Water, Construction, Trade, Tourism, Transportation and Communication, Finance, Real Estate and Prof. Activities, Government, Education, Health, Other Services, Household Services and Nonresident. There are 15 regions which include Auvergne-Rhône-Alpes, Bourgogne-Franche-Comté, Bretagne, Centre-Val de Loire, Grand Est, Hauts-de-France, Île-de-France, Normandie, Nouvelle-Aquitaine, Occitanie, Pays de la Loire, Provence-Alpes-Côte d'Azur, Département 20, Département 97, Département 99.

Table 1b: Definition of covariates (for persistent effects and survival analysis at the firm level)

| age dummies | |
|---|---|
| age1 - age7 | year 1 - year 7 of a spell |
| age 8 | year 8 or after |
| firm-country level control (large and restricted sample) | |
| initial size | initial export/import value at age 1. We define three binary variables by terciles (dini1, dini2, dini3) |
| dpto1, dpto2, dpto3 | comparative advantage tierce of France product (f.cou level main product at age 1) |
| dcou1, dcou2, dcou3 | 1 high risk, 2 medium risk and 3 low risk at age 1 |
| dimp | = 1 if import from the same country at age 1 for export spell |
| dexp | = 1 if export in the same country at age 1 for import spell |
| d_lc1997_ex | = 1 if firm-country exported in year 1997 (export spell left censored) |
| d_lc1997_im | = 1 if firm-country imported in year 1997 (import spell left censored) |
| lnpre_ex_exp | ln(firm-country previous export experience at age 1 + 1) |
| lnpre_im_exp | ln(firm-country previous import experience at age 1 + 1) |
| n_pre_spell_ex | number of previous completed export spells in a given country at age 1 |
| n_pre_spell_im | number of previous completed import spells in a given country at age 1 |
| repeated_spell | if the current spell is a repeated spell within a firm-country |
| gap_spell | number of year gap between the current spell and the last spell |
| r_lngap_spell | repeated_spell * ln(gap_spell) |
| dpto | = 1 if multiple products in a country at age 1 |
| border | = 1 if country at age 1 shares border with France |
| french | = 1 if language of country at age 1 is french |
| eu_eea | = 1 if country at age 1 in EU/EEA |
| euro | = 1 if country at age 1 in euro |
| firm level control (large and restricted sample) | |
| dini1, dini2, dini3 | initial value quantile (terce) at age 1 |
| dimp | = 1 if import at age 1 for export spell |
| dexp | = 1 if export at age 1 for import spell |
| d_lc1997_ex | = 1 if firm exported in year 1997 (export spell left censored) |
| d_lc1997_im | = 1 if firm imported in year 1997 (import spell left censored) |
| lnpre_ex_exp | ln(firm previous export experience at age 1 + 1) |
| lnpre_im_exp | ln(firm previous import experience at age 1 + 1) |
| n_pre_spell_ex | number of previous completed firm-export spells at age 1 |
| n_pre_spell_im | number of previous completed firm-import spells at age 1 |
| repeated_spell | if the current firm-spell is a repeated spell within a firm |
| gap_spell | number of year gap between the current firm-spell and the last firm-spell |
| r_lngap_spell | repeated_spell * ln(gap_spell) |
| dpto | = 1 if multiple products at age 1 |
| dcou | = 1 if multiple destinations at age 1 |
| firm characteristics (restricted sample) | |
| lnTFP | ln(TFP) at age 1 |
| ln(age+1) | ln(firm age) = ln(current year - firm creation year + 1) at age 1 |
| lnL | ln(labor force) at age 1 |
| lnwpL | ln(wage per labor force) at age 1 |
| FO | owned by foreign at age 1 |
| FA | have foreign affiliate at age 1 |
| nace | 1-digit NACE sector at age 1 |
| region | geographic region at age 1 |

Note: A spell is defined at the firm-country level. For import spells, destination means sourcing country. Except age dummies, all the other covariates refer to characteristics at age 1 for each export/import spell. At the f.cou level, initial value is firm-country export(import) value at age 1. At the firm level, initial value is firm export(import) value at age 1. Quantile (terce) is taken among all age 1 observations including left-censored spells. The main product is determined based on value (within the firm-country-year). dimp(dexp) is export(import) spell specific covariate. Previous firm-country export(import) experience is the number of years of exporting(importing) from 1997 in a given country. Previous firm export(import) experience is the number of years of exporting(importing) from 1997. gap_spell is not included as a covariate. For the definition of sectors and regions, see the footnote of table 1b.

Table 1c: Definition of covariates (for survival analysis at the firm country level)

A.2. Descriptive statistics

| Characteristic | Mean | Median | N |
|-------------------------------------|--------------------|-----------|---------|
| TFP | 2309.6 | 777.4 | 724,055 |
| value-added per labor | 66066.4 | 50085.7 | 739,657 |
| labor force(L) | 81.7 | 12 | 825,282 |
| wage per labor(wpL) | 32303 | 27678.8 | 739,709 |
| total sales(catotal) | 2.25×10^7 | 2,035,707 | 838,755 |
| export value(v_ex) | 5,052,536 | 69,047 | 838,755 |
| foreign owned (dummy: FO) | 0.099 | 0 | 838,755 |
| have foreign affiliates (dummy: FA) | 0.0105 | 0 | 838,755 |
| firm age(age) | 19.6 | 15 | 836,674 |

Note: The sample coverage is between 1998 and 2015. Both left-censored and non left-censored export spells are included. Number of observations varies across characteristics as some of them are missing.

Table 2a: Summary statistics by export-year (Restricted sample)

| Characteristic | Mean | Median | N |
|-------------------------------------|--------------------|-----------|---------|
| TFP | 2465.8 | 846.1 | 749,174 |
| value-added per labor | 67681.5 | 49904.6 | 765,811 |
| labor force(L) | 93.6 | 12 | 857,827 |
| wage per labor(wpL) | 32485.3 | 27448.5 | 765,906 |
| total sales(catotal) | 2.49×10^7 | 2,192,000 | 875,950 |
| import value(v_im) | 4,299,550 | 148718.5 | 875,950 |
| foreign owned (dummy: FO) | 0.107 | 0 | 875,950 |
| have foreign affiliates (dummy: FA) | 0.0104 | 0 | 875,950 |
| firm age(age) | 17.91 | 13 | 874,056 |

Note: The sample coverage is between 1998 and 2015. Both left-censored and non left-censored import spells are included. Number of observations varies across characteristics as some of them are missing.

Table 2b: Summary statistics by import-year (Restricted sample)

B. Further results on performance differences across entrants, exiters, and continuers over the business cycle

In this section, we provide additional evidence on the differences in firm performance of entrants, exiters and continuers between good and bad times. Table 3 displays performance differences for entrants, exiters and continuers using our *Restricted sample*. We carry out simple OLS regressions of the log of three measures of firm-level performance (namely, employment -labor force-, total factor productivity, and total sales) on a dummy capturing whether t is a "bad year" (i.e., 2008, 2009, 2010) including sector fixed effects.¹ In the columns of this table, we report the results for each measure of firm performance, for each group of firms (entrants on the top, continuers at middle, and exiters at the bottom part of the table).

The regression results for exporters (Table 3a) confirm our previous findings in section 2.2.3 in most of the cases. Firms that begin exporting during recessionary periods are more productive

¹There are 17 nace sectors in total. L is labor force and $catotal$ is total sales.

(and smaller) than those starting to export during upturns. However, for entrants' total sales, we get a different result. During bad times, their total sales are actually higher. In addition, continuers have higher labor force during bad times, which is different from our previous result using median. The slight inconsistency may be related to the use variables in logs rather than levels, the use of median performance in Table 2 (main text), or it may suggest that there exists some heterogeneity across sectors.

| | (1) | (2) | (3) |
|-----------|---------------------|----------------------|---------------------|
| | InTFP_ent | InL_ent | Incatotal_ent |
| year 8910 | 0.059 (0.008)*** | -0.104 (0.009)*** | 0.022 (0.010)** |
| nace | yes | yes | yes |
| N | 153299 | 157837 | 199441 |
| ll | -243543.439 | -279826.836 | -404290.963 |
| r2 | 0.048 | 0.038 | 0.029 |
| | (1) | (2) | (3) |
| | InTFP_con | InL_con | Incatotal_con |
| year 8910 | 0.079 (0.005)*** | 0.021 (0.006)*** | 0.076 (0.007)*** |
| nace | yes | yes | yes |
| N | 507394 | 515775 | 551965 |
| ll | -815532.538 | -951746.332 | -1108365.812 |
| r2 | 0.031 | 0.102 | 0.05 |
| | (1) | (2) | (3) |
| | InTFP_ext | InL_ext | Incatotal_ext |
| year 8910 | 0.113 (0.008)*** | -0.041 (0.009)*** | 0.082 (0.010)*** |
| nace | yes | yes | yes |
| N | 147054 | 152516 | 193522 |
| ll | -227230.655 | -266777.408 | -388376.069 |
| r2 | 0.058 | 0.034 | 0.031 |

Table 3a: Exporters' performance

Note: Sample coverage is 1998 to 2015. *year* 8910 = 1 if year 2008, 2009 or 2010. Entrant(_ent) in year t means export in t and not in $t - 1$. Exiter(_ext) in year t means export in t and not in $t + 1$. Continuer(_con) in year t is the one that exports in t and doesn't belong to entrant or exiter. Left-censored spells are included. We drop those export spells of which the gravity information of their main destination is missing, that are micro firms or in distribution sectors at age 1. Unit of total sales is euro. The number of observations varies across specifications because some observations have different missing variables. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In table 3b, we conduct the same analysis for importers. Concerning TFP, there are no significant differences between entrants at bad times and entrants at good times. In the previous analysis of medians reported in Table 2 (main text), although the difference is significant, the magnitude is actually small. Regarding total sales, continuers have higher total sales at bad times which is different from the finding using median (no statistically different). For exiters, the coefficient becomes significantly positive once log form is applied, which suggests that the negative coefficient using simple value could be driven by some extreme value.

| | (1) | (2) | (3) |
|-----------|---------------------|----------------------|---------------------|
| | InTFP_ent | InL_ent | Incatotal_ent |
| year 8910 | -0.008 (0.009) | -0.208 (0.009)*** | -0.06 (0.011)*** |
| nace | yes | yes | yes |
| N | 138796 | 143559 | 186155 |
| ll | -228944.619 | -255449.19 | -387345.022 |
| r2 | 0.036 | 0.056 | 0.04 |
| | (1) | (2) | (3) |
| | InTFP_con | InL_con | Incatotal_con |
| year 8910 | 0.061 (0.005)*** | -0.023 (0.006)*** | 0.033 (0.007)*** |
| nace | yes | yes | yes |
| N | 543632 | 552665 | 594619 |
| ll | -866774.696 | -1019242.187 | -1194134.78 |
| r2 | 0.039 | 0.144 | 0.097 |
| | (1) | (2) | (3) |
| | InTFP_ext | InL_ext | Incatotal_ext |
| year 8910 | 0.11 (0.008)*** | -0.084 (0.009)*** | 0.059 (0.011)*** |
| nace | yes | yes | yes |
| N | 134189 | 139633 | 181158 |
| ll | -211972.416 | -243566.505 | -370419.725 |
| r2 | 0.043 | 0.053 | 0.043 |

Table 3b: Importers' performance

Note: Sample coverage is 1998 to 2015. *year 8910* = 1 if year 2008, 2009 or 2010. Entrant(_ent) in year t means import in t and not in $t - 1$. Exiter(_ext) in year t means import in t and not in $t + 1$. Continuer(_con) in year t is the one that imports in t and doesn't belong to entrant or exiter. Left-censored spells are included. We drop those import spells of which the gravity information of their main sourcing country is missing, that are micro firms or in distribution sectors at age 1. Unit of total sales is euro. The number of observations varies across specifications because some observations have different missing variables. * $p < 0.10$, ** $p < .05$, *** $p < .01$

C. Full regression results

C.1. Hazard of exiting export markets

| | full sample | restricted sample |
|------|---------------------|---------------------|
| age1 | 0.579 (0.010)*** | 0.412 (0.052)*** |
| age2 | 0.402 (0.008)*** | 0.314 (0.040)*** |
| age3 | 0.353 (0.007)*** | 0.276 (0.035)*** |
| age4 | 0.328 (0.007)*** | 0.257 (0.033)*** |
| age5 | 0.311 | 0.247 |

| | | |
|-----------------|------------|------------|
| | (0.007)*** | (0.032)*** |
| age6 | 0.299 | 0.233 |
| | (0.007)*** | (0.030)*** |
| age7 | 0.278 | 0.216 |
| | (0.007)*** | (0.028)*** |
| age8 | 0.249 | 0.193 |
| | (0.005)*** | (0.025)*** |
| dyrp8910 | 1.204 | 1.21 |
| | (0.009)*** | (0.014)*** |
| p8910 | 0.893 | 0.902 |
| | (0.008)*** | (0.012)*** |
| dini2 | 0.829 | 0.845 |
| | (0.005)*** | (0.008)*** |
| dini3 | 0.579 | 0.611 |
| | (0.004)*** | (0.007)*** |
| dpto2 | 0.935 | 0.94 |
| | (0.005)*** | (0.008)*** |
| dpto3 | 0.828 | 0.885 |
| | (0.005)*** | (0.009)*** |
| dcou2 | 0.899 | 0.894 |
| | (0.007)*** | (0.011)*** |
| dcou3 | 0.713 | 0.733 |
| | (0.007)*** | (0.011)*** |
| dimp | 0.587 | 0.687 |
| | (0.004)*** | (0.007)*** |
| d_lc1997_fpc_ex | 1.012 | 0.985 |
| | (0.009) | (0.014) |
| d_lc1997_fpc_im | 1.013 | 0.971 |
| | (0.009) | (0.013)** |
| lnpre_ex_exp | 0.773 | 0.732 |
| | (0.006)*** | (0.009)*** |
| lnpre_im_exp | 1.192 | 1.11 |
| | (0.007)*** | (0.009)*** |
| n_pre_spell_ex | 1.043 | 1.037 |
| | (0.006)*** | (0.008)*** |
| n_pre_spell_im | 0.982 | 0.972 |
| | (0.005)*** | (0.007)*** |
| repeated_spell | 1.001 | 1.029 |
| | (0.012) | (0.019) |
| r_lngap_spell | 1.121 | 1.079 |
| | (0.007)*** | (0.009)*** |
| dpto | 0.666 | 0.669 |
| | (0.004)*** | (0.006)*** |
| dcou | 0.521 | 0.576 |
| | (0.003)*** | (0.006)*** |
| border | 1.053 | 1.04 |
| | (0.009)*** | (0.015)*** |
| french | 0.984 | 1.012 |
| | (0.005)*** | (0.009) |
| eu_eea | 0.897 | 0.94 |
| | (0.009)*** | (0.017)*** |

| | | |
|--------------|---------------------|---------------------|
| euro | 0.913 (0.008)*** | 0.995 (0.014) |
| InTFP | | 0.895 (0.005)*** |
| Inage | | 1.264 (0.006)*** |
| InL | | 0.996 (0.004) |
| InwpL | | 1.057 (0.008)*** |
| FO | | 0.916 (0.017)*** |
| FA | | 0.767 (0.043)*** |
| nace | | yes |
| region | | yes |
| m2_cons | 5.067 (0.062)*** | 4.69 (0.093)*** |
| logitp2_cons | 4.571 (0.109)*** | 3.694 (0.159)*** |
| N | 994199 | 386267 |
| ll | -517110.131 | -196997.317 |

Table 4: Hazard of exiting export markets

C.2. Hazard of exiting import markets

| | full sample | restricted sample |
|-----------|---------------------|---------------------|
| age1 | 0.289 (0.005)*** | 0.693 (0.097)*** |
| age2 | 0.222 (0.004)*** | 0.588 (0.082)*** |
| age3 | 0.214 (0.004)*** | 0.572 (0.080)*** |
| age4 | 0.201 (0.004)*** | 0.529 (0.074)*** |
| age5 | 0.189 (0.004)*** | 0.501 (0.071)*** |
| age6 | 0.193 (0.004)*** | 0.494 (0.070)*** |
| age7 | 0.192 (0.005)*** | 0.486 (0.069)*** |
| age8 | 0.192 (0.004)*** | 0.479 (0.067)*** |
| dyrgp8910 | 1.241 (0.008)*** | 1.272 (0.015)*** |
| p8910 | 0.991 (0.009) | 0.952 (0.013)*** |
| dini2 | 0.682 (0.004)*** | 0.706 (0.008)*** |
| dini3 | 0.375 | 0.411 |

| | | |
|-----------------|------------|------------|
| | (0.003)*** | (0.006)*** |
| dpto2 | 0.984 | 1.007 |
| | (0.006)*** | (0.011) |
| dpto3 | 0.955 | 0.938 |
| | (0.006)*** | (0.010)*** |
| dcou2 | 1.040 | 0.904 |
| | (0.014)*** | (0.028)*** |
| dcou3 | 1.089 | 0.9 |
| | (0.016)*** | (0.028)*** |
| dexp | 0.636 | 0.701 |
| | (0.004)*** | (0.008)*** |
| d_lc1997_fpc_ex | 1.055 | 0.956 |
| | (0.012)*** | (0.015)*** |
| d_lc1997_fpc_im | 1.011 | 1.008 |
| | (0.011) | (0.018) |
| lnpre_ex_exp | 1.151 | 1.106 |
| | (0.008)*** | (0.011)*** |
| lnpre_im_exp | 0.799 | 0.747 |
| | (0.008)*** | (0.011)*** |
| n_pre_spell_ex | 0.988 | 0.969 |
| | (0.006)** | (0.008)*** |
| n_pre_spell_im | 1.011 | 1.014 |
| | (0.008) | (0.012) |
| repeated_spell | 1.117 | 1.056 |
| | (0.017)*** | (0.024)** |
| r_lngap_spell | 1.101 | 1.079 |
| | (0.008)*** | (0.011)*** |
| dpto | 0.617 | 0.618 |
| | (0.004)*** | (0.007)*** |
| dcou | 0.645 | 0.659 |
| | (0.004)*** | (0.008)*** |
| border | 1.063 | 1.059 |
| | (0.009)*** | (0.015)*** |
| french | 1.149 | 1.111 |
| | (0.007)*** | (0.013)*** |
| eu_eea | 0.876 | 0.981 |
| | (0.010)*** | (0.018) |
| euro | 0.941 | 1.012 |
| | (0.008)*** | (0.015) |
| InTFP | | 0.882 |
| | | (0.005)*** |
| Inage | | 1.244 |
| | | (0.006)*** |
| InL | | 0.994 |
| | | (0.004) |
| InwpL | | 1.042 |
| | | (0.008)*** |
| FO | | 0.799 |
| | | (0.018)*** |
| FA | | 0.817 |
| | | (0.044)*** |

| | | |
|--------------|-------------|-------------|
| nace | | yes |
| region | | yes |
| m2_cons | 6.418 | 6.513 |
| | (0.075)*** | (0.124)*** |
| logitp2_cons | 4.021 | 3.244 |
| | (0.070)*** | (0.086)*** |
| N | 1052992 | 387117 |
| ll | -533903.334 | -190662.165 |

Table 5: Hazard of exiting import markets

C.3. Hazard of exiting export and import markets - joint estimation

| | full sample | | restricted sample | |
|-----------------|-------------|------------|-------------------|------------|
| | export | import | export | import |
| ex/im | 5.882 | 2.808 | 2.96 | 8.333 |
| | (0.087)*** | (0.058)*** | (0.508)*** | (1.533)*** |
| age2 | 0.569 | 0.710 | 0.648 | 0.745 |
| | (0.005)*** | (0.006)*** | (0.009)*** | (0.011)*** |
| age3 | 0.475 | 0.675 | 0.545 | 0.701 |
| | (0.005)*** | (0.008)*** | (0.010)*** | (0.013)*** |
| age4 | 0.433 | 0.626 | 0.505 | 0.634 |
| | (0.006)*** | (0.009)*** | (0.011)*** | (0.015)*** |
| age5 | 0.409 | 0.588 | 0.489 | 0.596 |
| | (0.007)*** | (0.010)*** | (0.013)*** | (0.016)*** |
| age6 | 0.397 | 0.611 | 0.465 | 0.594 |
| | (0.007)*** | (0.012)*** | (0.014)*** | (0.019)*** |
| age7 | 0.370 | 0.618 | 0.434 | 0.589 |
| | (0.008)*** | (0.013)*** | (0.015)*** | (0.021)*** |
| age8 | 0.348 | 0.651 | 0.409 | 0.61 |
| | (0.006)*** | (0.013)*** | (0.012)*** | (0.019)*** |
| dyrgp8910 | 1.272 | 1.363 | 1.283 | 1.386 |
| | (0.011)*** | (0.011)*** | (0.017)*** | (0.018)*** |
| p8910 | 0.861 | 0.988 | 0.881 | 0.951 |
| | (0.009)*** | (0.010) | (0.014)*** | (0.016)*** |
| dini2 | 0.760 | 0.577 | 0.797 | 0.636 |
| | (0.006)*** | (0.005)*** | (0.010)*** | (0.009)*** |
| dini3 | 0.468 | 0.275 | 0.533 | 0.333 |
| | (0.004)*** | (0.003)*** | (0.008)*** | (0.006)*** |
| dpto2 | 0.905 | 0.977 | 0.921 | 1.006 |
| | (0.007)*** | (0.008)*** | (0.011)*** | (0.014) |
| dpto3 | 0.764 | 0.937 | 0.844 | 0.922 |
| | (0.006)*** | (0.008)*** | (0.011)*** | (0.013)*** |
| dcou2 | 0.853 | 1.013 | 0.837 | 0.845 |
| | (0.009)*** | (0.020) | (0.014)*** | (0.035)*** |
| dcou3 | 0.604 | 1.064 | 0.644 | 0.829 |
| | (0.008)*** | (0.021)*** | (0.014)*** | (0.035)*** |
| dimp/dexp | 0.559 | 0.621 | 0.663 | 0.71 |
| | (0.005)*** | (0.006)*** | (0.009)*** | (0.010)*** |
| d_lc1997_fpc_ex | 0.949 | 0.854 | 0.966 | 0.842 |
| | (0.013)*** | (0.014)*** | (0.019)* | (0.019)*** |

| | | | | |
|-----------------------|---------------------|---------------------|---------------------|---------------------|
| d_lc1997_fpc_im | 0.800 (0.011)*** | 0.975 (0.016) | 0.868 (0.017)*** | 1.004 (0.024) |
| lnpre_ex_exp | 0.993 (0.012) | 1.382 (0.013)*** | 0.818 (0.013)*** | 1.18 (0.015)*** |
| lnpre_im_exp | 1.413 (0.011)*** | 1.160 (0.017)*** | 1.175 (0.012)*** | 0.907 (0.018)*** |
| n_pre_spell_ex | 0.830 (0.008)*** | 0.851 (0.007)*** | 0.892 (0.010)*** | 0.886 (0.010)*** |
| n_pre_spell_im | 0.847 (0.007)*** | 0.724 (0.009)*** | 0.888 (0.009)*** | 0.794 (0.012)*** |
| repeated_spell | 0.853 (0.014)*** | 0.837 (0.017)*** | 0.893 (0.022)*** | 0.858 (0.024)*** |
| r_lngap_spell | 1.170 (0.009)*** | 1.137 (0.010)*** | 1.137 (0.013)*** | 1.124 (0.015)*** |
| dpto | 0.610 (0.005)*** | 0.547 (0.004)*** | 0.615 (0.008)*** | 0.561 (0.008)*** |
| dcou | 0.457 (0.004)*** | 0.603 (0.005)*** | 0.519 (0.007)*** | 0.631 (0.009)*** |
| border | 1.051 (0.012)*** | 1.086 (0.012)*** | 1.039 (0.020)** | 1.07 (0.019)*** |
| french | 0.980 (0.007)*** | 1.216 (0.011)*** | 1.014 (0.012) | 1.139 (0.017)*** |
| eu_eea | 0.887 (0.012)*** | 0.862 (0.013)*** | 0.922 (0.021)*** | 0.999 (0.024) |
| euro | 0.927 (0.011)*** | 0.911 (0.011)*** | 1.022 (0.019) | 1.029 (0.019) |
| InTFP | | | 0.848 (0.006)*** | 0.834 (0.006)*** |
| Inage | | | 1.401 (0.009)*** | 1.367 (0.010)*** |
| InL | | | 0.994 (0.005) | 0.98 (0.005)*** |
| InwpL | | | 1.077 (0.011)*** | 1.048 (0.011)*** |
| FO | | | 0.888 (0.023)*** | 0.759 (0.022)*** |
| FA | | | 0.699 (0.052)*** | 0.758 (0.055)*** |
| nace | | | yes | yes |
| region | | | yes | yes |
| var(ex[firm]) | | 2.586 (0.047)*** | | 2.389 (0.065)*** |
| var(im[firm]) | | 3.654 (0.085)*** | | 3.302 (0.116)*** |
| cov(ex[firm]im[firm]) | | 2.165 (0.024)*** | | 1.88 (0.030)*** |
| N | | 2047191 | | 773384 |
| ll | | -1055898.777 | | -389193.551 |

