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Financial stress and the business cycle

David Gauthier

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