Table 6: Hazard of exiting export and import markets - joint estimation

D. Survival in foreign markets: some robustness checks

| bad dummy | Firm level | | | | Firm country level | | | |
|-----------------|-----------------|------------|-----------|------------|-------------------------|------------|-----------|------------|
| | 2008-2015 | | 2008-2015 | | 2008-2015 | | 2008-2015 | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 1.102*** | 1.153*** | 1.073*** | 1.079*** | 1.133*** | 1.103*** | 1.022*** | 1.028*** |
| current bad des | 0.838*** | 0.774*** | 0.958*** | 1.025*** | 0.836*** | 0.857*** | 1.042*** | 1.052*** |
| birth bad fr | 0.974*** | 0.970*** | 0.974*** | 0.970*** | 0.988*** | 0.990*** | 0.954*** | 0.956*** |
| birth bad des | 994199 | 386267 | 911305 | 354824 | 5834330 | 3503367 | 5524777 | 3345578 |
| continuous | Firm level | | | | | | | |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 1.169 | 0.928 | 0.659*** | 0.376*** | 0.961*** | 0.952*** | 0.829*** | 1.374** |
| current bad des | 0.773*** | 0.865 | 0.892** | 0.789*** | 0.997*** | 0.996* | 0.473*** | 0.487*** |
| birth bad fr | 12.281*** | 57.117*** | 1.230 | 2.217*** | 1.028*** | 1.012* | 2.386*** | 1.572*** |
| birth bad des | 1.263** | 1.122 | 1.085 | 1.251*** | 1.003** | 1.003 | 2.474*** | 2.458*** |
| N | 812713 | 320695 | 910753 | 354616 | 911305 | 354824 | 5022870 | 3045241 |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 1.169 | 0.928 | 0.659*** | 0.376*** | 0.961*** | 0.952*** | 0.829*** | 1.374** |
| current bad des | 0.773*** | 0.865 | 0.892** | 0.789*** | 0.997*** | 0.996* | 0.473*** | 0.487*** |
| birth bad fr | 12.281*** | 57.117*** | 1.230 | 2.217*** | 1.028*** | 1.012* | 2.386*** | 1.572*** |
| birth bad des | 1.263** | 1.122 | 1.085 | 1.251*** | 1.003** | 1.003 | 2.474*** | 2.458*** |
| N | 812713 | 320695 | 910753 | 354616 | 911305 | 354824 | 5022870 | 3045241 |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 1.169 | 0.928 | 0.659*** | 0.376*** | 0.961*** | 0.952*** | 0.829*** | 1.374** |
| current bad des | 0.773*** | 0.865 | 0.892** | 0.789*** | 0.997*** | 0.996* | 0.473*** | 0.487*** |
| birth bad fr | 12.281*** | 57.117*** | 1.230 | 2.217*** | 1.028*** | 1.012* | 2.386*** | 1.572*** |
| birth bad des | 1.263** | 1.122 | 1.085 | 1.251*** | 1.003** | 1.003 | 2.474*** | 2.458*** |
| N | 812713 | 320695 | 910753 | 354616 | 911305 | 354824 | 5022870 | 3045241 |

Note: Sample coverage is 1998 to 2015. Left-censored spells are excluded. In *Restricted* Sample, we drop those export spells of which the gravity information of their main destination is missing, that are micro firms or in distribution sectors at age 1. The number of N varies across specifications due to missing variables for some observations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Robustness check: export survival

| bad dummy | Firm level | | | | Firm country level | | | |
|-----------------|-----------------|------------|-----------|------------|-------------------------|------------|-----------|------------|
| | 2008-2015 | | 2008-2015 | | 2008-2015 | | 2008-2015 | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 1.235*** | 1.287*** | 0.894*** | 0.872*** | 1.175*** | 1.174*** | 0.936*** | 0.952*** |
| current bad des | 0.881*** | 0.748*** | 1.116*** | 1.111*** | 0.857*** | 0.791*** | 0.992** | 0.986** |
| birth bad fr | 10.723*** | 76.550*** | 3.077*** | 2.824*** | 1.003 | 1.021** | 1.267*** | 1.679*** |
| birth bad des | 2.603*** | 2.201*** | 1.493*** | 1.655*** | 0.994*** | 0.985*** | 3.016*** | 2.793*** |
| N | 1052992 | 387117 | 958322 | 352244 | 4530367 | 2324943 | 4119965 | 2125831 |
| continuous | Firm level | | | | | | | |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 0.106*** | 0.127*** | 0.503*** | 0.296*** | 0.973*** | 0.963*** | 0.397*** | 0.845 |
| current bad des | 0.395*** | 0.352*** | 0.659*** | 0.589*** | 0.997* | 1.005* | 0.338*** | 0.362*** |
| birth bad fr | 10.723*** | 76.550*** | 3.077*** | 2.824*** | 1.003 | 1.021** | 1.267*** | 1.679*** |
| birth bad des | 2.603*** | 2.201*** | 1.493*** | 1.655*** | 0.994*** | 0.985*** | 3.016*** | 2.793*** |
| N | 941476 | 350953 | 958019 | 352174 | 958322 | 352244 | 4059909 | 2102644 |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 0.106*** | 0.127*** | 0.503*** | 0.296*** | 0.973*** | 0.963*** | 0.397*** | 0.845 |
| current bad des | 0.395*** | 0.352*** | 0.659*** | 0.589*** | 0.997* | 1.005* | 0.338*** | 0.362*** |
| birth bad fr | 10.723*** | 76.550*** | 3.077*** | 2.824*** | 1.003 | 1.021** | 1.267*** | 1.679*** |
| birth bad des | 2.603*** | 2.201*** | 1.493*** | 1.655*** | 0.994*** | 0.985*** | 3.016*** | 2.793*** |
| N | 941476 | 350953 | 958019 | 352174 | 958322 | 352244 | 4059909 | 2102644 |
| | ln(country TFP) | | ln(GDP) | | GDP g (country - world) | | ln(GDP) | |
| | Full | Restricted | Full | Restricted | Full | Restricted | Full | Restricted |
| current bad fr | 0.106*** | 0.127*** | 0.503*** | 0.296*** | 0.973*** | 0.963*** | 0.397*** | 0.845 |
| current bad des | 0.395*** | 0.352*** | 0.659*** | 0.589*** | 0.997* | 1.005* | 0.338*** | 0.362*** |
| birth bad fr | 10.723*** | 76.550*** | 3.077*** | 2.824*** | 1.003 | 1.021** | 1.267*** | 1.679*** |
| birth bad des | 2.603*** | 2.201*** | 1.493*** | 1.655*** | 0.994*** | 0.985*** | 3.016*** | 2.793*** |
| N | 941476 | 350953 | 958019 | 352174 | 958322 | 352244 | 4059909 | 2102644 |

Note: Sample coverage is 1998 to 2015. Left-censored spells are excluded. In *Restricted* Sample, we drop those import spells of which the gravity information of their main sourcing country is missing, that are micro firms or in distribution sectors at age 1. Number of N varies across specifications due to missing variables for some observations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Robustness check: import survival

E. Negative age dependence: “true” duration dependence vs sorting

In this section, we plot normalized coefficients of age dummies for both specifications with/without controlling for frailty using the *Full sample*. Age 1 coefficient is normalized to 1. Recall that business cycle indicators *birth2008_10* and *current2008_10*, trade-related characteristics at age 1, and main destination/sourcing country characteristics at age 1 are included as covariates for export/import duration analysis.

E.1. Export duration

Figure 1 plots normalized coefficients of age dummies of export duration analysis. The blue(red) curve depicts normalized age coefficients of specification without(with) controlling for frailty. The green curve captures the difference between the two.

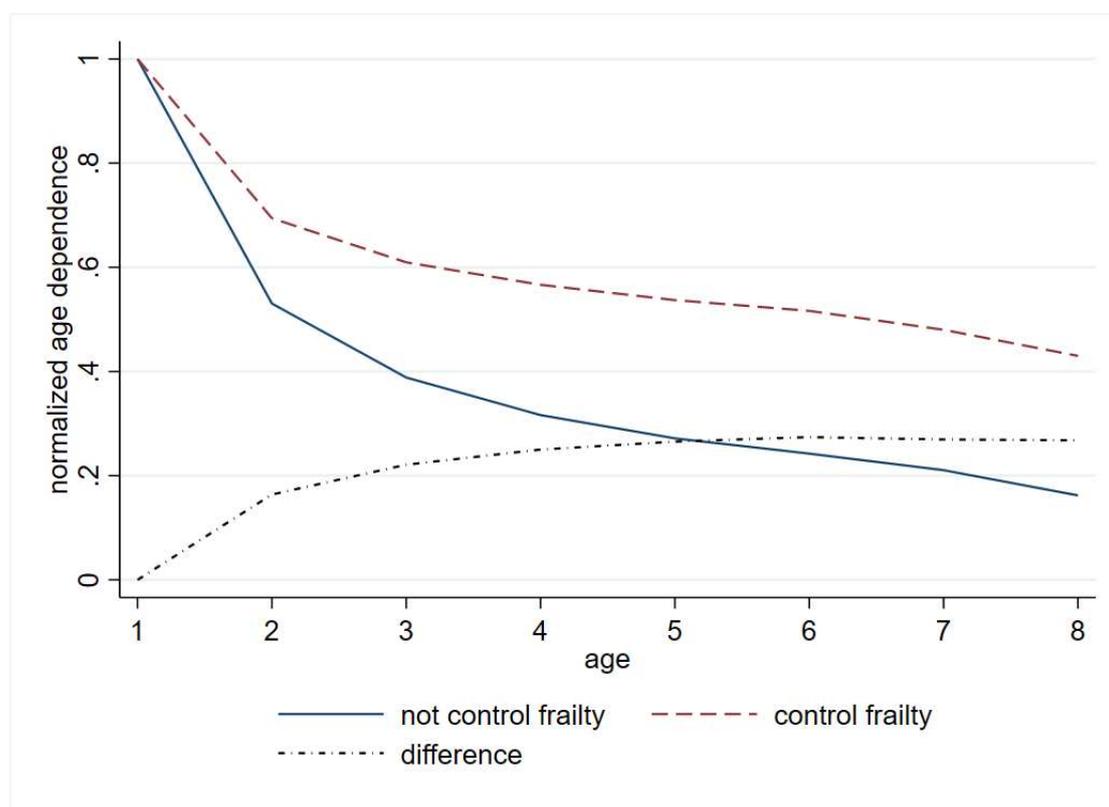


Figure 1: Export age dependence: frailty vs non-frailty

E.2. Import duration

Figure 2 plots normalized coefficients of age dummies of import duration analysis. The blue(red) curve depicts normalized age coefficients of specification without(with) controlling for frailty. The green curve captures the difference between the two.

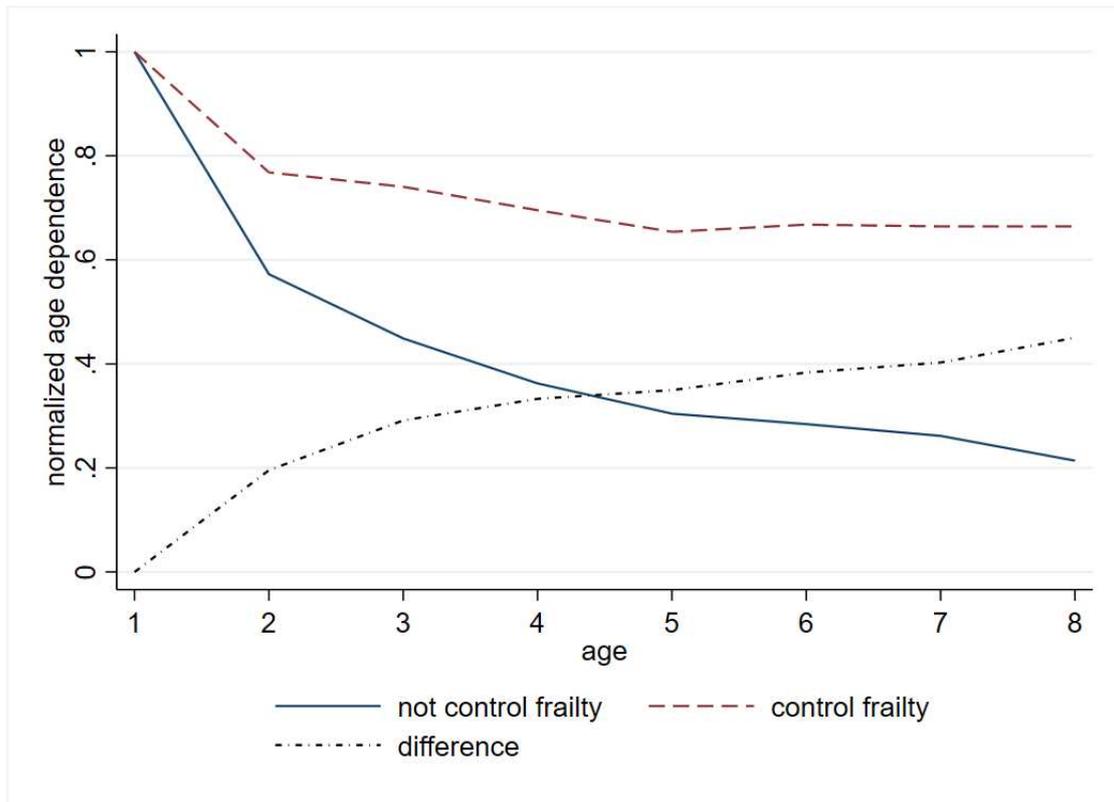


Figure 2: Import age dependence: frailty vs non-frailty

Chapter 3

Incomplete Contracts and Outcome-Based Trade Agreements

Abstract

The ongoing US-China trade war suggests that there exist some shortcomings of the WTO agreement which is mainly instrument-based. The import commitments made by China in the Phase One trade deal have a flavor of outcome-based agreement. In this paper, I revisit the instrument-based trade agreement model of Horn, Maggi, and Staiger (2006), where contract incompleteness means that the optimal agreement may not lead to the first-best outcome. I extend the model by introducing outcome-based agreements, namely an import volume constraint. When governments face uncertainty about the state of the economy, I first show that a state-contingent outcome-based agreement can replicate the first-best instrument-based agreement if the contracting costs are the same. Second, I show that a non state-contingent outcome-based agreement deals well with terms-of-trade manipulation and provides some flexibility regarding the choice of policy instruments at the same time to react to state uncertainty. Whether a non state-contingent outcome-based agreement is the optimal one jointly depends on the government's ability to manipulate the terms-of-trade, the size and source of state uncertainty and its contracting cost.

Keywords: Incomplete contract, Outcome-based agreement

1. Introduction

Two years after the start of the US-China trade war, on January 15 2020, the Phase One trade deal was signed which is intended to solve several long-existing trade-related problems between the US and China. One of the novel elements is the Expanding Trade chapter which includes a two-year \$200 billion purchase commitment of China from the US. Different purchase targets are established across broad categories of products which cover 60% of US total exports of goods to China in 2017. The Expanding Trade chapter is an outcome-based agreement which is dissimilar to an instrument-based agreement such as the World Trade Organization (WTO).¹ For quite some time, the US has been dissatisfied with functioning of the WTO. The US has blocked the reappointment of Appellate Body members since 2016 in order to force the WTO to be reformed. One major complaint of the US is about China's market access restrictions such as limiting trade flows and imposing restrictive non-tariff barriers. Instead of turning to an instrument-based agreement, the US attempted to use an outcome-based agreement to solve the trade issues with China. At first glance, if the main inefficiency comes from market access restrictions, an agreement that contracts on trade volume can be desirable as it lifts trade barriers by regulating trade flows directly while an instrument-based agreement, like the WTO, regulates market access and trade flows indirectly by imposing constraints on policy instruments such as tariffs and domestic subsidies. However, given that drafting a trade agreement is costly and the state of the world is uncertain, an expanding-trade type agreement can be unattractive once its contracting cost is too high and/or some downward adjustments of trade volume are needed in response to state uncertainty. In light of the above facts, using an outcome-based agreement, e.g., the Expanding Trade Chapter, as an alternative to an instrument-based agreement, e.g., the WTO, may or may not be welfare improving.

In this paper, I study outcome-based agreements, namely import volume constraint and compare them with instrument-based agreements, namely constraints on domestic and/or border instruments in an incomplete-contract framework where contracting is costly and the state of the world is uncertain. More precisely, the optimal agreement is endogenously chosen in a given set of agreements such that the global expected welfare net of contracting costs is maximized. This paper asks, under which conditions, an outcome-based agreement is able to outperform an instrument-based agreement, and tries to rationalize the conclusion of the Expanding Trade Chapter.

The incomplete contract framework follows that of Horn, Maggie and Staiger (2006, 2010) in which some core features of the GATT/WTO are well explained. Assuming that a rigid (non state contingent) outcome-based agreement on import volume is the second most costly, the welfare difference between a rigid outcome-based agreement and instrument-based agreements depends on how relatively advantageous an outcome-based agreement is with regard to lifting market access barriers, namely terms-of-trade manipulation and how relatively advantageous/disadvantageous an outcome-based agreement is with regard to reacting to state uncertainty. I focus on the trade-off between the above two dimensions and identify the circumstances under which a rigid outcome-based agreement is optimal across different sources of state uncertainty.

The sole cross-border inefficiency in this paper that a trade agreement is intended to solve is the terms-of-trade externality. More explicitly, as an importer, the home country has the incentive to manipulate foreign price downward in order to extract extra profits from the foreign country by using border and/or domestic policy instruments, which is inefficient. As mentioned in Maggi (2014), in the trade agreement literature, there are two main theories that explain the motives for trade agreements, namely, the terms-of-trade (TOT) theory and the domestic-

¹I call the WTO an instrument-based agreement as the WTO principally imposes constraints on border instruments such as tariff and domestic instruments such as subsidy.

commitment theory.² The terms-of-trade theory is the most developed one in the literature. Bagwell and Staiger (1999) propose a general framework of the TOT theory where they are able to rationalize GATT's principles of reciprocity and nondiscrimination (Most Favored Nation rule). These principles can help countries to move from a non-cooperative international equilibrium to an efficient equilibrium. Nevertheless, the export subsidy puzzle exists in the TOT theory. The TOT theory predicts that governments should increase export subsidies to reach an efficient equilibrium while trade agreements normally restrict export subsidies in reality. The domestic-commitment theory assumes that trade agreements serve as a commitment tool in order to deal with domestic issues. Liu and Ornelas (2014) propose a model where an incumbent democratic government faces the risk of a coup initiated by a domestic authoritarian group and free trade agreements serve as an instrument to destroy the rents of the authoritarian group. The motive for trade agreements is to stabilize a democratic regime. The literature on the suggestive evidence of motives for trade agreements is relatively scarce.³ Bagwell and Staiger (2016) find suggestive evidence that terms-of-trade indeed played a central role in GATT's design by checking the Haberler Report commissioned by GATT. Bagwell and Staiger (2011) find strong empirical support for the terms-of-trade theory by exploring the relationship between observed patterns of negotiated tariff cuts and pre-negotiation characteristics. Liu and Ornelas (2014) empirically test their model prediction that trade agreements serve as a commitment tool to destroy domestic rents. Using a sample of 116 countries over the period between 1960 and 2007, they find that signing preferential trade agreements lowers the probability of democratic failure and unstable democracies are more likely to sign preferential trade agreements.

With regard to the design of trade agreements, Horn, Maggie and Staiger (2006, 2010) first study the endogenous choice of trade agreement in a model where contracting is costly and the state of the world is uncertain. Their model is able to explain some core features of the GATT/WTO such as more restrictions on border measures relative to domestic measures, the National Treatment Clause, escape clauses and bound tariffs. They focus on a set of agreements that contract only on policy instruments, i.e., border instrument tariff and domestic instrument subsidy. HMS(2006)⁴ use a framework with linear supply and demand, where they can directly compare the difference in expected welfare between two agreements. HMS(2010) use a general functional form where they cannot compare welfare under two agreements directly. For instance, when they study whether to leave discretion over the subsidy, they compare welfare under the noncooperative choice of a subsidy with welfare under the efficient choice of a subsidy for a given tariff and realization of the state. They argue that if the difference is sufficiently small, discretion should be left over subsidy. However, they do not take into account the fact that the choice of tariff should change once the subsidy is contracted. Therefore, the general functional form is not well suited for making comparisons between agreements and I assume linear supply and demand framework when comparing different agreements.

Inspired by the signature of the Phase One deal, I introduce outcome-based agreements, namely an import volume constraint, in the HMS model. Like HMS, I focus on the sector where home is the importing country. Sector welfare can be studied independently due to the partial equilibrium setting. There are two domestic externalities in the importing sector, namely, consumption and production externalities, leading to a positive optimal tariff. In the baseline case where there is neither contracting cost nor state uncertainty, an outcome-based agreement on import volume is able to reach the first best outcome in which global welfare is maximized and a tariff or subsidy is only used to solve the domestic externalities. Since the foreign government

²Maggi (2014) also mentions the theories that relate the motives for trade agreements to non-terms-of-trade externalities and the management of uncertainty.

³Fajgelbaum and Khandelwal (2022) mention that the literature that provides evidence on government policy being guided by terms-of-trade manipulation includes Broda et al. (2008), Bagwell and Staiger (2011), Bown and Crowley (2013), Ludema and Mayda (2013), and Nicita et al. (2018).

⁴HMS represents Horn, Maggie and Staiger in the rest of paper.

is assumed to be policy-passive in the sector where home is the importing country, the import volume pins down foreign prices directly which further pin down foreign welfare. As a result, the home government cannot manipulate terms-of-trade, i.e., foreign price at all, and an efficient equilibrium can be reached. The result that the import volume constraint can reach the first best (efficient) outcome holds in alternative settings. More precisely, assuming that (i) the only inefficiency is that one country can manipulate other countries' welfare through the trade channel; (ii) a country's welfare is pinned down by its own policy choices and trade flows with the other countries; (iii) given fixed welfare of the other countries, a country maximizes its own welfare without manipulating other countries' welfare (behaves in an efficient way) and (iv) a unique efficient outcome is attained as all countries behave in an efficient way simultaneously and trade flows are set at an efficient level, in this case, an outcome-based agreement on trade flows can reach the first best outcome. An additional advantage of outcome-based agreements on import volume is that they are not affected by the number of border and domestic policy instruments used by the importing country. In other words, if the importing country can create substitutes for border and domestic policy instruments easily, an instrument-based agreement can be very hard to draft while an outcome-based agreement on import volume still works well.

The setting of contracting costs is similar to that of HMS. There exist three types of contracting costs. The first is the cost of contracting on policy instruments, namely subsidy and tariff; the second is the cost of contracting on import volume (trade outcome) and the third is the cost of making the agreement state contingent. As in Battigalli and Maggi (2002), the total contracting costs increase in the number of elements included. As in HMS, I assume that there are three sources of uncertainty that arise from consumption externality, production externality, and demand shifters in the importing sector, and I study them separately. Once import volume is contracted on, it is unnecessary to contract on the subsidy or tariff in addition. That is to say, it is redundant for a trade agreement to contract on both trade outcomes and policy instruments. The reasoning is trivial. As mentioned before, the import volume pins down foreign welfare directly. As import volume is contracted on, the importing country maximizes its own welfare without manipulating foreign welfare and further contracting on the subsidy and/or tariff becomes unnecessary. I assume a non-state-contingent (rigid) contract on import volume is the second most costly and aim to study the choice of outcome-based agreement in the worst-case scenario. Compared with the non-state-contingent agreement on both tariff and subsidy, rigid outcome-based agreement is preferable with regard to gross global welfare when the consumption externality or the production externality is the source of uncertainty. The expected foreign welfare is the same under the two agreements. However, under the rigid outcome-based agreement, the home country can choose its own policy instruments and this extra flexibility is appealing. As the demand shifter is the source of uncertainty, the non-state-contingent agreement on import volume underperforms. This is because the demand shifter affects the import volume directly and zero flexibility on import volume is extremely unappealing. Meanwhile, the non-state-contingent agreement on both tariff and subsidy reaches the first best outcome. As the demand shifter is independent of consumption and production externalities, in the first-best equilibrium, policy instruments are chosen in a non-state-contingent way to solve the two externalities. Since I assume the rigid outcome-based agreement is the second most costly and is more costly than the rigid agreement on both tariff and subsidy, in this case, the rigid outcome-based agreement is never chosen.

Compared with the non-state-contingent agreement on the tariff only, the rigid outcome-based agreement is preferred in terms of gross global welfare as the consumption externality is the source of uncertainty. In this case, to reach the first best outcome, both tariff and subsidy should react to the uncertainty. The rigid outcome-based agreement gives the home country the necessary flexibility such that home country uses both instruments to react to the shock. Nevertheless, under the non-state-contingent agreement on tariff, the tariff instrument is rigid and cannot react to shock. Therefore, the outcome-based agreement dominates with regard to

both killing terms-of-trade manipulation and reaction to shock. When the production externality is the source of uncertainty, in the first best outcome, only the domestic subsidy reacts to the uncertainty. In this case, the non-state-contingent agreement on the tariff closely mimics the first-best-outcome solution in terms of reaction to shock. Under this agreement, the tariff is chosen rigidly, and the home country employs a subsidy to address uncertainty. Still, the rigid outcome-based agreement forces the home country to use both tariff and subsidy to react to state uncertainty. Under the rigid outcome-based agreement, the home country has to vary the choice of tariff and subsidy simultaneously so as to satisfy the rigid import constraint imposed by the agreement, which makes the home country overreact to uncertainty. Therefore, the rigid outcome-based agreement is dominated in terms of reaction to shocks. When the home demand shifter is the source of uncertainty, the rigid outcome-based agreement still underperforms the rigid agreement on tariff in terms of shock reaction. The uncertainty of home demand shifter has a first-order impact on home's import volume. The rigid outcome-based agreement does not allow the import volume to vary across different states while the rigid agreement on the tariff does. Compared with state-contingent agreements, a non-state-contingent agreement on import volume is always dominated in terms of shock reaction. The deficiency of shock reaction jointly depends on the source of uncertainty and the parameters that magnify certain types of uncertainty. The main message of this paper is that a rigid outcome-based agreement is able to solve terms-of-trade manipulation efficiently and gives extra flexibility regarding the choice of policy instruments to the importing county. Whether the extra flexibility is appealing depends on the source of uncertainty. To put it another way, foreign welfare is forced to remain invariant across different realizations of the state under the non-state-contingent agreement on import volume. In this case, the importing country cannot manipulate foreign welfare, which is welfare efficient. However, it must bear all the variation due to state uncertainty, which can be welfare inefficient. For instance, if China's main uncertainty comes from the consumption demand which fluctuates a lot, an agreement such as the Expanding Trade Chapter can be undesirable. In other words, if China experiences a downward demand shock while the Expanding Trade Chapter does not allow for a corresponding decrease in purchases, the cost to China's welfare can be significant.

The remainder of the paper is organized as follows. In section 2, I discuss a baseline case where there are neither state uncertainty nor contracting costs. Section 3 introduces state uncertainty and contracting costs. Comparisons between the non-state-contingent outcome-based agreement and the other agreements are presented in section 4 and section 5 concludes.

2. Model with neither uncertainty nor contracting costs

I start by introducing the general setting in a framework with neither uncertainty nor contracting costs and then discuss some different equilibrium scenarios. There are two countries - home and foreign(*). Three different goods are produced and sold on perfectly competitive market. Goods 0 are numeraire which is produced one for one from labor and pins down the wage at unity. Goods 1 and 2 are nonnumeraire. Home is a natural importer of good 1 and foreign is a natural importer of good 2. Goods 1 and 2 sectors are assumed to be mirror-image. To be precise, sectors 1 and 2 are exactly the same except that the role of two countries exchanges - home importer (foreign exporter) in sector 1 is equivalent to foreign importer (home exporter) in sector 2. In the rest of this paper, like HMS, I focus on sector 1 problem. As the two sectors are a mirror-image, maximizing the global welfare of each sector is equivalent to maximizing the welfare of each country. The main reason why the sector's welfare can be studied independently is that it is a partial equilibrium model and there is no cross-sector externality. Below, I discuss supply and demand side problems using a non-specified functional form. In the latter sections where state uncertainty and contracting costs are introduced, I use a specification with linear

demand and supply.

2.1. Supply side problem

From now on, I focus on the home country problem since the discussion of foreign country is similar. The labor demand for producing X_j quantity of goods $j \in \{1, 2\}$ is $L_j = g_j(X_j)$ where $g'_j > 0$ and $g''_j > 0$. q_j is the home producer price. The home producer maximizes profits by choosing production quantity X_j given producer price q_j and the first order condition is

$$q_j = g'_j(X_j) \quad (1)$$

The solution $X_j(q_j)$ is an increasing function of producer price q_j .

2.2. Demand side problem

The mass of the population in each country is 1 and the utility function of home country is

$$U = c_0 + \sum_{j=1}^2 u_j(c_j) - \gamma_1 C_1 + \sigma_1 X_1, \quad (2)$$

where c_j is individual consumption and C_j is aggregate consumption of goods j . In each country, there exist externalities in its importing sector. γ_1 is negative externality of consuming good 1 in home country, e.g., a pollutant. σ_1 is positive externality of producing good 1 in the home country which can be taken as a simplified political element. By introducing importing-sector externalities, the country is given legitimacy to conduct certain policy interventions in its importing sector and free trade is not an efficient outcome.⁵ In the following sections, γ_1 and σ_1 are considered as two sources of state uncertainty that affect the endogenous choice of the optimal agreement differently. Individual maximizes U by choosing c_j such that budget constraint $c_0 + \sum_{j=1}^2 p_j c_j = 1$ is satisfied and ignores the effect of individual consumption c_j on aggregate consumption C_j . p_j is home consumer price of good j . u_j is a concave function and the first-order condition of good j is

$$u'_j(D_j) = p_j \quad (3)$$

The demand function $D_j(p_j)$ is a decreasing function of consumer price p_j . Because of the mirror-image assumption, in the rest of the paper, I drop the subscript for sectors and focus on sector 1 problem where home country is the importer.

2.3. Importing sector policy instruments and welfare functions

Like HMS, I focus on the government's importing sector intervention. Each country is assumed to possess two policy instruments in its importing sector. In goods 1 sector, the home country possesses a border instrument - import tariff τ and a domestic instrument - production subsidy s while the foreign country is totally passive.⁶ Therefore, the monopolistic power regarding terms-of-trade manipulation is assumed to be fully attributed to the importing country. The underlying assumption is that the primary inefficiency of international trade is terms-of-trade manipulation which mainly comes from the importer side. The Expanding Trade

⁵An efficient/first-best outcome is defined as the one where the global gross welfare is maximized.

⁶In sector 2, the role of home and foreign country is inverse.

Chapter in the Phase One agreement includes commitments from China to import US goods and services, which suggests that the US government believes the Chinese government intervenes in its import massively and opportunistically and terms-of-trade manipulation is one of the main issues that the Phase One agreement attempts to deal with. By introducing a relatively rich set of importing-sector policy instruments, when drafting a trade agreement becomes costly, there is a trade-off between the number of costly policy instruments included and the contracting costs. The following equations give price relations and market clearing condition in sector 1.⁷

$$\begin{aligned}
q &= p + s \\
p &= p^* + \tau \\
p^* &= q^* \\
D(p) + D^*(p^*) &= X(q) + X^*(q^*)
\end{aligned} \tag{4}$$

There are 4 equations and 6 unknowns. Producer prices and consumer prices can be written as a function of tariff τ and subsidy s . The partial derivative of home consumer price p regarding tariff τ and subsidy s are

$$\begin{aligned}
\frac{\partial p}{\partial \tau} &= \frac{D^{*'} - X^{*'}}{D' + D^{*'} - X' - X^{*'}} > 0 \\
\frac{\partial p}{\partial s} &= \frac{X'}{D' + D^{*'} - X' - X^{*'}} < 0
\end{aligned} \tag{5}$$

With the above two equations, it is easy to obtain $\frac{\partial q}{\partial \tau} = \frac{\partial p}{\partial \tau} > 0$, $\frac{\partial p^*}{\partial \tau} = \frac{\partial q^*}{\partial \tau} = \frac{\partial p}{\partial \tau} - 1 < 0$, $\frac{\partial q}{\partial s} = \frac{\partial p}{\partial s} + 1 > 0$ and $\frac{\partial p^*}{\partial s} = \frac{\partial q^*}{\partial s} = \frac{\partial p}{\partial s} < 0$. Country-specific welfare (W and W^*) and global welfare W^G of sector 1 can be written as a function of τ and s .

$$\begin{aligned}
W(\tau, s) &= \Gamma(\tau, s) + \Pi(\tau, s) + \tau M(\tau, s) - sX(\tau, s) + \sigma X(\tau, s) - \gamma D(\tau, s) \\
W^*(\tau, s) &= \Gamma^*(\tau, s) + \Pi^*(\tau, s) \\
W^G(\tau, s) &= W(\tau, s) + W^*(\tau, s),
\end{aligned} \tag{6}$$

where Γ (Γ^*) is home (foreign) consumer surplus, Π (Π^*) is home (foreign) producer profits, $\tau M - sX$ is home government's net revenue and $\sigma X - \gamma D$ captures the home net externality. Before proceeding to equilibrium solution, recall that the following conditions should hold.

$$\begin{aligned}
u'(D(p)) &= p & q &= g'(X(q)) & M &= D(p) - X(q) \\
\Gamma(p) &= u(D(p)) - pD(p) & \Pi(q) &= qX(q) - g(X(q)) & M &= E^* \\
u^{*'}(D^*(p^*)) &= p^* & q^* &= g^{*'}(X^*(q^*)) & E^* &= X^*(q^*) - D^*(p^*) \\
\Gamma^*(p^*) &= u^*(D^*(p^*)) - p^*D^*(p^*) & \Pi^*(q^*) &= q^*X^*(q^*) - g^*(X^*(q^*)), & &
\end{aligned}$$

where M is home import and E^* is foreign export.

2.4. Equilibria

In this subsection, I discuss several equilibrium scenarios under different objectives and constraints, which helps to better understand where inefficiency comes from and how to solve it.

⁷Subsidy s and tariff τ follow an additive form. Using a multiplicative form, the results are similar.

2.4.1. Efficient equilibrium

I begin with an efficient equilibrium where global welfare W^G is maximized and it is the first-best outcome. The first-order conditions are

$$\begin{aligned}\frac{\partial W^G(\tau, s)}{\partial \tau} &= [(\tau - \gamma)D' - (\tau + s - \sigma)X'] \frac{D^{*'} - X^{*'}}{D' + D^{*'} - X' - X^{*'}} = 0 \\ \frac{\partial W^G(\tau, s)}{\partial s} &= [(\tau - \gamma)D' - (\tau + s - \sigma)X'] \frac{X'}{D' + D^{*'} - X' - X^{*'}} - (\tau + s - \sigma)X' = 0\end{aligned}\quad (7)$$

Solve the above two equations and the first-best solution is

$$\begin{aligned}\tau^e &= \gamma \\ s^e &= \sigma - \gamma\end{aligned}\quad (8)$$

The first-best solution is a Pigouvian tax where tariff τ and subsidy s are only used to correct consumption externality γ and production externality σ such that government revenue net of externality terms $\tau M - sX + \sigma X - \gamma D$ equals 0. Free trade is not an efficient outcome as externalities exist.

2.4.2. Nash equilibrium (NE)

In the Nash equilibrium, the home country chooses tariff τ and subsidy s so as to maximize its welfare in sector 1 and it is a non cooperative equilibrium. The first-order conditions are

$$\begin{aligned}\frac{\partial W(\tau, s)}{\partial \tau} &= [-D + X + (\tau - \gamma)D' - (\tau + s - \sigma)X'] \frac{D^{*'} - X^{*'}}{D' + D^{*'} - X' - X^{*'}} + D - X = 0 \\ \frac{\partial W(\tau, s)}{\partial s} &= [-D + X + (\tau - \gamma)D' - (\tau + s - \sigma)X'] \frac{X'}{D' + D^{*'} - X' - X^{*'}} - (\tau + s - \sigma)X' = 0\end{aligned}\quad (9)$$

Solve the above two equations and NE solution is

$$\begin{aligned}\tau^n &= \gamma + \frac{E^*}{E^{*'}} \\ s^n &= \sigma - \gamma,\end{aligned}\quad (10)$$

where $E^{*'} = X^{*'} - D^{*'} = \frac{\partial X^*}{\partial q^*} - \frac{\partial D^*}{\partial p^*} > 0$ and $E^* = X^* - D^* = D - X > 0$. $\frac{E^*}{E^{*'}}$ captures home country's motive to manipulate terms-of-trade by taxing excessively foreign exports. The motive is stronger as either the trade volume E^* is greater or the foreign export elasticity $E^{*'}$ is smaller. Compared to the above efficient equilibrium, the solution for the home subsidy is the same - $s = \sigma - \gamma$ while there is an extra terms-of-trade manipulation term $\frac{E^*}{E^{*'}}$ in the tariff solution. When both tariff τ and subsidy s can be chosen freely, the home country prefers to use τ rather than s to manipulate the terms-of-trade, which implies that tariff τ , as a border policy instrument, is more efficient to manipulate terms-of-trade.⁸

⁸As shown in HMS, restricting the use of tariff alone can improve over the NE outcome while it cannot reach the first-best outcome because subsidy is used to manipulate the terms-of-trade instead. Moreover, HMS show that restricting the use of subsidy alone cannot improve over the NE outcome.

2.4.3. NE with import volume constraint

In this subsection, I consider an outcome-based constraint, namely import volume constraint which corresponds approximately to China's import commitments in the Expanding Trade Chapter. Suppose there exists an additional constraint such that home import volume is bound over $M \geq m$. I assume that this constraint is always binding which is equivalent to $M = m$. For a given import volume constraint, the home country chooses tariff τ and subsidy s to maximize its own welfare.

$$\begin{aligned} & \max_{\tau, s} W(\tau, s) \\ & s.t. M(\tau, s) = D(\tau, s) - X(\tau, s) \geq m \end{aligned} \quad (11)$$

The Lagrangian problem can be written as

$$\begin{aligned} \mathcal{L} &= W(\tau, s) + \mu(D(\tau, s) - X(\tau, s) - m) \\ &= \Gamma(\tau, s) + \Pi(\tau, s) + (\tau + \mu)M(\tau, s) - sX(\tau, s) + \sigma X(\tau, s) - \gamma D(\tau, s) - \mu m \end{aligned} \quad (12)$$

As the constraint is assumed to be always binding, $\mu > 0$ is a shadow welfare price of the home country due to increasing import volume. In other words, μ captures the extra weight that the home country puts on import volume M . $(\tau + \mu)M$ is the sum of tariff revenue and the extra weight of the import volume, and the manner in which the import volume constraint affects the Lagrangian equation is similar to that of a tariff. The first-order conditions are

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial \tau} &= [-D + X + (\tau + \mu - \gamma)D' - (\tau + \mu + s - \sigma)X'] \frac{D^{*'} - X^{*'}}{D' + D^{*'} - X' - X^{*'}} + D - X = 0 \\ \frac{\partial \mathcal{L}}{\partial s} &= [-D + X + (\tau + \mu - \gamma)D' - (\tau + \mu + s - \sigma)X'] \frac{X'}{D' + D^{*'} - X' - X^{*'}} - (\tau + \mu + s - \sigma)X' = 0 \end{aligned} \quad (13)$$

The above equations are very similar to (9) in NE except that τ is substituted by $\tau + \mu$. Therefore, the solution is also similar to NE solution.

$$\begin{aligned} \tau^m &= \gamma + \frac{E^*}{E^{*'}} - \mu \\ s^m &= \sigma - \gamma \end{aligned} \quad (14)$$

As import volume is constrained, only the tariff is used to satisfy this constraint while the subsidy remains at efficient level $\sigma - \gamma$. The import volume constraint is a constraint on a border outcome. The above result implies that the border instrument tariff τ is the first-best instrument to be applied as the border outcome is constrained. Recall that the foreign country is totally passive in goods 1 sector. There is a one-to-one mapping between home import (foreign export), foreign prices and foreign welfare. Constraining home import pins down foreign welfare directly. Thus, the choice of home instruments cannot affect foreign welfare. Denote home imports in efficient equilibrium by M^e . Imposing an import volume constraint such that $M \geq M^e$ is able to reach the first-best outcome.⁹ There is the following proposition.

Proposition 1

When terms-of-trade manipulation is the only source of cross-border externality, an outcome-based constraint $M \geq M^e$ can achieve the first-best outcome where global welfare W^G is maximized. This is equivalent to a (first-best) instrument-based constraint such that $\tau = \gamma$ and $s = \sigma - \gamma$.

⁹Given import volume M and subsidy s , tariff τ is assumed to be uniquely determined.

Proposition 1 states that in addition to constraining both border and domestic policy instruments, constraining the import volume outcome alone can achieve the first best outcome.¹⁰ In the current framework, the import volume constraint is highly effective in addressing terms-of-trade manipulation which is the sole source of cross-border inefficiency. The result is robust when a micro-founded political element is included; the foreign country is an active policy-instrument user; product standards are considered as an alternative policy instrument and multiple countries are introduced.¹¹ Here, I provide a brief explanation for the case where the foreign country is also policy-active. When both countries are policy active, the way that one affects the other's welfare is through the world price p^w . A country's welfare is pinned down by the world price p^w and its own choice of policy instruments. For a given choice of policy instruments, there is a one-to-one mapping between world price p^w and import (export) volume. In other words, for a given import volume constraint and foreign country's choice of policy instruments, the world price p^w is pinned down and the home country cannot use its policy instruments to manipulate foreign welfare and extract extra profits through world price p^w . Therefore, the import volume constraint deals well with the inefficiency of terms-of-trade manipulation.

Remark 1

The import/export volume constraint generates the first best (efficient) outcome in a set of models where (i) the inefficiency comes from one country being able to manipulate the other countries' welfare through the trade channel; (ii) for a given country, its welfare is pinned down by its policy choices, e.g, tariff, subsidy, etc., and trade flows with the other countries; (iii) given fixed welfare of the other country, a country maximizes its own welfare without manipulating the other country's welfare (behaves in an efficient way) and (iv) a unique efficient outcome is achieved when all countries behave in an efficient way simultaneously and trade flows are set at the first-best level.

The above results regarding import volume constraint are not robust when other cross-border externalities exist. In Appendix B, I show a case where there are two policy-active countries and non-trade cross-border externalities exist. The intuition is that the terms-of-trade manipulation is a cross-border inefficiency that is directly related to trade volume. For cross-border externalities that are not directly related to trade volume, they cannot be solved by import volume constraints. In the rest of the paper, I use a linear demand and supply framework as in HMS(2006) where

$$\begin{aligned}
D(p) &= \alpha - \beta p & X(q) &= \lambda q & u(p) &= \frac{\alpha^2}{2\beta} - \frac{\beta}{2}p^2 \\
M &= D(p) - X(q) & \Gamma(p) &= u(D(p)) - pD(p) & \Pi(q) &= \frac{1}{2}\lambda q^2 \\
M &= E^* & D^*(p^*) &= \alpha^* - \beta^*p^* & X^*(q^*) &= \lambda^*q^* \\
u^*(p^*) &= \frac{\alpha^{*2}}{2\beta^*} - \frac{\beta^*}{2}p^{*2} & E^* &= X^*(q^*) - D^*(p^*) & \Gamma^*(p^*) &= u^*(D^*(p^*)) - p^*D^*(p^*) \\
\Pi^*(q^*) &= \frac{1}{2}\lambda^*q^{*2}
\end{aligned}$$

The prices and home import can be written as a function of tariff τ and subsidy s .¹² The prices

¹⁰Not all types of outcome-based agreements can achieve the first-best outcome. For example, imposing a constraint on domestic production X cannot reach the first best outcome. However, it can still improve over NE.

¹¹For product standard as an alternative policy instrument, see Appendix A for more details.

¹²Using linear demand and supply, the solution of efficient import volume is $M^e = \frac{(\alpha - \lambda\sigma - \beta\gamma)(\beta^* + \lambda^*) - \alpha^*(\beta + \lambda)}{\beta + \lambda + \beta^* + \lambda^*}$.

and home import volume are assumed to be positive.¹³

$$\begin{aligned}
p(\tau, s) &= \frac{\alpha + \alpha^* + (\beta^* + \lambda^*)\tau - \lambda s}{\beta + \lambda + \beta^* + \lambda^*} \\
q(\tau, s) &= \frac{\alpha + \alpha^* + (\beta^* + \lambda^*)\tau + (\beta + \beta^* + \lambda^*)s}{\beta + \lambda + \beta^* + \lambda^*} \\
p^*(\tau, s) &= q^*(\tau, s) = \frac{\alpha + \alpha^* - (\beta + \lambda)\tau - \lambda s}{\beta + \lambda + \beta^* + \lambda^*} \\
M(\tau, s) &= \frac{(\beta^* + \lambda^*) \left[\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - (\beta + \lambda)\tau - \lambda s \right]}{\beta + \lambda + \beta^* + \lambda^*}
\end{aligned} \tag{15}$$

3. State uncertainty and costs of contracting

In this section, state uncertainty and contracting costs are illustrated in detail where I follow the setting of HMS (2006) closely. Compared to HMS (2006), I also take into account contracting costs on import volume M . As the state of the world is assumed to be uncertain, the home country is permitted to alter its policy choice from one state to another, which can bring a global welfare improvement. Meanwhile, the home country also has the incentive to alter its policy choice in order to manipulate its terms-of-trade, which is inefficient. As contracting is costly, there is a trade-off between the completeness of the contract and contracting costs. In addition, when an agreement is not state contingent and only includes one policy instrument, to make it complete, there is a trade-off between introducing state contingency or contracting on another policy instrument.

As in HMS, I assume that there are three sources of uncertainty - a home consumption externality γ , a home production externality σ , and a home demand shifter α , which are referred to as state variables. The negative consumption externality $-\gamma$ can be taken as pollution due to home consumption. The positive production externality $+\sigma$ can represent the home country's support for domestic production. The demand shifter α can represent domestic consumers' preferences and/or income. In the real world, these three state variables are very likely to be uncertain and the choice of the optimal trade agreement depends on both the source and magnitude of uncertainty. To keep the model simple, each state variable is assumed to follow a two-point distribution. Namely, γ can be either $\gamma_h = \bar{\gamma} + \Delta_\gamma$ or $\gamma_l = \bar{\gamma} - \Delta_\gamma$ with probability $\frac{1}{2}$; σ can be either $\sigma_h = \bar{\sigma} + \Delta_\sigma$ or $\sigma_l = \bar{\sigma} - \Delta_\sigma$ with probability $\frac{1}{2}$ and α can be either $\alpha_h = \bar{\alpha} + \Delta_\alpha$ or $\alpha_l = \bar{\alpha} - \Delta_\alpha$ with probability $\frac{1}{2}$. Both countries are equally informed of all parameters. In the next section, I discuss each source of uncertainty at a time.

Unlike HMS, I consider both instrument-based agreements and outcome-based agreements. An instrument-based agreement contracts on policy instruments - tariff τ and/or subsidy s . An outcome-based agreement contracts on import volume M . There exist three types of contracting costs. The cost of contracting on a state variable γ , σ or α is c_s . The cost of contracting on a policy instrument τ or s is c_p . The cost of contracting on import-volume outcome M is c_o . Once a state variable is contracted on, the agreement can be written state-contingently regarding this variable. For instance, suppose that an agreement contracts on tariff τ state-contingently regarding consumption externality γ . The agreement is able to set a specific constraint on τ for each possible γ state. However, if it's non state-contingent, the agreement can only set the same constraint on τ across different possible γ states. For simplicity, I only consider agreements that impose separate equality constraints on τ , s and M . As in HMS, if one variable is included in the agreement, the associated cost is assumed to be incurred only once, regardless of how many

¹³See appendix F for a discussion on parameter constraints.

times that variable is mentioned in the agreement. The total cost of writing an agreement is

$$C = c_s \cdot n_s + c_p \cdot n_p + c_o \cdot n_o \quad (16)$$

where n_s , n_p and n_o are the number of state, policy and outcome variables included in an agreement respectively. A non state-contingent agreement $\{\tau = 3\}$ costs c_p ; a state-contingent agreement $\{\tau = \gamma, s = 5\}$ costs $2c_p + c_s$ and a state-contingent agreement $\{M = m(\gamma)\}$ costs $c_0 + c_s$. The contracting cost setting is similar to Battigalli and Maggi (2002). As a trade agreement is more complete, i.e., with more policy or outcome variables included and/or more state variables included, it becomes more costly.

Some additional assumptions are imposed on contracting costs. The cost of contracting on import volume c_o is assumed to be greater than $2c_p$ and $c_p + c_s$ and smaller than $2c_p + c_s$, i.e., $c_o \geq 2c_p$, $c_o \geq c_p + c_s$ and $c_o \leq 2c_p + c_s$. In other words, I assume that a non-state-contingent agreement on import volume costs more than all the other policy-instrument-based agreements except for a (first-best) state-contingent agreement on both tariff and subsidy which costs $2c_p + c_s$. By making the above assumptions, I am able to examine under which conditions a non-state-contingent agreement on import volume can be preferred even if it is extremely costly.

Before closing this section, I would like to mention one extra advantage of an outcome-based agreement. Consider a case where the home country possesses multiple perfectly substitutable border and domestic policy instruments other than tariff and subsidy. The price relations can be written as

$$\begin{aligned} p &= p^* + \sum_{i=1}^{n_b} b_i = p^* + b \\ q &= p^* + \sum_{i=1}^{n_b} b_i + \sum_{j=1}^{n_d} d_j = p^* + b + d, \end{aligned} \quad (17)$$

where n_b is number of border instruments and n_d is number of domestic instruments. b_i is a specific border policy instrument and d_i is a specific domestic policy instrument. b and d capture the overall effect of border instruments and domestic instruments respectively. To reach the first-best outcome, imposing constraints on policy instruments can be very costly since all of the border and domestic instruments need to be included and the number is $n_b + n_d$ in total. Instead, contracting state-contingently on import volume alone can reach the first-best outcome. In this case, an outcome-based contract can be relatively more appealing.

Remark 2

When the home country possesses a larger number of substitutable policy instruments, an outcome-based contract on import volume M becomes relatively more appealing.

Remark 2 states that when the home country owns a vast array of border and domestic policy instruments or is able to invent new instruments easily, comprehensive control over all policy instruments is required for an instrument-based agreement which can be very costly. An outcome-based agreement becomes more preferable as it includes only one constraint on import volume. In the rest of the paper, I just focus on the case where the home country possesses only two policy instruments - tariff and subsidy.

I follow HMS timing of the model: (i) the agreement is drafted; (ii) the uncertainty is resolved; and (iii) the country chooses policies to maximize its own welfare provided that they are not set by the agreement directly. In the next section, I show the comparison between non-state-contingent outcome-based agreement and other instrument-based agreements under different state uncertainty.

4. Optimal agreement choice: non state-contingent outcome-based agreement vs the others

As trade agreement contract is costly, an optimal agreement is the one in which the expected global welfare net of contracting costs is maximized. I focus on one-dimensional uncertainty and treat different cases of uncertainty separately. Denote the set that includes all feasible trade agreements by A . The optimal trade agreement a^o solves

$$a^o = \operatorname{argmax}_{a \in A} \Omega(a) - C(a) \quad (18)$$

Where $\Omega(a) = EW^G(a)$ is the expected gross global welfare and $C(a)$ are the contracting costs of trade agreement a . All feasible trade agreements can be depicted on a (C, Ω) plane. a is the optimal agreement if and only if for any other feasible agreement $a' \in A$, $(C(a'), \Omega(a'))$ lies below the 45 degree line that passes through $(C(a), \Omega(a))$.

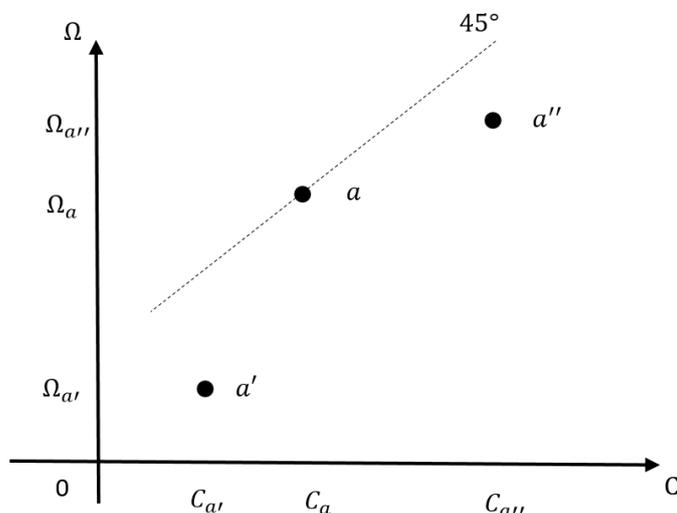


Figure 1: Optimal agreement

Figure 1 gives a simple illustration of the definition of the optimal agreement. Among the three agreements a , a' and a'' , a is the optimal agreement. Although a is more costly than a' , the increase in welfare from a' to a is able to cover the extra cost. Meanwhile, the increase in welfare from a to a'' is not sufficiently high enough and cannot cover the extra cost of moving from a to a'' . Below, I focus on the pairwise comparison between the non-state-contingent outcome-based agreement and other agreements under different state uncertainty.

4.1. Uncertainty over the consumption externality γ

I begin with the case where the consumption externality γ is the only source of uncertainty. Recall that the realization of γ can be either the high state $\gamma_h = \bar{\gamma} + \Delta_\gamma$ or the low state $\gamma_l = \bar{\gamma} - \Delta_\gamma$ with probability $\frac{1}{2}$. The expectation of γ is $E(\gamma) = \bar{\gamma}$. γ can be considered pollutants. As consumption becomes more polluting, the home country has the incentive to increase the tariff and reduce the subsidy so as to reduce home consumption. $\tau(\gamma)$ and $s(\gamma)$ or $M(\gamma)$ denote state-contingent policy or outcome variable. As a state-contingent policy or outcome variable is included, the trade agreement is able to set a specific value of the variable in each state. τ and s or M denote the non state-contingent policy or outcome variable. As a non state-contingent policy or outcome variable is included, the trade agreement is only able to

set one specific value of the variable which is invariant across different states. $\{FB\}$ denotes the agreement that reaches the first-best outcome of *gross* welfare. There are two ways to draft a first-best agreement, namely, a state-contingent instrument-based agreement $\{\tau(\gamma), s(\gamma)\}$ and state-contingent outcome-based agreement $\{M(\gamma)\}$. Since there is no cost of rewriting, the former costs $2c_p + c_s$ and the latter costs $c_o + c_s$. The other possible agreements are $\{\tau, s\}$, $\{\tau(\gamma)\}$, $\{M\}$, $\{\tau\}$ and $\{\emptyset\}$. $\{\emptyset\}$ means there is no trade agreement. As mentioned in HMS, a trade agreement that contracts on subsidy s alone cannot improve over non cooperative equilibrium. Thus a trade agreement such as $\{s(\gamma)\}$ or $\{s\}$ will never be chosen. The following lemma states that $\{M, \tau\}$ and $\{M, s\}$ agreements are dominated by $\{M\}$ agreement.

Lemma 1

As import volume M is contracted on in a trade agreement, there is further no need to contract on tariff τ or subsidy s additionally.

Proof: As foreign country is assumed to be totally passive, both foreign welfare $W^*(p^*)$ and foreign export $E^*(p^*)$ are a function of foreign price p^* . As foreign exports equal home imports $E^*(p^*) = M$ and there is a one-to-one mapping between p^* and M , foreign welfare W^* can be rewritten as a function of M and agreement $\{M\}$ is able to pin down foreign welfare directly. Conditional on a fixed foreign welfare W^* , global welfare W^G is maximized when home welfare W is maximized and it is sub-optimal to further contract on tariff or subsidy.

Lemma 1 implies that under agreement $\{M\}$, the home country and a social planner that maximizes global welfare make the same decision. In other words, the only inefficiency comes from the non-state-contingency of $\{M\}$ itself rather than the home country's incentive to manipulate the terms-of-trade. Recall that the costs of contracting on import volume c_o are assumed to be greater than $2c_p$ and $c_p + c_s$ and smaller than $2c_p + c_s$, i.e., $c_o \geq 2c_p$, $c_o \geq c_p + c_s$ and $c_o \leq 2c_p + c_s$. Agreement $\{M\}$ is the second most costly. $\{M\}$ is more costly than agreements $\{\tau, s\}$ and $\{\tau(\gamma)\}$ but less costly than the first-best agreement $\{\tau(\gamma), s(\gamma)\}$.¹⁴ As the welfare can be written as a function of τ and s , the table below shows the solutions of τ and s under different trade agreements.¹⁵

¹⁴As I assume $c_o > 2c_p$, the first-best agreement $\{M(\gamma)\}$ costs more than the first-best agreement $\{\tau(\gamma), s(\gamma)\}$ and the latter is always preferred.

¹⁵See appendix C for more details. In appendix C, I also give a pairwise comparison between the gross welfare of each agreement and the properties of each pairwise comparison. $\star_\gamma = \frac{\beta(\beta^* + \lambda^*)}{k} \Delta_\gamma$ and $\circ_\gamma = \frac{(\Upsilon - \beta)\Upsilon - \lambda(\beta + \lambda)}{\Upsilon^2 - \lambda(\beta + \lambda)} \Delta_\gamma$.

| all possible agreements | costs | solution for (τ, s) |
|--|--------------------------------|--|
| $\{FB\} = \{\tau(\gamma), s(\gamma)\}$ or $\{M(\gamma)\}$ | $2c_p + c_s$ or $c_o + c_s$ | $\tau = \bar{\gamma} \pm \Delta_\gamma$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ |
| $\{M\}$ | c_o | $\tau = \bar{\gamma} \pm \Delta_\gamma \mp \frac{\beta \Delta_\gamma}{\beta + \lambda}$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ |
| $\{\tau, s\}$ | $2c_p$ | $\tau = \bar{\gamma}$ $s = \sigma - \bar{\gamma}$ |
| $\{\tau(\gamma)\}$ | $c_p + c_s$ | $\tau = \bar{\gamma} + \lambda \bar{\xi}_\gamma \pm \Delta_\gamma \mp \lambda \star_\gamma$ $s = \sigma - \bar{\gamma} + \Upsilon \bar{\xi}_\gamma \mp \Delta_\gamma \mp \Upsilon \star_\gamma$ |
| $\{\tau\}$ | c_p | $\tau = \bar{\gamma} + \lambda \bar{\xi}_\gamma$ $s = \sigma - \bar{\gamma} + \Upsilon \bar{\xi}_\gamma \mp \Delta_\gamma \pm \circ_\gamma$ |
| $\{\emptyset\}$ | 0 | $\tau = \bar{\gamma} + \bar{\delta}_\gamma \pm \Delta_\gamma \mp \frac{\beta}{\beta + \lambda + \Upsilon} \Delta_\gamma$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ |

Table 1: Solution of (τ, s)

\pm means high state is $+$ and low state is $-$. \mp means high state is $-$ and low state is $+$. The orange terms solve the baseline home domestic externality and baseline refers to the case where there is no state uncertainty, i.e., $\Delta_\gamma = 0$. Across all the trade agreement specifications, the orange terms are the same. This is because dealing with the baseline externality is the common interest of both home country and the trade agreement designer. The blue terms capture the baseline terms-of-trade manipulation motive. $\bar{\delta}_\gamma$ is the magnitude of terms-of-trade manipulation in the case where there is no state uncertainty and the home country chooses τ and s freely. $\bar{\xi}_\gamma = \frac{(\beta^* + \lambda^*)(\beta + \lambda + \Upsilon)}{k} \bar{\delta}_\gamma$ which is a function of $\bar{\delta}_\gamma$.¹⁶ As agreement $\{M\}$ is able to reach the first-best outcome in the case of zero uncertainty, it can deal well with the motive of baseline terms-of-trade manipulation and the blue terms do not appear in the solution of agreement $\{M\}$. The same reasoning applies to agreement $\{\tau, s\}$. The purple terms capture the reaction to uncertainty. One advantage of agreement $\{M\}$ is that both tariff τ and subsidy s are able to react to the state uncertainty Δ_γ . The reactions to shock Δ_γ between $\{M\}$ and $\{FB\}$ are similar except that tariff τ under-reacts to shock in agreement $\{M\}$. Before proceeding to the comparison between different agreements, I would like to discuss the $\{M\}$ agreement further. There is the following remark.

Remark 3

When the consumption externality γ or the production externality σ is the source of uncertainty, under the non-state-contingent $\{M\}$ agreement, the solution of tariff τ and subsidy s between high state and low state should have the following relation: $(\beta + \lambda)\tau_h + \lambda s_h = (\beta + \lambda)\tau_l + \lambda s_l$. When the home demand shifter α is the source of uncertainty, the following relation should be satisfied: $(\beta + \lambda)\tau_h + \lambda s_h - \alpha_h = (\beta + \lambda)\tau_l + \lambda s_l - \alpha_l$.

Proof is straightforward as $M(\tau, s) = \frac{(\beta^* + \lambda^*) \left[\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - (\beta + \lambda)\tau - \lambda s \right]}{\beta + \lambda + \beta^* + \lambda^*}$ and under agreement $\{M\}$, import volume M is invariant across the high and low states.

Remark 3 states that as γ or σ are the source of state uncertainty, under agreement $\{M\}$, it is impossible that only tariff τ (subsidy s) reacts to the shock while subsidy s (tariff τ) does not. The non-state contingency of agreement $\{M\}$ imposes some constraints on τ and s across high

¹⁶ $\bar{\delta}_\gamma = \frac{\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - \lambda \sigma - \beta \bar{\gamma}}{\beta + \lambda + \Upsilon}$, $\Upsilon = \beta + \lambda + \beta^* + \lambda^*$ and $k = \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2$.

and low states. Recall that between import volume M , tariff τ and subsidy s , any two of the three pin down the value of the third one. In terms of flexibility, agreement $\{M\}$ is similar to the non-state-contingent agreement on tariff $\{\tau\}$. Nevertheless, they are not the same. Under the non-state-contingent agreement on tariff $\{\tau\}$, the home country can still use subsidy s to manipulate its terms of trade. At the same time, agreement $\{\tau\}$ allows import volume M to change between the high and low states, which can be appealing in some cases. Later I show that the choice between these two agreements depends on the source and magnitude of state uncertainty. When the consumption externality γ is the source of uncertainty and there are no contracting costs, the following proposition illustrates the relation between agreement $\{M\}$ and the other agreements.

Proposition 2

When there is state uncertainty $\Delta_\gamma > 0$ and zero contracting costs ($c_p = c_s = c_o = 0$), the following pairwise relations between $\{M\}$ and the other trade agreements are satisfied:

- (1) $\{M\} \prec \{FB\} \sim \{\tau(\gamma), s(\gamma)\} \sim \{M(\gamma)\}$
- (2) $\{M\} \succ \{\tau, s\}$
- (3) $\{M\} \succ \{\tau(\gamma)\}$ if Δ_γ is not large
- (4) $\{M\} \succ \{\tau\}$
- (5) $\{M\} \succ \{\emptyset\}$ if Δ_γ is not large

Proof: See the pairwise comparison table between each trade agreement in appendix C.

The first inequality (1) is straightforward. From table 1, agreement $\{M\}$ under-reacts to uncertainty Δ_γ compared to the $\{FB\}$ agreement. This is because $\{M\}$ is a semi-flexible agreement. In other words, with regard to trade volume, $\{M\}$ is perfectly inflexible. To reach the first-best outcome, trade volume M should react to the state uncertainty. Without contracting costs, $\{M\}$ is preferred to $\{\tau, s\}$. Both agreements can deal well with the baseline terms-of-trade manipulation. However, under agreement $\{M\}$, the solution of tariff τ and subsidy s is state-contingent while under $\{\tau, s\}$ agreement, the solution is non state-contingent. The state-contingency under agreement $\{M\}$ is desirable. As both solutions are compared with the first-best solution, the solution for agreement $\{M\}$ is relatively more similar to the first-best solution with regard to reaction to shocks. Compared to the state-contingent agreement $\{\tau(\gamma)\}$, agreement $\{M\}$ is able to shut down the baseline terms-of-trade manipulation entirely while $\{\tau(\gamma)\}$ agreement cannot. However, agreement $\{\tau(\gamma)\}$ is able to give more flexibility. Namely, under agreement $\{\tau(\gamma)\}$, import volume M is flexible while it is totally inflexible under agreement $\{M\}$. When uncertainty Δ_γ is large, $\{\tau(\gamma)\}$ is preferred as it offers more flexibility. Compared with the non-state-contingent agreement $\{\tau\}$, agreement $\{M\}$ shuts down baseline terms-of-trade manipulation and provides more flexibility regarding the use of tariff τ . Putting $\{M\}$ and $\{\tau\}$ side by side with $\{FB\}$, the solution for agreement $\{M\}$ is close to the first-best solution regarding the reaction to state uncertainty. Under agreement $\{\tau\}$, the choice of tariff is totally inflexible, which is unappealing. Recall that tariff τ is the wedge between home consumer price p and foreign consumer price p^* . When home consumption externality γ is the source of uncertainty, the first best way is to target home consumers only. However, an inflexible tariff ties the foreign consumer price to the home consumer price, which means home consumers can not be targeted separately without affecting foreign consumers directly. The last pairwise comparison is trivial. Agreement $\{M\}$ solves the baseline terms-of-trade manipulation while there is more flexibility under the empty trade agreement. It is also easy to make a triple-wise comparison and there is a following lemma.

Lemma 2

The indifference curves between three trade agreements share the same intersection point on a $(\Delta^2, \bar{\delta}^2)$ plane as long as they are nonparallel.

Proof: Suppose there exist three agreements $\{a\}$, $\{b\}$ and $\{c\}$ with contracting costs c_a , c_b and c_c respectively. Three indifference curves $\frac{\Omega_{\{a\}} - \Omega_{\{b\}}}{c_a - c_b} = 1$, $\frac{\Omega_{\{a\}} - \Omega_{\{c\}}}{c_a - c_c} = 1$ and $\frac{\Omega_{\{b\}} - \Omega_{\{c\}}}{c_b - c_c} = 1$ divide the plane (x, y) where x denotes Δ^2 and y denotes $\bar{\delta}^2$. Assume that the three curves are nonparallel. $(x_{ab,ac}, y_{ab,ac})$ denotes the intersection point of $\frac{\Omega_{\{a\}} - \Omega_{\{b\}}}{c_a - c_b} = 1$ and $\frac{\Omega_{\{a\}} - \Omega_{\{c\}}}{c_a - c_c} = 1$. Moreover, $\frac{\Omega_{\{b\}} - \Omega_{\{c\}}}{c_b - c_c} = 1$ as $x = x_{ab,ac}$ and $y = y_{ab,ac}$, which means $(x_{ab,ac}, y_{ab,ac})$ also locates on the line $\frac{\Omega_{\{b\}} - \Omega_{\{c\}}}{c_b - c_c} = 1$. In other words, $\frac{\Omega_{\{a\}} - \Omega_{\{b\}}}{c_a - c_b} = 1$, $\frac{\Omega_{\{a\}} - \Omega_{\{c\}}}{c_a - c_c} = 1$ and $\frac{\Omega_{\{b\}} - \Omega_{\{c\}}}{c_b - c_c} = 1$ share the same intersection point.

Using the above lemma 2, I can pick any three agreements and compare them easily on a $(\Delta^2, \bar{\delta}^2)$ plane. I first compare agreement $\{M\}$ with the two non state-contingent agreements $\{\tau, s\}$ and $\{\tau\}$. From the above lemma, the intersection point of $\frac{\Omega_{\{M\}} - \Omega_{\{\tau\}}}{c_o - c_p} = 1$ and $\frac{\Omega_{\{\tau, s\}} - \Omega_{\{\tau\}}}{c_p} = 1$ should locate on the line $\frac{\Omega_{\{M\}} - \Omega_{\{\tau, s\}}}{c_o - 2c_p} = 1$.

Lemma 3:

On a plane $(\Delta_\gamma^2, \bar{\delta}_\gamma^2)$, $\Delta_\gamma^2 = \frac{2(\beta+\lambda)}{\beta\lambda}(c_o - 2c_p)$ is indifference curve between $\{M\}$ and $\{\tau, s\}$ agreements; $\bar{\delta}_\gamma^2 = -k_1\Delta_\gamma^2 + k_3(c_o - c_p)$ is the indifference curve between agreements $\{M\}$ and $\{\tau\}$; $\bar{\delta}_\gamma^2 = k_2\Delta_\gamma^2 + k_3c_p$ is the indifference curve between agreements $\{\tau, s\}$ and $\{\tau\}$.¹⁷ The three indifference curves divide $(\Delta_\gamma^2, \bar{\delta}_\gamma^2)$ into three regions where $\{\tau\}$, $\{\tau, s\}$ or $\{M\}$ is the optimal one among the three respectively.

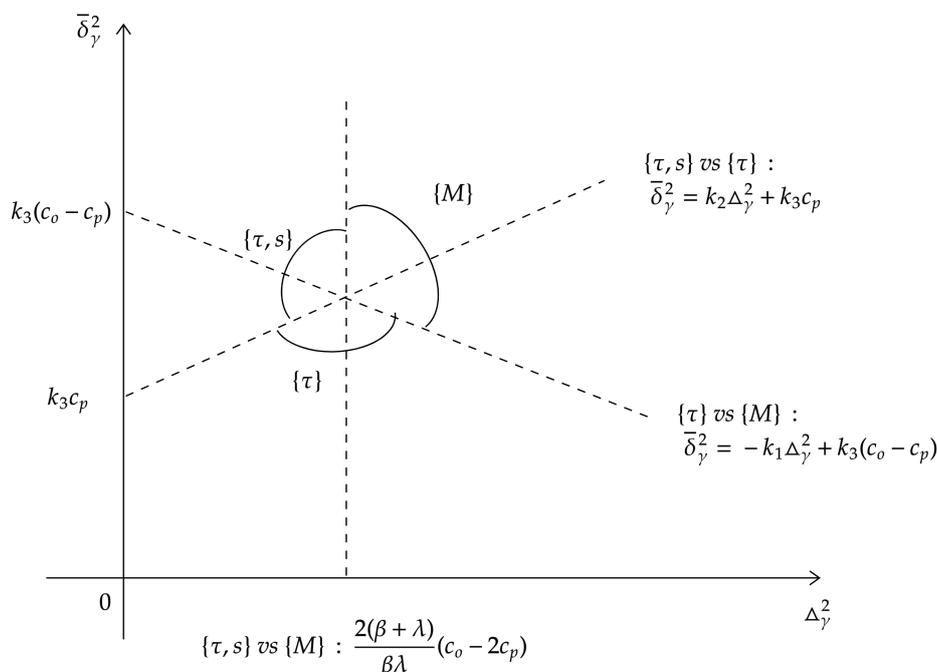


Figure 2: 3 agreement case - non state contingent

The circular arc indicates the corresponding optimal region for each agreement. When baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ and state uncertainty Δ_γ are relatively small, agreement $\{\tau\}$ is preferred to $\{\tau, s\}$ and $\{M\}$. Agreement $\{\tau\}$ is able to partially solve the baseline terms-of-trade manipulation and give some flexibility such that subsidy s is able to react to γ shock. As state uncertainty Δ_γ becomes greater, $\{\tau\}$ is more and more preferred to $\{\tau, s\}$. Compared to the non-state-contingent agreement $\{\tau, s\}$, the extra flexibility provided by agreement $\{\tau\}$ becomes substantially more desirable when uncertainty is large. When baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ becomes greater, $\{\tau\}$ becomes less and less preferred to $\{M\}$ and $\{\tau, s\}$. The choice is made between $\{\tau, s\}$ and $\{M\}$ agreements. When baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ is relatively intense in comparison with the state uncertainty Δ_γ , agreement $\{\tau, s\}$ is preferred as it solves the baseline terms-of-trade manipulation and is less costly. Nevertheless, when state uncertainty Δ_γ is large, $\{M\}$ becomes relatively more preferred as it allows both τ and s to react to the uncertainty. In addition, there is a following lemma.

Lemma 4:

When the home consumption externality γ or the production externality σ is the source of uncertainty, the expected foreign welfare is the same for agreements $\{\tau, s\}$ and $\{M\}$.

As the baseline terms-of-trade manipulation is perfectly solved under both agreements $\{\tau, s\}$ and $\{M\}$, their indifference curve is only a function of state uncertainty Δ_γ . Lemma 4 states that $\{M\}$ outperforms agreement $\{\tau, s\}$ with respect to the expected home welfare. Namely, the extra flexibility under agreement $\{M\}$ allows the home country to better react to the uncertainty. Moreover, the indifference curve between the two is a decreasing function of home's demand slope β and supply slope λ . As β or λ becomes larger (home consumers or producers become more price-sensitive), changing tariff τ or subsidy s has a stronger effect on welfare. Since agreement $\{\tau, s\}$ does not allow tariff τ or subsidy s to react to the uncertainty, it becomes more unattractive in this case. As β tends toward 0, the slope of the indifference curve between $\{\tau, s\}$ and $\{\tau\}$ and the slope of the indifference curve between $\{\tau\}$ and $\{M\}$ tend toward 0.¹⁸ In this case, the reaction to the state uncertainty Δ_γ is a second order problem compared to the terms-of-trade manipulation. The intuition is simple. As β tends toward 0, home demand becomes extremely inelastic and $D(p) \rightarrow \alpha$. The direct effect of the consumption externality γ on welfare is through the term $\gamma D(p)$. When home demand is inelastic, the expectation of this term is close to $\bar{\gamma}\alpha$ which does not react to the uncertainty. As a consequence, the terms-of-trade manipulation becomes the only first-order concern.

I next compare agreement $\{M\}$ with the two state-contingent agreements $\{\tau(\gamma), s(\gamma)\}$ and $\{\tau(\gamma)\}$. Similarly, I draw three indifference curves $\frac{\Omega_{\{\tau(\gamma), s(\gamma)\}} - \Omega_{\{M\}}}{2c_p + c_s - c_o} = 1$, $\frac{\Omega_{\{\tau(\gamma), s(\gamma)\}} - \Omega_{\{\tau(\gamma)\}}}{c_p} = 1$ and $\frac{\Omega_{\{M\}} - \Omega_{\{\tau(\gamma)\}}}{c_o - c_p - c_s} = 1$ which share the same intersection point.

Lemma 5:

On a plane $(\Delta_\gamma^2, \bar{\delta}_\gamma^2)$, $\Delta_\gamma^2 = \frac{2(\beta+\lambda)\Upsilon}{\beta^2(\beta^*+\lambda^*)}(2c_p + c_s - c_o)$ is indifference curve between $\{\tau(\gamma), s(\gamma)\}$ and $\{M\}$ agreements; $\bar{\delta}_\gamma^2 = -\beta^2 k_4 \Delta_\gamma^2 + k_3 c_p$ is indifference curve between $\{\tau(\gamma), s(\gamma)\}$ and $\{\tau(\gamma)\}$ agreements; $\bar{\delta}_\gamma^2 = \beta^2 k_5 \Delta_\gamma^2 + k_3(c_o - c_p - c_s)$ is indifference curve between $\{M\}$ and

¹⁷ $k_1 = \frac{\beta[k+\beta\Upsilon^2 - \beta\lambda(\beta+\lambda)]\Upsilon k}{(\beta+\lambda)(\beta^*+\lambda^*)(k+\beta\Upsilon^2)^2}$, $k_2 = \frac{\beta^2[k-\lambda(\beta+\lambda)(\beta^*+\lambda^*)]k}{(\beta^*+\lambda^*)^2(k+\beta\Upsilon^2)^2}$ and $k_3 = \frac{2\Upsilon k}{\lambda(\beta^*+\lambda^*)^2(\beta+\lambda+\Upsilon)^2}$ where $k = \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2$. Based on the assumption of contracting costs, $c_o > 2c_p$ and $k_3(c_o - c_p) > k_3 c_p$. $\frac{k_1}{k_2} = \frac{(\beta^*+\lambda^*)\Upsilon[k+\beta\Upsilon^2 - \beta\lambda(\beta+\lambda)]}{\beta(\beta+\lambda)[k-\lambda(\beta+\lambda)(\beta^*+\lambda^*)]}$.

¹⁸ A caveat is that the change of β also has an effect on baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ itself.

$\{\tau(\gamma)\}$ agreements.¹⁹ The three indifference curves divide $(\Delta_\gamma^2, \bar{\delta}_\gamma^2)$ into three regions where $\{\tau(\gamma)\}$, $\{M\}$ or $\{\tau(\gamma), s(\gamma)\}$ is the optimal agreement.

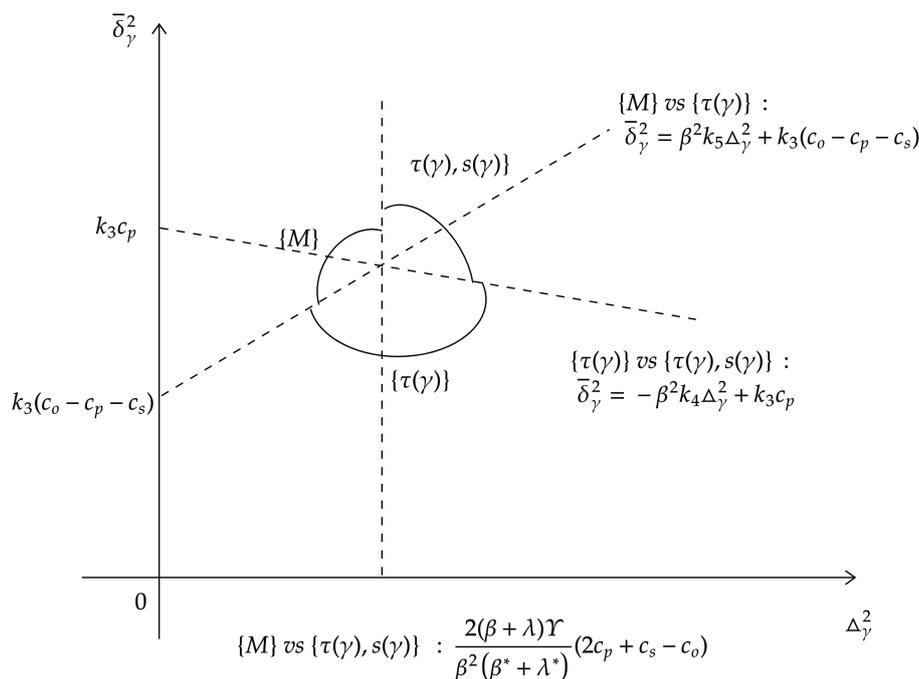


Figure 3: 3 agreement case - state contingent

The circular arc indicates the corresponding optimal region for each agreement. When baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ is not intense, $\{\tau(\gamma)\}$ is preferred to $\{M\}$ and $\{\tau(\gamma), s(\gamma)\}$. When the state uncertainty Δ_γ becomes greater, $\{\tau(\gamma)\}$ is more and more preferred to $\{M\}$. Agreement $\{\tau(\gamma)\}$ allows both import volume M and tariff (wedge between home consumer price and foreign consumer price) to react to the shock while import volume is rigid under agreement $\{M\}$. Moreover, in terms of the reaction to uncertainty, $\{\tau(\gamma)\}$ is relatively more similar to the first-best agreement $\{\tau(\gamma), s(\gamma)\}$ than to agreement $\{M\}$. It is easy to show that $\beta^2 k_4 < \frac{1}{4}$ and $\frac{k_5}{k_4} > 3$. Compared to the first-best agreement $\{\tau(\gamma), s(\gamma)\}$, the major disadvantage of $\{\tau(\gamma)\}$ is regarding the baseline terms-of-trade manipulation. In other words, regarding the reaction to shocks, agreement $\{M\}$ underperforms the other two agreements. However, as home demand slope β tends toward 0, home consumption is inelastic and reaction to shock becomes less important. In this case, agreement $\{M\}$ becomes relatively more preferred than the other two. Comparing $\{M\}$ with $\{\tau(\gamma), s(\gamma)\}$, the difference increases when the slope of home supply λ decreases. The intuition is that as home supply becomes more inelastic (smaller λ), the adjustment of home consumption relies more on import volume and a fixed import volume under $\{M\}$ agreement becomes less desirable. As baseline terms-of-trade manipulation $\bar{\delta}_\gamma$ and state uncertainty Δ_γ are large, the first-best agreement $\{\tau(\gamma), s(\gamma)\}$ is preferred to both $\{M\}$ and $\{\tau(\gamma)\}$, which is trivial.

¹⁹ $k_4 = \frac{1}{(\beta+\lambda+\Upsilon)^2}$, $k_5 = \frac{k-\lambda(\beta+\lambda)(\beta^*+\lambda^*)}{\lambda(\beta+\lambda)(\beta^*+\lambda^*)(\beta+\lambda+\Upsilon)^2}$ and $k_3 = \frac{2\Upsilon k}{\lambda(\beta^*+\lambda^*)^2(\beta+\lambda+\Upsilon)^2}$ where $k = \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2$. As c_o is assumed to be greater than $c_p + c_s$ and smaller than $2c_p + c_s$, $k_3 c_p > k_3(c_o - c_p - c_s) > 0$. $\beta^2 k_4 < \frac{1}{4}$ and $\frac{k_5}{k_4} = \frac{\Upsilon[\Upsilon^2 + \lambda(\beta^* + \lambda^* - \beta - \lambda)]}{\lambda(\beta + \lambda)(\beta^* + \lambda^*)}$ is greater than 3.

4.2. Uncertainty over the production externality σ

In this subsection, the production externality σ is the source of uncertainty. The realization of σ can be either the high state $\sigma_h = \bar{\sigma} + \Delta_\sigma$ or the low state $\sigma_l = \bar{\sigma} - \Delta_\sigma$ with probability $\frac{1}{2}$. There are two ways to draft a first best agreement $\{FB\} - \{\tau(\sigma), s(\sigma)\}$ and $\{M(\sigma)\}$. The other possible agreements are $\{\tau, s\}$, $\{\tau(\sigma)\}$, $\{M\}$, $\{\tau\}$ and $\{\emptyset\}$. As above, I assume that c_o is greater than $2c_p$ and $c_p + c_s$ and smaller than $2c_p + c_s$, i.e., $c_o \geq 2c_p$, $c_o \geq c_p + c_s$ and $c_o \leq 2c_p + c_s$, which means the first-best agreement $\{M(\sigma)\}$ is never chosen and a non-state-contingent agreement on import volume $\{M\}$ is the second most costly. The table below shows the solutions of τ and s under different trade agreements.²⁰

| all possible agreements | costs | solution of (τ, s) |
|---|-----------------------------|--|
| $\{FB\} = \{\tau(\sigma), s(\sigma)\}$ or $\{M(\sigma)\}$ | $2c_p + c_s$ or $c_o + c_s$ | $\tau = \gamma$ $s = \bar{\sigma} - \gamma \pm \Delta_\sigma$ |
| $\{M\}$ | c_o | $\tau = \gamma \mp \frac{\lambda \Delta_\sigma}{\beta + \lambda}$ $s = \bar{\sigma} - \gamma \pm \Delta_\sigma$ |
| $\{\tau, s\}$ | $2c_p$ | $\tau = \gamma$ $s = \bar{\sigma} - \gamma$ |
| $\{\tau(\sigma)\}$ | $c_p + c_s$ | $\tau = \gamma + \lambda \xi_\sigma \mp \lambda \star_\sigma$ $s = \bar{\sigma} - \gamma + \Upsilon \bar{\xi}_\sigma \pm \Delta_\sigma \mp \Upsilon \star_\sigma$ |
| $\{\tau\}$ | c_p | $\tau = \gamma + \lambda \xi_\sigma$ $s = \bar{\sigma} - \gamma + \Upsilon \bar{\xi}_\sigma \pm \Delta_\sigma \mp \bigcirc_\sigma$ |
| $\{\emptyset\}$ | 0 | $\tau = \gamma + \bar{\delta}_\sigma \mp \frac{\lambda}{\beta + \lambda + \Upsilon} \Delta_\sigma$ $s = \bar{\sigma} - \gamma \pm \Delta_\sigma$ |

Table 2: Solution of (τ, s)

\pm means high state is $+$ and low state is $-$. \mp means high state is $-$ and low state is $+$. As in the section of γ uncertainty, the orange terms solve the baseline home domestic externality and the blue terms capture the motive of baseline terms-of-trade manipulation.²¹ The purple terms capture the reaction to uncertainty. Unlike the case of state uncertainty γ , the first best tariff $\tau = \gamma$ does not react to uncertainty Δ_σ . In the previous γ case, the main advantage of agreement $\{M\}$ is that both tariff τ and subsidy s are able to react to the state uncertainty Δ_γ . In the current case, the reaction of τ to the state uncertainty is unappealing. Agreement $\{\tau\}$ becomes relatively more attractive as it performs better in terms of the reaction to shocks, i.e., non state contingent tariff τ and state contingent subsidy s . The proposition below gives the pairwise comparison between $\{M\}$ and the other agreements when there are no contracting costs.

Proposition 3

As there is state uncertainty $\Delta_\sigma > 0$ and no contracting costs, the following pairwise relations between $\{M\}$ and the other trade agreements are satisfied.

- (1) $\{M\} \prec \{FB\} \sim \{\tau(\sigma), s(\sigma)\} \sim \{M(\sigma)\}$
- (2) $\{M\} \succ \{\tau, s\}$

²⁰See Appendix D for more details. In Appendix D, I give a pairwise comparison between gross welfare of each agreement and the property of each pairwise comparison. $\star_\sigma = \frac{\lambda(\beta^* + \lambda^*)}{k} \Delta_\sigma$ and $\bigcirc_\sigma = \frac{\lambda(\beta^* + \lambda^*)}{\Upsilon^2 - \lambda(\beta + \lambda)} \Delta_\sigma$.

²¹ $\bar{\delta}_\sigma = \frac{\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - \lambda \bar{\sigma} - \beta \gamma}{\beta + \lambda + \Upsilon}$ and $\bar{\xi}_\sigma = \frac{(\beta^* + \lambda^*)(\beta + \lambda + \Upsilon)}{k} \bar{\delta}_\sigma$ which is a function of $\bar{\delta}_\sigma$.

(3) $\{M\} \succ \{\tau(\sigma)\}$ if Δ_σ is not large

(4) $\{M\} \succ \{\tau\}$ if Δ_σ is not large

(5) $\{M\} \succ \{\emptyset\}$ if Δ_σ is not large

Proof: see the pairwise comparison table between each trade agreement in Appendix D.

Without contracting costs, $\{M\}$ still outperforms $\{\tau, s\}$ and the intuition is the same as before. Compared to agreement $\{\tau\}$, agreement $\{M\}$ is preferred in terms of dealing with baseline terms-of-trade manipulation while it is less desirable in terms of the reaction to uncertainty. In order to impose a non-state-contingent import constraint, under agreement $\{M\}$, tariff τ is forced to react to the state uncertainty, which means home consumers and foreign consumers are targeted differently across high and low states. In other words, under agreement $\{M\}$, home producer cannot be targeted separately without treating home and foreign consumers differently across high and low states, which is unappealing. Under agreement $\{\tau\}$, the choice of τ is totally inflexible. In this case, home and foreign consumers are able to be treated equally across high and low states and only home producers receive different treatment across the two states. Consequently, as state uncertainty Δ_σ becomes larger, $\{\tau\}$ becomes more and more preferred to $\{M\}$.

Using the lemma of triple-comparison, I first compare agreement $\{M\}$ with the two non-state-contingent agreements $\{\tau, s\}$ and $\{\tau\}$ as in the previous section. The three indifference curves $\frac{\Omega_{\{M\}} - \Omega_{\{\tau\}}}{c_o - c_p} = 1$, $\frac{\Omega_{\{\tau, s\}} - \Omega_{\{\tau\}}}{c_p} = 1$ and $\frac{\Omega_{\{M\}} - \Omega_{\{\tau, s\}}}{c_o - 2c_p} = 1$ divide plane $(\Delta_\sigma^2, \bar{\delta}_\sigma^2)$ and share the same intersection point.

Lemma 6:

On a plane $(\Delta_\sigma^2, \bar{\delta}_\sigma^2)$, $\Delta_\sigma^2 = \frac{2(\beta+\lambda)}{\beta\lambda}(c_o - 2c_p)$ is indifference curve between $\{M\}$ and $\{\tau, s\}$ agreements; $\bar{\delta}_\sigma^2 = k_6\Delta_\sigma^2 + k_3(c_o - c_p)$ is indifference curve between $\{M\}$ and $\{\tau\}$ agreements; $\bar{\delta}_\sigma^2 = \left(\frac{\beta\lambda}{2(\beta+\lambda)}k_3 + k_6\right)\Delta_\sigma^2 + k_3c_p$ is indifference curve between $\{\tau, s\}$ and $\{\tau\}$ agreements.²² The three indifference curves divide $(\Delta_\sigma^2, \bar{\delta}_\sigma^2)$ into three regions where $\{\tau\}$, $\{\tau, s\}$ or $\{M\}$ is the optimal one among the three respectively.

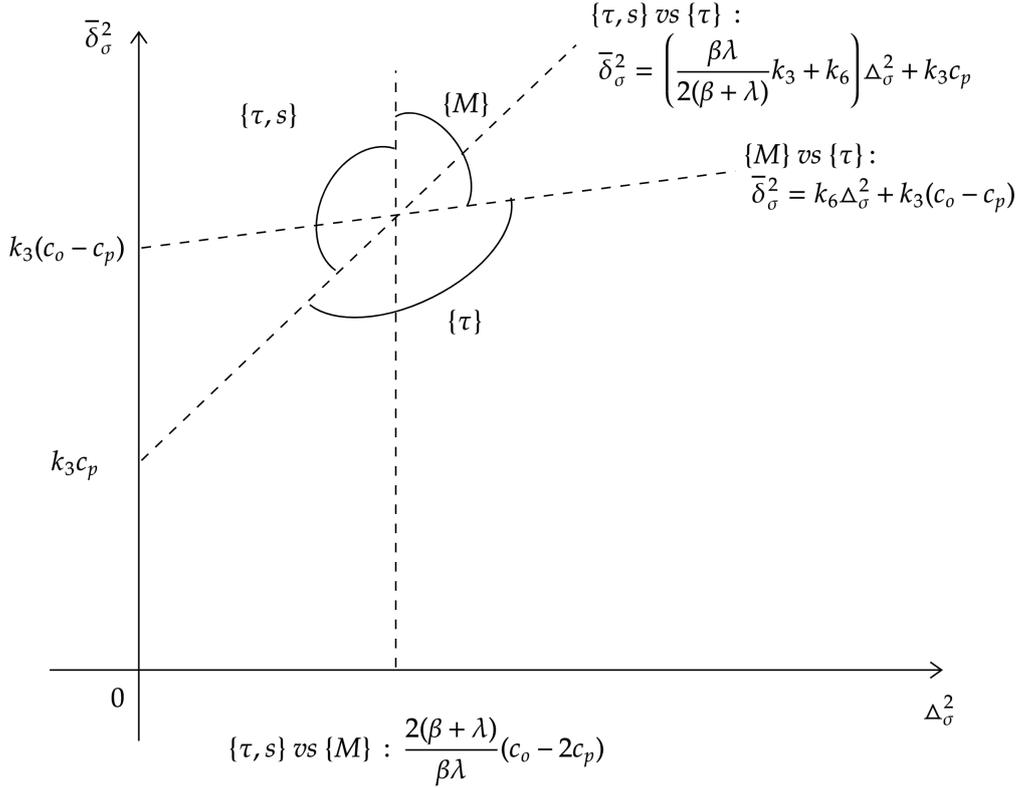


Figure 4: 3 agreement case - non state contingent

The circular arc indicates the corresponding optimal region for each agreement. Compared to the previous γ case, the angle of the optimal $\{M\}$ region is smaller. When σ is the source of uncertainty, the solution for the first-best agreement is semi-state-contingent in that tariff τ is non-flexible and only subsidy s reacts to the uncertainty. Under agreement $\{M\}$, both tariff and subsidy react to the uncertainty and they over-react. Agreement $\{\tau\}$ is similar to the first-best agreement and is semi-flexible in which only the subsidy is flexible. Unlike in previous γ case, agreement $\{\tau\}$ is relatively more preferred to agreement $\{M\}$ in terms of reaction to shocks. An interesting point is that comparing $\{\tau, s\}$ with $\{M\}$, the indifference curve is the same as in the previous section of γ uncertainty. The shrinkage of the optimal $\{M\}$ region is only driven by the decline in performance of $\{M\}$ relative to $\{\tau\}$.

I next compare agreement $\{M\}$ with the two state-contingent agreements $\{\tau(\sigma), s(\sigma)\}$ and $\{\tau(\sigma)\}$. The three indifference curves are $\frac{\Omega_{\{\tau(\sigma), s(\sigma)\}} - \Omega_{\{M\}}}{2c_p + c_s - c_o} = 1$, $\frac{\Omega_{\{\tau(\sigma), s(\sigma)\}} - \Omega_{\{\tau(\sigma)\}}}{c_p} = 1$ and $\frac{\Omega_{\{M\}} - \Omega_{\{\tau(\sigma)\}}}{c_o - c_p - c_s} = 1$ respectively.

Lemma 7:

On a plane $(\Delta_\sigma^2, \bar{\delta}_\sigma^2)$, $\Delta_\sigma^2 = \frac{2(\beta + \lambda)\Upsilon}{\lambda^2(\beta^* + \lambda^*)}(2c_p + c_s - c_o)$ is the indifference curve between agreements $\{\tau(\sigma), s(\sigma)\}$ and $\{M\}$; $\bar{\delta}_\sigma^2 = -\lambda^2 k_4 \Delta_\sigma^2 + k_3 c_p$ is the indifference curve between agreements $\{\tau(\sigma), s(\sigma)\}$ and $\{\tau(\sigma)\}$; $\bar{\delta}_\sigma^2 = \lambda^2 k_5 \Delta_\sigma^2 + k_3(c_o - c_p - c_s)$ is the indifference curve between agreements $\{M\}$ and $\{\tau(\sigma)\}$. The three indifference curves divide $(\Delta_\sigma^2, \bar{\delta}_\sigma^2)$ into three regions

$${}^{22}k_6 = \frac{\lambda[k - \lambda\Upsilon^2 - \lambda(\beta + \lambda)(2\beta^* + 2\lambda^* - \lambda)]\Upsilon k}{(\beta + \lambda)(\beta^* + \lambda^*)(k + \beta\Upsilon^2)^2} \text{ and } k_3 = \frac{2\Upsilon k}{\lambda(\beta^* + \lambda^*)^2(\beta + \lambda + \Upsilon)^2} \text{ where } k = \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2.$$

By assumption, $k_3(c_o - c_p) > k_3 c_p$.

where $\{\tau(\sigma)\}$, $\{M\}$ or $\{\tau(\sigma), s(\sigma)\}$ is the optimal one among the three respectively.

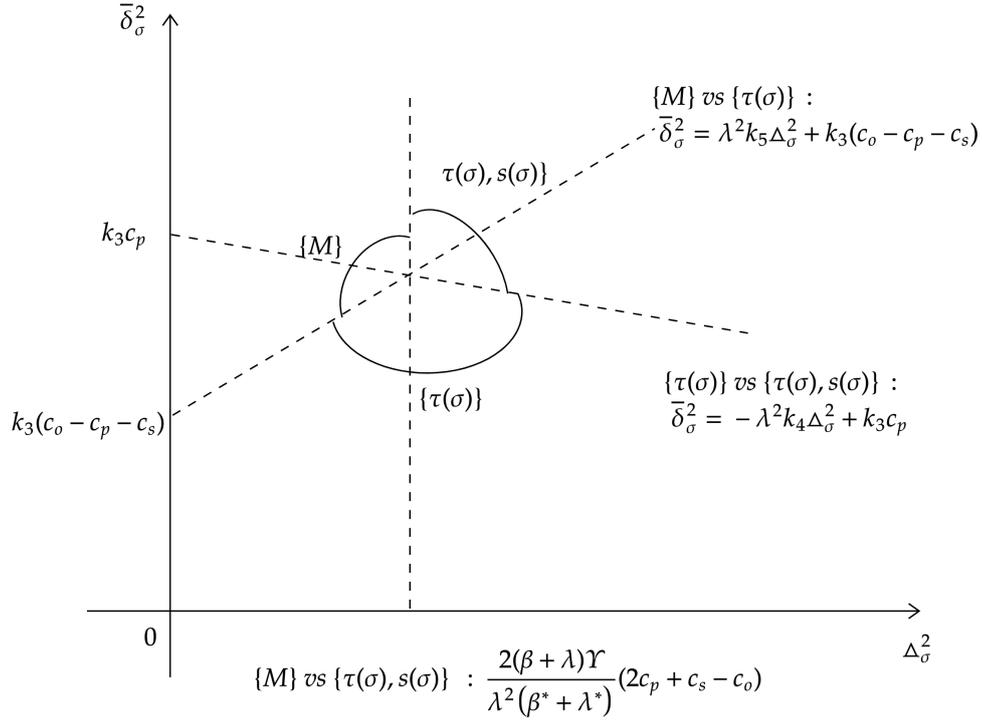


Figure 5: 3 agreement case - state contingent

The circular arc indicates the corresponding optimal region for each agreement. The graph is very similar to that in the γ case except that the magnitude of uncertainty Δ_σ is rescaled by a factor λ rather than β . The reason is that for the consumption externality γ , the uncertainty is directly magnified by the consumption slope β and for the production externality σ , the uncertainty is directly magnified by the supply slope λ . In the next subsection, I discuss the case where the home demand shifter is the source of uncertainty and compare the relative performance of agreement $\{M\}$ across the three sources of uncertainty.

4.3. Uncertainty over the home demand shifter α

In this subsection, the home demand shifter α is the source of uncertainty. The realization of α can be either high state $\alpha_h = \bar{\alpha} + \Delta_\alpha$ or low state $\alpha_l = \bar{\alpha} - \Delta_\alpha$ with probability $\frac{1}{2}$. There exist three ways to draft a first-best agreement $\{FB\}$ - $\{\tau(\alpha), s(\alpha)\}$, $\{M(\alpha)\}$ and $\{\tau, s\}$. Compared to the previous two cases, state contingency under $\{\tau(\alpha), s(\alpha)\}$ becomes redundant as a non state-contingent agreement $\{\tau, s\}$ is also the first best. However, the first-best outcome-based agreement $\{M(\alpha)\}$ still requires state contingency as α affects import volume M directly. The other possible agreements are $\{\tau(\alpha)\}$, $\{M\}$, $\{\tau\}$ and $\{\emptyset\}$. Recall that I assume $c_o \geq 2c_p$, $c_o \geq c_p + c_s$ and $c_o \leq 2c_p + c_s$. The table below shows the solutions of τ and s under different trade agreements.²³

²³See Appendix E for more details. In Appendix E, I also give a pairwise comparison between gross welfare of each agreement and the property of each pairwise comparison. $\bar{\xi}_\alpha = \frac{(\beta^* + \lambda^*)\bar{\alpha} - (\beta + \lambda)\alpha^* - \lambda(\beta^* + \lambda^*)\sigma - \beta(\beta^* + \lambda^*)\gamma}{k}$, $\star_\alpha = \frac{\beta^* + \lambda^*}{k}\Delta_\alpha$, $\circ_\alpha = \frac{\beta^* + \lambda^*}{\Upsilon^2 - \lambda(\beta + \lambda)}\Delta_\alpha$ and $\bar{\delta}_\alpha = \frac{\bar{\alpha} - \frac{\beta + \lambda}{\beta^* + \lambda^*}\alpha^* - \lambda\sigma - \beta\gamma}{\beta + \lambda + \Upsilon}$.

| all possible agreements | costs | solution of (τ, s) |
|---|---|--|
| $\{FB\} =$ $\{\tau(\alpha), s(\alpha)\}$ or $\{M(\alpha)\}$ or $\{\tau, s\}$ | $2c_p + c_s$ or $c_o + c_s$ or $2c_p$ | $\tau = \gamma$ $s = \sigma - \gamma$ |
| $\{M\}$ | c_o | $\tau = \gamma \pm \frac{\Delta_\alpha}{\beta + \lambda}$ $s = \sigma - \gamma$ |
| $\{\tau(\alpha)\}$ | $c_p + c_s$ | $\tau = \gamma + \lambda \bar{\xi}_\alpha \pm \lambda \star_\alpha$ $s = \sigma - \gamma + \Upsilon \bar{\xi}_\alpha \pm \Upsilon \star_\alpha$ |
| $\{\tau\}$ | c_p | $\tau = \gamma + \lambda \bar{\xi}_\alpha$ $s = \sigma - \gamma + \Upsilon \bar{\xi}_\alpha \pm \circ_\alpha$ |
| $\{\emptyset\}$ | 0 | $\tau = \gamma + \bar{\delta}_\alpha \pm \frac{\Delta_\alpha}{\beta + \lambda + \Upsilon}$ $s = \sigma - \gamma$ |

Table 3: Solution of (τ, s)

\pm means high state is $+$ and low state is $-$. \mp means high state is $-$ and low state is $+$. The first best solution for tariff τ and subsidy s is the same as that in the case of no uncertainty and is entirely non-state-contingent. When the home demand shifter α is the source of uncertainty, agreement $\{M\}$ becomes highly unattractive in terms of reacting to uncertainty. Under agreement $\{M\}$, the solution of tariff τ overreacts to uncertainty Δ_α . As agreement $\{M\}$ is assumed to be extremely costly and $c_o \geq 2c_p$, agreement $\{M\}$ is always dominated by $\{\tau, s\}$ and never chosen. The below proposition gives a pairwise comparison between $\{M\}$ and the other agreements as there are no contracting costs.

Proposition 4

As there is state uncertainty $\Delta_\alpha > 0$ and no contracting costs, there exist the following pairwise relations between $\{M\}$ and the other trade agreements:

- (1) $\{M\} \prec \{FB\} \sim \{\tau(\alpha), s(\alpha)\} \sim \{M(\alpha)\} \sim \{\tau, s\}$
- (2) $\{M\} \succ \{\tau(\alpha)\}$ if Δ_α is not large
- (3) $\{M\} \succ \{\tau\}$ if Δ_α is not large
- (4) $\{M\} \succ \{\emptyset\}$ if Δ_α is not large

Proof: see a pairwise comparison table between each trade agreement in Appendix E.

Without contracting costs, $\{M\}$ underperforms $\{\tau, s\}$. The first best agreement only needs to solve consumption and production externalities. Demand shifter α is independent of these two externalities. Therefore, the first-best instrument-based agreement on tariff τ and subsidy s does not need to correct for the uncertainty that comes from the demand shifter. Nevertheless, demand shifter α has a direct impact on import volume M . A non state-contingent agreement $\{M\}$ becomes unattractive as it does not allow import volume to change across states.

In Figure 6, I show the comparison between $\{M\}$, $\{\tau, s\}$ and $\{\tau\}$ across the three state uncertainties. The circular arc indicates the corresponding optimal region for each agreement. The rightmost one illustrates the case where demand shifter α is the source of uncertainty. As a non-state-contingent instrument-based agreement $\{\tau, s\}$ is the first best agreement and is less costly, the region in which $\{M\}$ is the optimal agreement is outside the feasible region where both

$\bar{\delta}_\alpha$ and Δ_α should be positive and agreement $\{M\}$ is never chosen. As non-state contingency of tariff τ and subsidy s is desired, $\{\tau\}$ underperforms agreement $\{\tau, s\}$ with respect to the reaction to uncertainty. Under agreement $\{\tau\}$, home country makes use of subsidy s to manipulate the terms-of-trade and overreacts to state uncertainty. The indifference curve between agreements $\{M\}$ and $\{\tau\}$ in the α uncertainty case is very similar to that in the σ uncertainty.²⁴ In both σ and α cases, $\{\tau\}$ outperforms $\{M\}$ in terms of reacting to state uncertainty. The underlying message is that letting τ react to a shock is undesirable when it should have been non-state contingent.

When the three uncertainty cases are compared in figure 6, for a given agreement among the three, I can rank its relative attractiveness across the three sources of uncertainty. For agreement $\{M\}$, its relative performance is the highest under the uncertainty over the home consumption externality γ , followed by the uncertainty over the home production externality σ and then followed by the uncertainty over the home demand shifter α . From γ to α uncertainty, less and less state contingency regarding policy instruments, e.g., tariff and subsidy is needed and $\{M\}$ becomes less and less attractive. For agreement $\{\tau\}$, its relative performance is best under uncertainty over σ , followed by uncertainty over γ and then followed by uncertainty over α . As agreement $\{\tau\}$ is capable of providing semi-state contingency on policy instrument s , it is more effective when only semi-state contingency on subsidy s is needed. For agreement $\{\tau, s\}$, its relative performance is the highest under α uncertainty, followed by γ uncertainty and then followed by σ uncertainty.

In Figure 7, I also show the comparison between $\{M\}$ and the two state-contingent agreements across the three state uncertainties. The relative position of each agreement's optimal region is similar across the three uncertainties except that the slopes of the indifference curves are rescaled by the home consumption slope β in the home consumption externality γ case and by home supply slope λ in the home production externality σ case. If Δ_γ is rescaled by β and Δ_σ is rescaled by λ , the three cases can be taken as the same. The performance of agreement $\{M\}$ is stable compared to the other two state-contingent agreements across different state uncertainties and is dominated by the other two with regard to reacting to uncertainty. The main advantage of $\{M\}$ is to solve the baseline terms-of-trade manipulation and costs relatively less (the costs for agreement $\{M\}$ is ranked second). For a given agreement among the three, I can also rank its relative attractiveness across the three sources of uncertainty, which depends on the relationship between β , λ and 1. For instance, assume $\beta > 1 > \lambda$. For agreement $\{M\}$, its relative performance is highest under home production externality σ uncertainty, followed by home demand shifter α uncertainty and then followed by home consumption externality γ uncertainty. As the performance of $\{M\}$ regarding the reaction to uncertainty is the worst among the three, it performs relatively better in the case where a reaction to uncertainty is less needed, i.e., under σ uncertainty with low supply slope λ .

²⁴The slope in the $\alpha(\sigma)$ uncertainty case is $\frac{k_6}{\lambda^2}(k_6)$. It is because the effect of home production externality σ is rescaled by the supply slope λ .

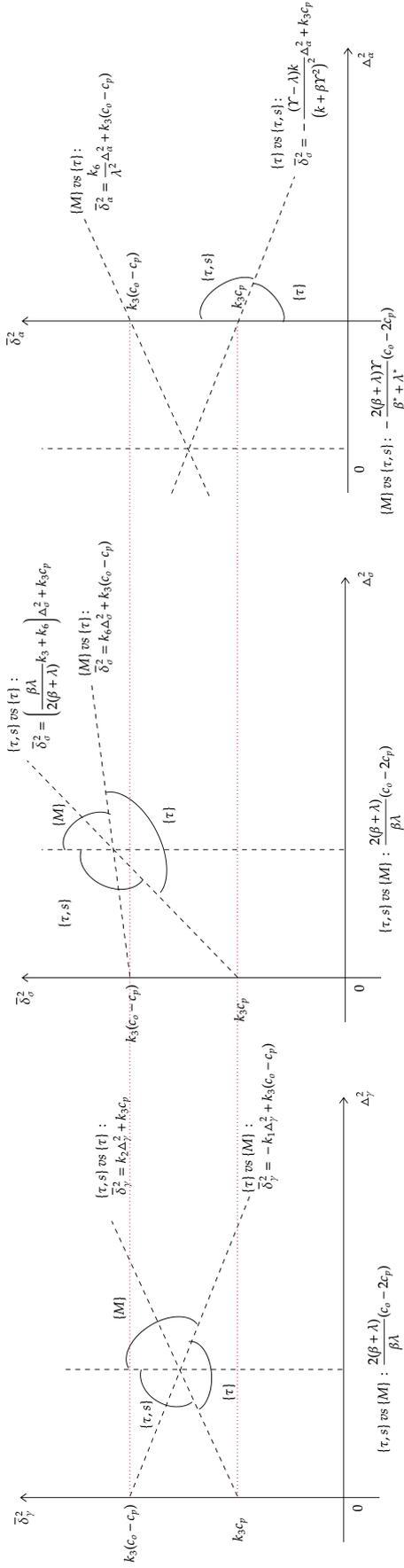


Figure 6: comparison across three uncertainties (from left to right - γ , σ and α)

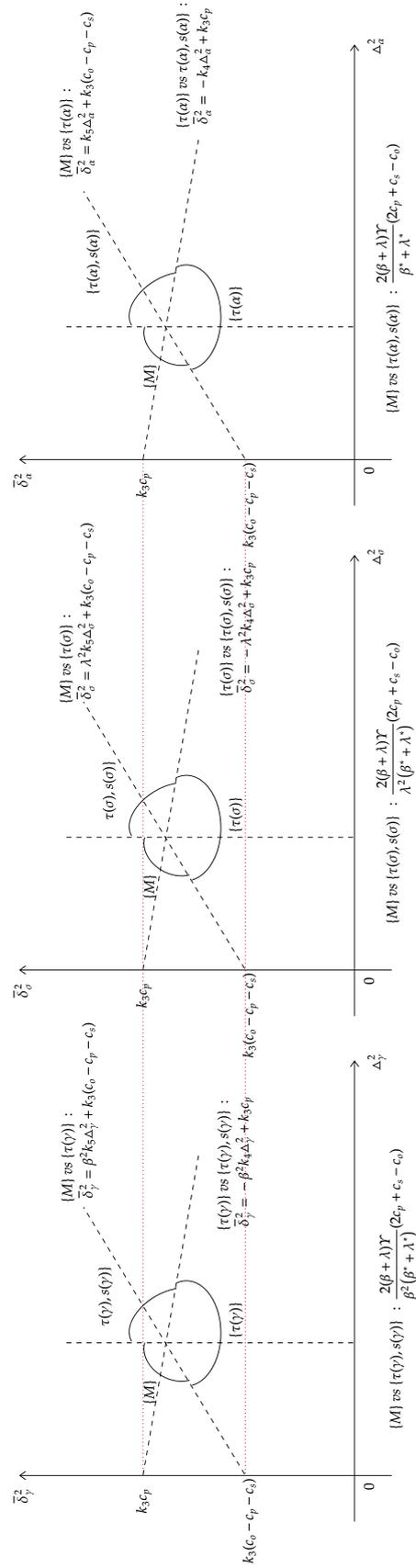


Figure 7: comparison across three uncertainties (from left to right - γ , σ and α)

5. Conclusion

In this paper, I study an outcome-based trade agreement, specifically on import volume constraint, in Horn, Maggi, and Staiger's framework with contracting costs and state uncertainty. This is inspired by the signature of the Phase One deal between the US and China. The Expanding Trade Chapter aims to address the US trade deficit with China where China makes a two-year purchasing commitment. It suggests that the US believes that China restricts its market access and this problem cannot be solved by the WTO's instrument-based system. In HMS framework, the way in which the importing country restricts its market access is by taxing foreign goods (directly or indirectly) so as to manipulate the terms-of-trade. Namely, the importing country exploits its market power by lowering foreign prices and transferring profits from foreign to home. My first finding is that when terms-of-trade manipulation is the only source of cross-border inefficiency and there are no contracting costs nor state uncertainty, an outcome-based agreement on import volume is able to solve the terms-of-trade manipulation perfectly and reach the first-best outcome. More specifically, as the only cross-border channel is through international trade and the home country manipulates foreign welfare exclusively via the world price, an outcome-based agreement on import volume can achieve the first-best outcome. This result is robust across various model settings. One important advantage of outcome-based agreements compared to instrument-based agreements is that outcome-based agreements only need to set one constraint on import volume to reach the first-best outcome while instrument-based agreements need to set constraints on all policy instruments. If we believe that China can easily invent a new policy instrument, in order to reach the first-best outcome, the cost of contracting on all policy instruments can actually be quite high, which is unfeasible.

When both state uncertainty and contracting costs are considered, a non-state-contingent outcome-based agreement gives the importing country some extra flexibility in terms of the use of tariffs and subsidies, which can be appealing in some cases. By assuming that a non-state-contingent outcome-based agreement is the second most costly, I am able to study the lower bound of the attractiveness of an outcome-based agreement. I focus on the trade-off between solving terms-of-trade manipulation and better reactions to state uncertainty. Compared with the two state-contingent instrument-based agreements, the non-state-contingent outcome-based agreement underperforms in terms of reactions to shocks and outperforms in terms of solving baseline terms-of-trade manipulation. The result is robust across the three different sources of state uncertainty. Compared with the two non-state-contingent instrument-based agreements, the non-state-contingent outcome-based agreement performs better in terms of solving the baseline terms-of-trade manipulation. Moreover, the outcome-based agreement performs better in terms of reaction to shocks when more flexibility regarding policy instruments is needed, i.e., under consumption externality uncertainty. The outcome-based agreement performs mediocre in terms of reaction to shocks when only semi-flexibility on policy instruments is needed, i.e., under production externality uncertainty. The outcome-based agreement underperforms in terms of reaction to shocks when no flexibility is needed, i.e., under demand shifter uncertainty. If we believe that drafting state-contingent contracts is too costly, an outcome-based agreement can be an appealing option which depends on the source of uncertainty.

One potential advantage of an outcome-based agreement that is not modeled in this paper is that an outcome-based agreement like import volume constraint can be revised more easily and frequently. For instance, the Phase One deal only sets a two-year purchase commitment, which suggests that the purchase commitment can be revised in a relatively shorter window while revising a WTO rule normally takes a much longer time. If we believe that the source and magnitude of uncertainty change from year to year, a shorter revision window of outcome-based agreements can be desired. So far I have been silent on the enforcement problem which is actually very important. As became evident, China failed its two-year purchase commitment in

the end.²⁵ I suggest studying outcome-based agreements and the enforcement problem together in future research. In addition, I study outcome-based agreements in a very simple framework and only consider international trade as the sole cross-border channel. More advanced trade models that incorporate monopolistic competition, extensive margin, financial assets, and other cross-border externalities, should be applied to study outcome-based agreements in the future.

²⁵It is partially caused by Covid. It is very likely that China had low demand during Covid and this negative demand shock cannot be well handled by an outcome-based agreement.

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Appendix

A. Product standard

Staiger and Sykes (2011) introduce product standard in a term of trade model. Here I show that import volume constraint is able to reach first best outcome as product standard is also an available instrument. Because of the existence of numeraire good sector, they can focus on one sector problem. There are two countries - home and foreign. They study the sector where goods are produced in both countries but only consumed in home country. Home demand function is $D(p) = \alpha - p$. Home and foreign supply function are $S = q - \phi(r)$ and $S^* = q^* - \phi^*(\rho)$ separately. r is standard on domestic produced goods. ρ is standard on imported goods. Both standards are set by home country. The price relation and market clearing condition are

$$\begin{aligned} p &= q + t \\ p &= q^* + \tau + \tau^* + t \\ q &= q^* + \tau + \tau^* \\ \alpha - p &= q - \phi(r) + q^* - \phi^*(\rho) \end{aligned} \tag{1}$$

Prices can be written as a function of τ , τ^* , t , r and ρ .

$$\begin{aligned} p &= \frac{\alpha + \tau + \tau^* + 2t + \phi(r) + \phi^*(\rho)}{3} \\ q &= \frac{\alpha + \tau + \tau^* - t + \phi(r) + \phi^*(\rho)}{3} \\ q^* &= \frac{\alpha - 2(\tau + \tau^*) - t + \phi(r) + \phi^*(\rho)}{3} \end{aligned} \tag{2}$$

The welfare functions are

$$\begin{aligned} W &= CS + PS + TR - Z \\ W^* &= PS^* + TR^* \\ W^G &= W + W^* \end{aligned} \tag{3}$$

Where

$$\begin{aligned} CS &= \frac{1}{2}\alpha^2 - \alpha p + \frac{1}{2}p^2 & PS &= \frac{1}{2}q^2 - \phi(r)q + \frac{1}{2}\phi^2(r) \\ TR &= t \cdot (\alpha - p) + \tau \cdot (q^* - \phi^*(\rho)) & Z &= \theta(r) \cdot (q - \phi(r)) + \theta^*(\rho) \cdot (q^* - \phi^*(\rho)) \\ PS^* &= \frac{1}{2}q^{*2} - \phi^*(\rho)q^* + \frac{1}{2}\phi^{*2}(\rho) & TR^* &= \tau^* \cdot (q^* - \phi^*(\rho)) \end{aligned}$$

Therefore, the solution of efficient equilibrium, NE and NE with import volume constraint are

$$\begin{array}{lll} \tau^e + \tau^{*e} = \theta^*(\rho^e) - \theta(r^e) & \tau^n = \theta^*(\rho^n) - \theta(r^n) + S^{*n} & \tau^m + \mu = \theta^*(\rho^m) - \theta(r^m) + S^{*m} \\ \backslash & \tau^{*n} = \frac{S^{*n}}{2} & \tau^{*m} + \mu^* = \frac{S^{*m}}{2} \\ t^e = \theta(r^e) & t^n = \theta(r^n) & t^m = \theta(r^m) \\ -\theta'(r^e) = \phi'(r^e) & -\theta'(r^n) = \phi'(r^n) & -\theta'(r^m) = \phi'(r^m) \\ -\theta^{*'}(\rho^e) = \phi^{*'}(\rho^e) & -\theta^{*'}(\rho^n) = \phi^{*'}(\rho^n) & -\theta^{*'}(\rho^m) = \phi^{*'}(\rho^m) \end{array}$$

Comparing efficient equilibrium with NE, the only difference is tariff choice. In NE, tariffs are used to manipulate terms-of-trade which is captured by S^{*n} . Like in HMS framework, an import volume constraint can reach the first best outcome by choosing efficient import volume.

B. No uncertainty - two policy active countries and cross-border externalities

Here I consider a general case where, for a given sector, both home and foreign country are policy active and both home and foreign externalities can cross border. I still assume that home is importer and foreign is exporter. Like home country, foreign can use export subsidy and production subsidy.

In the conclusion of HMS(2010), they mentioned "Also, we have ruled out the existence of (nonpecuniary) cross-border externalities associated with production and consumption: such externalities could alter the nature of the optimal trade agreement (if those externalities were not handled in another international forum), and their inclusion would be a valuable extension to explore." Considering cross-border externalities is interesting as it enlarges the set of cross-border channels (there exists only goods channel before). Import volume constraint works less efficiently as it can only take care of goods channel.

HMS(2010) also mentioned "The assumption that externalities are experienced only by the importing country does not play a critical role in our results, but seems natural in light of the focus on import-sector intervention that we introduce below." I don't fully agree with what they said. As we will see below, externalities in foreign country cannot be fully resolved by home policy instruments and in this case, it is better that foreign is also policy active.

The old version HMS(2006) mentioned "We could relax this assumption and allow each good to have externalities in both countries, but this would only complicate the analysis without adding to the insights of the model. Notice also that, if one considers political-economy motives (as in section 6) instead of consumption externalities, such an asymmetric structure would capture situations where import-competing interests are organized but export interests are not." They argued that assuming there exist externalities in foreign country is unnecessary. However, they don't mean that adding cross border (from home to foreign) is unnecessary. Moreover, they argue that contracting on subsidy s alone is sub-optimal as the best outcome it can reach is non cooperative equilibrium. However, I think this is not true as there exist cross border externalities.

The price relations and market clearing condition are as follows.

$$\begin{aligned} q &= p + s \\ p^w &= p - \tau = p^* - \tau^* \\ q^* &= p^* + s^* \\ D(p) + D^*(p^*) &= X(q) + X^*(q^*) \end{aligned} \tag{4}$$

p^w is world price. $\tau^* > 0$ ($\tau^* < 0$) if it is a export subsidy (tax) for foreign country. τ and τ^* are home and foreign border instrument separately. There are 5 equations and 9 unknowns. I can solve the problem as a function of τ , τ^* , s and s^* .¹ By assumption, home is importer and foreign is exporter

$$D(p) > X(q) \Leftrightarrow D^*(p^*) < X^*(q^*) \tag{5}$$

¹As we ignore p^w and take $\tau - \tau^*$ as a unity, all prices can be written as a function of $\tau - \tau^*$, s and s^* . Import volume M can be also pinned down by $\tau - \tau^*$, s and s^* . As τ and τ^* are perfectly substitutable, only their difference matters.

As the market clearing condition should be always satisfied, there are

$$\begin{aligned}
\frac{\partial D(p)}{\partial p} \frac{\partial p}{\partial \tau} + \frac{\partial D^*(p^*)}{\partial p^*} \frac{\partial p^*}{\partial \tau} &= \frac{\partial X(q)}{\partial q} \frac{\partial q}{\partial \tau} + \frac{\partial X^*(q^*)}{\partial q^*} \frac{\partial q^*}{\partial \tau} \\
\frac{\partial D(p)}{\partial p} \frac{\partial p}{\partial s} + \frac{\partial D^*(p^*)}{\partial p^*} \frac{\partial p^*}{\partial s} &= \frac{\partial X(q)}{\partial q} \frac{\partial q}{\partial s} + \frac{\partial X^*(q^*)}{\partial q^*} \frac{\partial q^*}{\partial s} \\
\frac{\partial D(p)}{\partial p} \frac{\partial p}{\partial \tau^*} + \frac{\partial D^*(p^*)}{\partial p^*} \frac{\partial p^*}{\partial \tau^*} &= \frac{\partial X(q)}{\partial q} \frac{\partial q}{\partial \tau^*} + \frac{\partial X^*(q^*)}{\partial q^*} \frac{\partial q^*}{\partial \tau^*} \\
\frac{\partial D(p)}{\partial p} \frac{\partial p}{\partial s^*} + \frac{\partial D^*(p^*)}{\partial p^*} \frac{\partial p^*}{\partial s^*} &= \frac{\partial X(q)}{\partial q} \frac{\partial q}{\partial s^*} + \frac{\partial X^*(q^*)}{\partial q^*} \frac{\partial q^*}{\partial s^*}
\end{aligned} \tag{6}$$

Where

$$\begin{aligned}
\frac{\partial p^w}{\partial \tau} &= \frac{\partial p}{\partial \tau} - 1 = \frac{\partial p^*}{\partial \tau} = \frac{\partial q}{\partial \tau} - 1 = \frac{\partial q^*}{\partial \tau} & \frac{\partial p^w}{\partial s} &= \frac{\partial p}{\partial s} = \frac{\partial p^*}{\partial s} = \frac{\partial q}{\partial s} - 1 = \frac{\partial q^*}{\partial s} \\
\frac{\partial p^w}{\partial \tau^*} &= \frac{\partial p}{\partial \tau^*} = \frac{\partial p^*}{\partial \tau^*} - 1 = \frac{\partial q}{\partial \tau^*} = \frac{\partial q^*}{\partial \tau^*} - 1 & \frac{\partial p^w}{\partial s^*} &= \frac{\partial p}{\partial s^*} = \frac{\partial p^*}{\partial s^*} = \frac{\partial q}{\partial s^*} = \frac{\partial q^*}{\partial s^*} - 1
\end{aligned}$$

Therefore, we have

$$\begin{aligned}
\frac{\partial p^w}{\partial \tau} &= \frac{D' - X'}{X' + X^{*'} - D' - D^{*'}} < 0 \\
\frac{\partial p^w}{\partial s} &= \frac{-X'}{X' + X^{*'} - D' - D^{*'}} < 0 \\
\frac{\partial p^w}{\partial \tau^*} &= \frac{D^{*'} - X^{*'}}{X' + X^{*'} - D' - D^{*'}} < 0 \\
\frac{\partial p^w}{\partial s^*} &= \frac{-X^{*'}}{X' + X^{*'} - D' - D^{*'}} < 0
\end{aligned} \tag{7}$$

The sector welfare function for each country is

$$W = \Gamma + \Pi + \tau M - sX + \sigma X - \gamma D + \sigma_c^* X^* - \gamma_c^* D^* \tag{8}$$

$$W^* = \Gamma^* + \Pi^* - \tau^* E^* - s^* X^* + \sigma^* X^* - \gamma^* D^* + \sigma_c X - \gamma_c D \tag{9}$$

Where Γ is consumer surplus. σ_c and σ_c^* are cross border externality as a result of home and foreign production separately (home and foreign producer lobby). γ_c and γ_c^* are cross border externality as a result of home and foreign consumption separately (pollutant). For both countries, we have

$$\begin{aligned}
u'(D(p)) &= p & q &= g'(X(q)) & M &= D(p) - X(q) = -E \\
\Gamma(p) &= u(D(p)) - pD(p) & \Pi(q) &= qX(q) - g(X(q)) & M &= E^* > 0 \\
u^{*'}(D^*(p^*)) &= p^* & q^* &= g^{*'}(X^*(q^*)) & E^* &= X^*(q^*) - D^*(p^*) = -M^* \\
\Gamma^*(p^*) &= u^*(D^*(p^*)) - p^* D^*(p^*) & \Pi^*(q^*) &= q^* X^*(q^*) - g^*(X^*(q^*)) & &
\end{aligned}$$

B.1. Non cooperative equilibrium

Home chooses τ and s to maximize W given τ^* and s^* . Foreign chooses τ^* and s^* to maximize W^* given τ and s . Therefore, simultaneous fixed point solves

$$\begin{aligned}
\frac{\partial W}{\partial \tau} &= [-D + X + (\tau - \gamma)D' - (\tau + s - \sigma)X' + \sigma_c^* X^{*'} - \gamma_c^* D^{*'}] \frac{\partial p^w}{\partial \tau} + (\tau - \gamma)D' - (\tau + s - \sigma)X' = 0 \\
\frac{\partial W}{\partial s} &= [-D + X + (\tau - \gamma)D' - (\tau + s - \sigma)X' + \sigma_c^* X^{*'} - \gamma_c^* D^{*'}] \frac{\partial p^w}{\partial s} - (\tau + s - \sigma)X' = 0 \\
\frac{\partial W^*}{\partial \tau^*} &= [-D^* + X^* + (\tau^* - \gamma^*)D^{*'} - (\tau^* + s^* - \sigma^*)X^{*'} + \sigma_c X' - \gamma_c D'] \frac{\partial p^w}{\partial \tau^*} + (\tau^* - \gamma^*)D^{*'} - (\tau^* + s^* - \sigma^*)X^{*'} = 0 \\
\frac{\partial W^*}{\partial s^*} &= [-D^* + X^* + (\tau^* - \gamma^*)D^{*'} - (\tau^* + s^* - \sigma^*)X^{*'} + \sigma_c X' - \gamma_c D'] \frac{\partial p^w}{\partial s^*} - (\tau^* + s^* - \sigma^*)X^{*'} = 0
\end{aligned} \tag{10}$$

Solve the above 4 equations and the NE solution is

$$\begin{aligned}
\tau &= \gamma + \frac{E^*}{E^{*'}} + \frac{\gamma_c^* D^{*'} - \sigma_c^* X^{*'}}{E^{*'}} \\
s &= \sigma - \gamma \\
\tau^* &= \gamma^* + \frac{M}{M'} - \frac{\gamma_c D' - \sigma_c X'}{M'} \\
s^* &= \sigma^* - \gamma^*
\end{aligned} \tag{11}$$

Where $M = D - X = E^* = X^* - D^*$, $E^{*' } = X^{*' } - D^{*' } > 0$ and $M' = D' - X' < 0$. Both countries explore their terms-of-trade motive. Recall that home is assumed to be importer. The terms-of-trade motive for home country is $\frac{E^*}{E^{*' }} > 0$ which is positive. Home country has an incentive to elevate import tariff in order to decrease world price p^w and extract profits from foreign country. The terms-of-trade motive for foreign country is $\frac{M}{M'} < 0$ which is negative. Foreign country has an incentive to reduce export subsidy (increase export tax) τ^* in order to increase world price p^w and extract profits from home country. In this type of model, without externalities, exporting country actually wants to tax its exports. $\frac{\gamma_c^* D^{*' } - \sigma_c^* X^{*' }}{E^{*' }}$ is home country's choice to deal with foreign cross border externalities. σ_c^* can be considered as foreign producer lobby. γ_c^* can be considered as foreign cross-border pollutant. As σ_c^* and γ_c^* increases, home import tariff decreases. The intuition of the former is straightforward. The intuition of the latter is that as γ_c^* increases, home country wants foreign consumer to consume less, home country reduces its tariff in order to increase foreign consumer price. The interesting result is that both countries don't use subsidy s to deal with cross-border externalities while this is not true in the first-best (efficient equilibrium) case.

We can see that as both home and foreign country are policy active, foreign country is actually able to alter terms of trade. HMS only focus on the case where home is the solo manipulator of terms of trade and it is also easier to solve.

B.2. Efficient equilibrium

τ , s , τ^* and s^* are chosen to maximize global welfare W^G .

$$\begin{aligned}
\frac{\partial W^G}{\partial \tau} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (\tau^* - \gamma^* - \gamma_c^*)D^{*'} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial \tau} + (\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' \\
\frac{\partial W^G}{\partial s} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (\tau^* - \gamma^* - \gamma_c^*)D^{*'} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial s} - (\tau + s - \sigma - \sigma_c)X' \\
\frac{\partial W^G}{\partial \tau^*} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (\tau^* - \gamma^* - \gamma_c^*)D^{*'} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial \tau^*} + (\tau^* - \gamma^* - \gamma_c^*)D^{*'} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'} \\
\frac{\partial W^G}{\partial s^*} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (\tau^* - \gamma^* - \gamma_c^*)D^{*'} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial s^*} - (\tau^* + s^* - \sigma^* - \sigma_c^*)X^{*'}
\end{aligned} \tag{12}$$

Solve the above 4 equations and the efficient solution is

$$\begin{aligned}
\tau - \tau^* &= \gamma + \gamma_c - \gamma^* - \gamma_c^* \\
s &= \sigma + \sigma_c - \gamma - \gamma_c \\
s^* &= \sigma^* + \sigma_c^* - \gamma^* - \gamma_c^*
\end{aligned} \tag{13}$$

Unlike non cooperative equilibrium, subsidy s and s^* are used to correct externality. There is no unique solution for τ and τ^* . The intuition is that only the sum of welfare matters but not the distribution of revenue among the 2 countries. In footnote 1, I have mentioned that import volume M is pinned down by $\tau - \tau^*$, s and s^* . Therefore, the above efficient solution pins down a unique efficient import volume M^e .

B.3. Import volume constraint

Home chooses τ and s to maximize W given τ^* and s^* such that $M = m$ is satisfied. Foreign chooses τ^* and s^* to maximize W^* given τ and s such that $E^* = m$ is satisfied. Therefore, simultaneous fixed point solves

$$\begin{aligned}
 \frac{\partial W}{\partial \tau} &= [-D + X + (\tau + \mu - \gamma)D' - (\tau + \mu + s - \sigma)X' + \sigma_c^* X^{**'} - \gamma_c^* D^{**'}] \frac{\partial p^w}{\partial \tau} + (\tau + \mu - \gamma)D' - (\tau + \mu + s - \sigma)X' \\
 \frac{\partial W}{\partial s} &= [-D + X + (\tau + \mu - \gamma)D' - (\tau + \mu + s - \sigma)X' + \sigma_c^* X^{**'} - \gamma_c^* D^{**'}] \frac{\partial p^w}{\partial s} - (\tau + \mu + s - \sigma)X' \\
 \frac{\partial W^*}{\partial \tau^*} &= [-D^* + X^* + (\tau^* + \mu^* - \gamma^*)D^{*'} - (\tau^* + \mu^* + s^* - \sigma^*)X^{*'} + \sigma_c X' - \gamma_c D'] \frac{\partial p^w}{\partial \tau^*} + (\tau^* + \mu^* - \gamma^*)D^{*'} - (\tau^* + \mu^* + s^* - \sigma^*)X^{*'} \\
 \frac{\partial W^*}{\partial s^*} &= [-D^* + X^* + (\tau^* + \mu^* - \gamma^*)D^{*'} - (\tau^* + \mu^* + s^* - \sigma^*)X^{*'} + \sigma_c X' - \gamma_c D'] \frac{\partial p^w}{\partial s^*} - (\tau^* + \mu^* + s^* - \sigma^*)X^{*'}
 \end{aligned} \tag{14}$$

Solve the above 4 equations

$$\begin{aligned}
 \tau + \mu &= \gamma + \frac{E^*}{E^{*'}} + \frac{\gamma_c^* D^{*'} - \sigma_c^* X^{*'}}{E^{*'}} \\
 s &= \sigma - \gamma \\
 \tau^* + \mu^* &= \gamma^* + \frac{M}{M'} - \frac{\gamma_c D' - \sigma_c X'}{M'} \\
 s^* &= \sigma^* - \gamma^*
 \end{aligned} \tag{15}$$

As there exist cross-border externalities, import volume constraint cannot reach the first best outcome. As there are no cross-border externalities, all the cross-border effects go through the international trade channel and import volume constraint works efficiently (reach the first best). However, as there exist cross-border channels, e.g., cross-border externalities, other than trade channel, the import volume constraint cannot reach first best. More importantly, an instrument-based constraint is still able to reach the first best outcome.

B.4. Only home country is policy active

It is equivalent to assuming that foreign policy is $\tau^* = 0$ and $s^* = 0$. The solutions of non cooperative equilibrium and equilibrium with import volume constraint should be similar.² The efficient equilibrium is as follows

²Actually, for those 2 equilibria, I don't really give the explicit solution.

$$\begin{aligned}
\frac{\partial WG}{\partial \tau} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (-\gamma^* - \gamma_c^*)D^{*'} - (-\sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial \tau} + (\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' \\
\frac{\partial WG}{\partial s} &= [(\tau - \gamma - \gamma_c)D' - (\tau + s - \sigma - \sigma_c)X' + (-\gamma^* - \gamma_c^*)D^{*'} - (-\sigma^* - \sigma_c^*)X^{*'}] \frac{\partial p^w}{\partial s} - (\tau + s - \sigma - \sigma_c)X'
\end{aligned} \tag{16}$$

Solve the above 2 equations and the efficient solution is

$$\begin{aligned}
\tau &= \gamma + \gamma_c + \frac{(\gamma^* + \gamma_c^*)D^* - (\sigma^* + \sigma_c^*)X^*}{E^{*'}} \\
s &= \sigma + \sigma_c - \gamma - \gamma_c
\end{aligned} \tag{17}$$

Where $E^{*'} = X^{*'} - D^{*'}$. As there exist foreign externalities γ^* , γ_c^* , σ^* and σ_c^* . The current outcome is suboptimal than that of the efficient equilibrium with 4 instruments. They are equivalent iff $\gamma^* = \gamma_c^* = \sigma^* = \sigma_c^* = 0$. Personally, I prefer to include only γ , γ_c , σ and σ_c and assume that only home country is policy active. In this case, it can reach the efficient equilibrium as if foreign is also policy active. In the current case with only home policy active, the way efficient equilibrium takes care of foreign cross-border externalities γ_c^* and σ_c^* is the same as NE case with both home and foreign policy active.

C. State uncertainty γ Table 1: Source of uncertainty: γ

| Type of agreement | $\{FB\}$ | $\{\tau, s\}$ | $\{\tau(\gamma)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|-------------------------|--|--|--|--|---|---|
| Solution of (τ, s) | $\tau = \bar{\gamma} \pm \Delta_\gamma$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ | $\tau = \bar{\gamma}$ $s = \sigma - \bar{\gamma}$ | $\tau = \bar{\gamma} + \lambda \bar{\xi}_\gamma \pm \Delta_\gamma \mp \lambda \star \bar{\xi}_\gamma$ $s = \sigma - \bar{\gamma} + \Upsilon \bar{\xi}_\gamma \mp \Delta_\gamma \mp \Upsilon \star \bar{\xi}_\gamma$ | $\tau = \bar{\gamma} \pm \Delta_\gamma \mp \frac{\beta \Delta_\gamma}{\beta + \lambda}$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ | $\tau = \bar{\gamma} + \lambda \bar{\xi}_\gamma$ $s = \sigma - \bar{\gamma} + \Upsilon \bar{\xi}_\gamma \mp \Delta_\gamma \pm \text{O}_\gamma$ | $\tau = \bar{\gamma} + \delta_\gamma \pm \Delta_\gamma \mp \frac{\beta}{\beta + \lambda + \Upsilon} \Delta_\gamma$ $s = \sigma - \bar{\gamma} \mp \Delta_\gamma$ |
| Costs of agreement | $2c_p + c_s$ | $2c_p$ | $c_p + c_s$ | c_o | c_p | 0 |

Table 2: Pairwise gross welfare difference

| row – column | $\{FB\}$ | $\{\tau, s\}$ | $\{\tau(\gamma)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|--------------------|----------|---|--|--|--|--|
| $\{FB\}$ | 0 | $\frac{\beta[\beta(\beta^* + \lambda^*) + \lambda \Upsilon]}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2$ | $\frac{\lambda k(\bar{\xi}_\gamma^2 + \star \bar{\xi}_\gamma^2)}{2\Upsilon}$ | $\frac{\beta^2(\beta^* + \lambda^*)}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2$ | $\frac{\lambda(\Upsilon - \lambda)}{2\Upsilon} \text{O}_\gamma^2 - \frac{\lambda(\beta^* + \lambda^*)}{(\beta + \lambda)(\beta^* + \lambda^*)} \text{O}_\gamma \Delta_\gamma + \frac{\lambda k \bar{\xi}_\gamma^2}{2\Upsilon}$ | $\frac{(\beta + \lambda)(\beta^* + \lambda^*)}{2\Upsilon} \left(\frac{\beta^2 \Delta_\gamma^2}{(\beta + \lambda + \Upsilon)^2} + \delta_\gamma^2 \right)$ |
| $\{\tau, s\}$ | \ | 0 | $-\frac{\beta \lambda \Upsilon + \beta^2(\beta^* + \lambda^*)}{\lambda k(\bar{\xi}_\gamma^2 + \star \bar{\xi}_\gamma^2)} \Delta_\gamma^2 + \frac{\beta \lambda}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2$ | $-\frac{\beta \lambda}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2$ | $\frac{\lambda(\Upsilon - \lambda) \text{O}_\gamma^2}{2\Upsilon} - \frac{\lambda(\beta^* + \lambda^*)}{(\beta + \lambda)(\beta^* + \lambda^*)} \text{O}_\gamma \Delta_\gamma + \frac{\lambda k \bar{\xi}_\gamma^2}{2\Upsilon}$ | $-\frac{\beta \lambda}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2 + \frac{\beta^2(2\beta + 2\lambda + \Upsilon)\Upsilon}{(\beta + \lambda)^2(\beta + \lambda + \Upsilon)^2} \Delta_\gamma^2$ |
| $\{\tau(\gamma)\}$ | \ | \ | 0 | $\frac{\beta^2(\beta^* + \lambda^*)}{\lambda k(\bar{\xi}_\gamma^2 + \star \bar{\xi}_\gamma^2)} \Delta_\gamma^2 - \frac{\beta \lambda}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2$ | $\frac{\lambda(\Upsilon - \lambda)}{2\Upsilon} \text{O}_\gamma^2 - \frac{\lambda(\beta^* + \lambda^*)}{(\beta + \lambda)(\beta^* + \lambda^*)} \text{O}_\gamma \Delta_\gamma + \frac{\lambda k \star \bar{\xi}_\gamma^2}{2\Upsilon}$ | $\frac{(\beta + \lambda)(\beta^* + \lambda^*)}{2\Upsilon} \left(\frac{\beta^2(2\beta + 2\lambda + \Upsilon)\Upsilon}{(\beta + \lambda)^2(\beta + \lambda + \Upsilon)^2} \Delta_\gamma^2 \right)$ |
| $\{M\}$ | \ | \ | \ | 0 | $\frac{\lambda(\Upsilon - \lambda)}{2\Upsilon} \text{O}_\gamma^2 - \frac{\lambda(\beta^* + \lambda^*)}{(\beta + \lambda)(\beta^* + \lambda^*)} \text{O}_\gamma \Delta_\gamma + \frac{\lambda k \bar{\xi}_\gamma^2}{2\Upsilon}$ | $\frac{(\beta + \lambda)(\beta^* + \lambda^*)}{2\Upsilon} \left(\delta_\gamma^2 - \frac{\beta^2(2\beta + 2\lambda + \Upsilon)\Upsilon}{(\beta + \lambda)^2(\beta + \lambda + \Upsilon)^2} \Delta_\gamma^2 \right)$ |
| $\{\tau\}$ | \ | \ | \ | \ | 0 | $-\frac{\lambda(\Upsilon - \lambda)}{2\Upsilon} \text{O}_\gamma^2 + \frac{\lambda(\beta^* + \lambda^*)}{(\beta + \lambda)(\beta^* + \lambda^*)} \text{O}_\gamma \Delta_\gamma + \frac{\beta^2(2\beta + 2\lambda + \Upsilon)\Upsilon}{(\beta + \lambda)^2(\beta + \lambda + \Upsilon)^2} \Delta_\gamma^2$ |
| $\{\emptyset\}$ | \ | \ | \ | \ | \ | 0 |

Table 3: Pairwise gross welfare difference properties

| row - column | $\{FB\}$ | $\{\tau, s\}$ | $\{\tau(\gamma)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|--------------------|----------|---|--|--|--|--|
| $\{FB\}$ | 0 | initially 0 increase in Δ_γ + | initially positive increase in Δ_γ + | initially 0 increase in Δ_γ + | initially positive increase in Δ_γ + | initially positive increase in Δ_γ + |
| $\{\tau, s\}$ | \ | 0 | initially positive decrease in Δ_γ ? | initially 0 decrease in Δ_γ - | initially positive decrease in Δ_γ ? | initially positive decrease in Δ_γ ? |
| $\{\tau(\gamma)\}$ | \ | \ | 0 | initially negative increase in Δ_γ ? | initially 0 increase in Δ_γ + | initially positive increase in Δ_γ + |
| $\{M\}$ | \ | \ | \ | 0 | initially positive increase in Δ_γ + | initially positive decrease in Δ_γ ? |
| $\{\tau\}$ | \ | \ | \ | \ | 0 | initially positive decrease in Δ_γ ? |
| $\{\emptyset\}$ | \ | \ | \ | \ | \ | 0 |

Where

$$\begin{aligned}
\bar{\xi}_\gamma &= \frac{(\beta^* + \lambda^*)\alpha - (\beta + \lambda)\alpha^* - \lambda(\beta^* + \lambda^*)\sigma - \beta(\beta^* + \lambda^*)\bar{\gamma}}{k} \\
\star_\gamma &= \frac{\beta(\beta^* + \lambda^*)}{k} \Delta_\gamma \\
O_\gamma &= \frac{(\Upsilon - \beta)\Upsilon - \lambda(\beta + \lambda)}{\Upsilon^2 - \lambda(\beta + \lambda)} \Delta_\gamma \\
\bar{\delta}_\gamma &= \frac{\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - \lambda\sigma - \beta\bar{\gamma}}{\beta + \lambda + \Upsilon} \\
k &= \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2 \\
\frac{\lambda(\Upsilon - \lambda)}{2\Upsilon} O_\gamma^2 - \frac{\lambda(\beta^* + \lambda^*)}{2(\beta + \lambda)\Upsilon} O_\gamma \Delta_\gamma + \frac{\lambda(2\beta + \lambda)(\beta^* + \lambda^*) \Delta_\gamma^2}{2(\beta + \lambda)\Upsilon} &= \beta\lambda \frac{\beta^2 + (\beta^* + \lambda^*)(\Upsilon + \beta + \lambda) [\beta^2 + (\beta^* + \lambda^*)(\Upsilon + \beta + \lambda)]}{2(\beta + \lambda) [\Upsilon^2 - \lambda(\beta + \lambda)]^2} \Delta_\gamma^2 > 0 \\
&= \frac{\beta\lambda(\beta^* + \lambda^*) [k + \beta\Upsilon^2 - \beta\lambda(\beta + \lambda)]}{2(\beta + \lambda) [\Upsilon^2 - \lambda(\beta + \lambda)]^2} \Delta_\gamma^2
\end{aligned} \tag{18}$$

The solution of $\{\tau(\gamma), s\}$ is

$$\begin{aligned}\tau &= \bar{\gamma} \pm \frac{\beta}{\beta + \lambda} \Delta_\gamma \\ s &= \sigma - \bar{\gamma} \\ \Omega_{\{M\}} - \Omega_{\{\tau(\gamma), s\}} &= \frac{\beta\lambda\Upsilon - \beta^2(\beta^* + \lambda^*)}{2(\beta + \lambda)\Upsilon} \Delta_\gamma^2 ?\end{aligned}\tag{19}$$

The solution of $\{\tau, s(\gamma)\}$ is

$$\begin{aligned}\tau &= \bar{\gamma} \\ s &= \sigma - \bar{\gamma} \mp \frac{\beta}{\Upsilon - \lambda} \Delta_\gamma \\ \Omega_{\{M\}} - \Omega_{\{\tau, s(\gamma)\}} &= \frac{\beta\lambda(\beta^* + \lambda^*)(\beta + \Upsilon)}{2(\beta + \lambda)(\Upsilon - \lambda)\Upsilon} \Delta_\gamma^2 > 0\end{aligned}\tag{20}$$

Where

$$\begin{aligned}
 \bar{\xi}_\sigma &= \frac{(\beta^* + \lambda^*)\alpha - (\beta + \lambda)\alpha^* - \lambda(\beta^* + \lambda^*)\bar{\sigma} - \beta(\beta^* + \lambda^*)\gamma}{k} \\
 \star_\sigma &= \frac{\lambda(\beta^* + \lambda^*)}{k} \Delta_\sigma \\
 \bigcirc_\sigma &= \frac{\lambda(\beta^* + \lambda^*)}{\Upsilon^2 - \lambda(\beta + \lambda)} \Delta_\sigma \\
 \bar{\delta}_\sigma &= \frac{\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - \lambda \bar{\sigma} - \beta \gamma}{\beta + \lambda + \Upsilon} \\
 k &= \Upsilon^3 + \lambda(\beta^* + \lambda^*)\Upsilon - \lambda(\beta + \lambda)^2
 \end{aligned}
 \tag{21}$$

Table 6: Pairwise gross welfare difference properties

| row – column | {FB} | {\tau, s} | {\tau(\sigma)} | {M} | {\tau} | {\emptyset} |
|----------------|------|---|--|--|--|--|
| {FB} | 0 | initially 0 increase in Δ_σ + | initially positive increase in Δ_σ + | initially 0 increase in Δ_σ + | initially positive increase in Δ_σ + | initially positive increase in Δ_σ + |
| {\tau, s} | \ | 0 | initially positive decrease in Δ_σ ? | initially 0 decrease in Δ_σ – | initially positive decrease in Δ_σ ? | initially positive decrease in Δ_σ ? |
| {\tau(\sigma)} | \ | \ | 0 | initially negative increase in Δ_σ ? | initially 0 increase in Δ_σ + | initially positive increase in Δ_σ + |
| {M} | \ | \ | \ | 0 | initially positive decrease in Δ_σ ? | initially positive decrease in Δ_σ ? |
| {\tau} | \ | \ | \ | \ | 0 | initially positive increase in Δ_σ + |
| {\emptyset} | \ | \ | \ | \ | \ | 0 |

$\{\tau, s(\sigma)\}$ is the first best agreement. The solution of $\{\tau(\sigma), s\}$ is

$$\begin{aligned}\tau &= \gamma \pm \frac{\lambda}{\beta + \lambda} \Delta_\sigma \\ s &= \bar{\sigma} - \gamma \\ \Omega_{\{M\}} - \Omega_{\{\tau(\sigma), s\}} &= \frac{\beta\lambda\Upsilon - \lambda^2(\beta^* + \lambda^*)}{2(\beta + \lambda)\Upsilon} \Delta_\sigma^2 \geq 0\end{aligned}\tag{22}$$

E. State uncertainty α Table 7: Source of uncertainty: α

| Type of agreement | $\{FB\}$ | $\{\tau(\alpha)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|-------------------------|--|--|--|---|---|
| Solution of (τ, s) | $\tau = \gamma$ $s = \sigma - \gamma$ | $\tau = \gamma + \lambda \bar{\xi}_\alpha \pm \lambda \star \alpha$ $s = \sigma - \gamma + \Upsilon \bar{\xi}_\alpha \pm \Upsilon \star \alpha$ | $\tau = \gamma \pm \frac{\Delta_\alpha}{\beta + \lambda}$ $s = \sigma - \gamma$ | $\tau = \gamma + \lambda \bar{\xi}_\alpha$ $s = \sigma - \gamma + \Upsilon \bar{\xi}_\alpha \pm \Upsilon \star \alpha$ | $\tau = \gamma + \delta_\alpha \pm \frac{\Delta_\alpha}{\beta + \lambda + \Upsilon}$ $s = \sigma - \gamma$ |
| Costs of agreement | $2c_p$ | $c_p + c_s$ | c_o | c_p | 0 |

Table 8: Source of uncertainty: α

| row - column | $\{FB\}$ | $\{\tau(\alpha)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|--------------------|----------|---|--|--|---|
| $\{FB\}$ | 0 | $\frac{\lambda k (\bar{\xi}_\alpha^2 + \star \alpha^2)}{2\Upsilon}$ | $\frac{\beta^* + \lambda^*}{2(\beta + \lambda)\Upsilon} \Delta_\alpha^2$ | $\frac{\lambda(\beta + \beta^* + \lambda^*)}{2\Upsilon} \bar{\xi}_\alpha^2 + \frac{\lambda(\beta + \beta^* + \lambda^*)}{2\Upsilon} \star \alpha^2 + \frac{\Delta_\alpha^2}{(\beta + \lambda + \Upsilon)^2} + \delta_\alpha^2$ | |
| $\{\tau(\alpha)\}$ | \ | 0 | $\frac{\beta^* + \lambda^*}{2(\beta + \lambda)\Upsilon} \Delta_\alpha^2 - \frac{\lambda k (\bar{\xi}_\alpha^2 + \star \alpha^2)}{2\Upsilon}$ | $\frac{\lambda(\beta + \beta^* + \lambda^*)}{2\Upsilon} \bar{\xi}_\alpha^2 + \frac{\lambda(\beta + \beta^* + \lambda^*)}{2\Upsilon} \star \alpha^2 - \frac{\Delta_\alpha^2}{(\beta + \lambda + \Upsilon)^2}$ | |
| $\{M\}$ | \ | \ | 0 | $-\frac{(\beta^* + \lambda^*) \Delta_\alpha^2}{2(\beta + \lambda)\Upsilon} + \frac{\lambda(\beta + \beta^* + \lambda^*) \star \alpha^2}{2\Upsilon} + \frac{\lambda k \bar{\xi}_\alpha^2}{2\Upsilon}$ | $\frac{(\beta + \lambda)(\beta^* + \lambda^*)}{2\Upsilon} \left(\delta_\alpha^2 - \frac{(2\beta + 2\lambda + \Upsilon)\Upsilon}{(\beta + \lambda)^2(\beta + \lambda + \Upsilon)^2} \Delta_\alpha^2 \right)$ |
| $\{\tau\}$ | \ | \ | \ | 0 | $\frac{(\beta + \lambda)(\beta^* + \lambda^*)}{2\Upsilon} \left(\delta_\alpha^2 + \frac{\Delta_\alpha^2}{(\beta + \lambda + \Upsilon)^2} \right) - \frac{\lambda(\beta + \beta^* + \lambda^*)}{2\Upsilon} \star \alpha^2 + \frac{\lambda k \bar{\xi}_\alpha^2}{2\Upsilon}$ |
| $\{\emptyset\}$ | \ | \ | \ | \ | 0 |

Where

$$\begin{aligned} \bar{\xi}_\alpha &= \frac{(\beta^* + \lambda^*) \bar{\alpha} - (\beta + \lambda) \alpha^* - \lambda(\beta^* + \lambda^*) \sigma - \beta(\beta^* + \lambda^*) \gamma}{k} \\ \star \alpha &= \frac{\beta^* + \lambda^*}{k} \Delta_\alpha \\ \bigcirc_\alpha &= \frac{\beta^* + \lambda^*}{\Upsilon^2 - \lambda(\beta + \lambda)} \Delta_\alpha \\ \bar{\delta}_\alpha &= \frac{\bar{\alpha} - \frac{\beta + \lambda}{\beta^* + \lambda^*} \alpha^* - \lambda \sigma - \beta \gamma}{\beta + \lambda + \Upsilon} \\ k &= \Upsilon^3 + \lambda(\beta^* + \lambda^*) \Upsilon - \lambda(\beta + \lambda)^2 \end{aligned} \tag{23}$$

Table 9: Source of uncertainty: α

| <i>row - column</i> | $\{FB\}$ | $\{\tau(\alpha)\}$ | $\{M\}$ | $\{\tau\}$ | $\{\emptyset\}$ |
|---------------------|----------|--|--|--|--|
| $\{FB\}$ | 0 | initially positive increase in Δ_α + | initially 0 increase in Δ_α + | initially positive increase in Δ_α + | initially positive increase in Δ_α + |
| $\{\tau(\alpha)\}$ | \ | 0 | initially negative increase in Δ_α ? | initially 0 increase in Δ_α + | initially positive increase in Δ_α + |
| $\{M\}$ | \ | \ | 0 | initially positive decrease in Δ_α ? | initially positive decrease in Δ_α ? |
| $\{\tau\}$ | \ | \ | \ | 0 | initially positive increase in Δ_α + |
| $\{\emptyset\}$ | \ | \ | \ | \ | 0 |

F. Discussion about parameter constraints

For feasible solutions, all the prices should be positive. In addition, demand/supply and home import should also be positive, given that I assume home is the import country. The following conditions should be satisfied simultaneously.

$$\begin{aligned}
\alpha + \alpha^* + (\beta^* + \lambda^*)\tau - \lambda s &> 0 \Leftrightarrow p > 0 \\
\alpha + \alpha^* + (\beta^* + \lambda^*)\tau + (\beta + \beta^* + \lambda^*)s &> 0 \Leftrightarrow q > 0 \\
\alpha + \alpha^* - (\beta + \lambda)\tau - \lambda s &\Leftrightarrow p^* = q^* > 0 \\
\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*}\alpha^* - (\beta + \lambda)\tau - \lambda s &> 0 \Leftrightarrow M > 0 \\
\alpha^* - \beta^* \frac{\alpha + \alpha^* - (\beta + \lambda)\tau - \lambda s}{\beta + \lambda + \beta^* + \lambda^*} &> 0 \Leftrightarrow D^* > 0
\end{aligned} \tag{24}$$

q and q^* being positive implies that X and X^* are positive. M and X being positive implies that D is positive. To sustain positive prices, a large world demand shifter $\alpha + \alpha^*$ is needed, which is intuitive. A positive home import M implies that $\alpha - \frac{\beta + \lambda}{\beta^* + \lambda^*}\alpha^*$ should be relatively large, which implies that home demand shifter α should be relatively large compared to foreign demander shifter α^* and/or home consumer and producer are less price sensitive compared to foreign ones ($\frac{\beta + \lambda}{\beta^* + \lambda^*}$ small). The last inequality constraint requires a positive foreign demand. Therefore, foreign demand shifter α^* cannot be too small compared to home demand shifter α and/or foreign consumers cannot be too price sensitive (β^* small). Moreover, tariff τ and subsidy s related terms should be relatively small, which requires that home consumption externality γ and production externality σ should be relatively small.

In terms of contracting costs c_p , c_s and c_o , in order to make sure that all intersection points of welfare indifference curves, y axis $\bar{\delta}^2$ and x axis $\bar{\Delta}^2$ are feasible, contracting costs should be relatively small such that all the potential trade agreements that have been mentioned in the main text should be feasible. As the contracting costs of some types of trade agreements are too large, it is trivial to understand that the corresponding welfare indifference curves shouldn't be feasible.

Regarding the constraints of state uncertainty terms, namely home consumption externality γ , production externality σ , and demand shifter α , the mean is assumed to be positive ($\bar{\gamma}$, $\bar{\sigma}$ and $\bar{\alpha}$ positive). Furthermore, their low value realization γ_l , σ_l and α_l should also be positive, which means shock Δ cannot be greater than the mean value. All the above constraints can be satisfied if the value of each parameter is chosen carefully.

Conclusion

This thesis aims to understand the effects of trade policy uncertainty, the business cycle, and firms' idiosyncratic shocks on firms' trade decisions and it examines how to design more efficient trade agreements. The thesis is motivated by the recent increase in trade policy uncertainty, such as the US-China trade war; business cycle fluctuations, such as the 2008-2009 Great Recession; and the signature of the Phase One deal, which includes a trade-outcome-based agreement, namely the Expanding Trade chapter.

Chapter 1 investigates the impact of trade policy uncertainty (TPU) on potential exporters' entry decisions by introducing demand learning in models that deviate from classical sunk cost models. Unlike the TPU model of Handley and Limão (2015, 2017), in the learning model, the impact of TPU on the entry cutoff depends on both future bad news and future good news. Bad news discourages entry as it generates an option value of waiting. Good news has a positive effect on entry cutoff in sunk cost learning models as learning brings extra value. Moreover, in the fixed cost learning model, future good news can even deter firms' current entry. Empirical results show that the probability of a product being traded bilaterally starts to increase from six years before the signature, which is consistent with the model's prediction that good news encourages firms' entry.

Chapter 2 investigates how macroeconomic conditions at birth affect the survival chances of French exporters and/or importers over their export/import lifetimes. The study contributes to the existing literature by examining the relationship between the business cycle and firm-level export/import survival rates, a topic that has not been explored in-depth before. The research findings show that during economic downturns, there is a higher rate of exit from the foreign market compared to entry, and firms that enter during bad times are generally smaller but more productive. Additionally, firms that exit during recessions have a higher productivity threshold. The main finding of the survival analysis is that, despite the overall higher hazard of leaving export/import markets during economic downturns, firms that enter the market under bad macroeconomic conditions have a lower hazard of ending their export/import spells. This finding is robust to the use of different business cycle measures. Finally, bivariate duration models suggest that the joint pattern of firms' export and import duration tends to be either long-long or short-short.

Chapter 3 investigates trade-outcome-based agreements, inspired by the Expanding Trade chapter, and compares them with instrument-based trade agreements in an incomplete contract framework where contracting is costly and the state of the world is uncertain. The paper identifies the circumstances under which a rigid outcome-based agreement is optimal and focuses on the trade-off between lifting market access barriers and reacting to state uncertainty. It gives clear pairwise and triple-wise comparisons between different agreements. The study argues that once import volume is contracted on, it is unnecessary to also contract on policy instruments. When there is no state uncertainty, the non-state-contingent agreement on import volume is able to reach the first-best outcome. When there is state uncertainty, its relative performance is high under uncertainty over the home consumption externality, followed by uncertainty over the home production externality, then followed by uncertainty over the home demand shifter.

Titre : Trois essais sur la Dynamique Commerciale, l'Incertitude de la Politique Commerciale et le Cycle Économique

Mots clés : Dynamique d'Exportation et d'Importation, Incertitude de la Politique Commerciale, Cycle Économique, Contrat Incomplet

Résumé : Cette thèse vise à comprendre les effets de l'incertitude de la politique commerciale, du cycle économique et des chocs idiosyncratiques des entreprises sur les décisions commerciales des entreprises et à examiner comment concevoir un accord commercial plus efficace. La thèse est motivée par l'augmentation récente de l'incertitude de la politique commerciale, telle que la guerre commerciale entre les États-Unis et la Chine ; les fluctuations du cycle économique, comme la Grande Récession de 2008-2009 ; et la signature de l'accord de Phase Un, qui inclut un accord basé sur les résultats, à savoir le chapitre sur l'Expansion du Commerce. Le chapitre 1 étudie comment l'incertitude de la politique commerciale et l'apprentissage de la demande affectent conjointement les décisions d'exportation en construisant un modèle qui intègre les deux facteurs. Le modèle fournit plusieurs nouvelles perspectives sur les décisions d'exportation et est presque toujours traçables. En outre, en se concentrant sur un ensemble spécifique de produits parmi les pays membres de l'OMC, le chapitre teste empiriquement les prédictions du

modèle et trouve des preuves suggestifs. Le chapitre 2 examine la survie des entreprises françaises sur le marché de l'exportation/importation au cours du cycle économique, un sujet qui n'a pas été étudié dans la littérature. Après avoir contrôlé les caractéristiques initiales des périodes d'exportation/importation, le chapitre étudie l'effet des conditions du cycle économique à la naissance et au cours de l'année en cours sur la survie des entreprises. Le chapitre 3 compare les accords basés sur les résultats, tels que le chapitre sur l'Expansion du Commerce, avec les accords commerciaux basés sur des instruments, tels que l'OMC, dans un cadre de contrat incomplet où la contractualisation est coûteuse et l'état est incertain. Le chapitre se concentre sur le compromis entre la résolution de la manipulation des termes de l'échange et une meilleure réaction à l'incertitude de l'état et donne des comparaisons claires par paires et par triplets entre l'accord basé sur les résultats non contingent à l'état et les autres accords basés sur des instruments.

Title : Three Essays on Trade Dynamics, Trade Policy Uncertainty and Business Cycle

Keywords : Export and Import Dynamics, Trade Policy Uncertainty, Business Cycle, Incomplete Contract

Abstract : This thesis aims to understand the effects of trade policy uncertainty, the business cycle, and firms' idiosyncratic shocks on firms' trade decisions and to examine how to design a more efficient trade agreement. The thesis is motivated by the recent increase in trade policy uncertainty, such as the US-China trade war ; business cycle fluctuations, such as the 2008-2009 Great Recession ; and the signature of the Phase One deal, which includes an outcome-based agreement, namely the Expanding Trade chapter. Chapter 1 investigates how trade policy uncertainty and demand learning jointly affect exporting decisions by constructing a model that incorporates both factors. The model provides several novel insights into export decisions and is almost always tractable. Additionally, by focusing on a specific set of products among WTO countries, the chapter empirically tests the model's predictions and finds suggestive evi-

dence. Chapter 2 examines the survival of French firms in the exporting/importing market over the business cycle, a topic that has not been studied in the literature. After controlling for the initial characteristics of export/import spells, the chapter studies the effect of business cycle conditions at birth and in the current year on firms' survival. Chapter 3 compares outcome-based agreements, such as the Expanding Trade chapter, with instrument-based trade agreements, such as the WTO, in an incomplete contract framework where contracting is costly and state is uncertain. The chapter focuses on the trade-off between solving terms-of-trade manipulation and better reacting to state uncertainty and gives clear pairwise and triple-wise comparisons between the non-state-contingent outcome-based agreement and other instrument-based agreements.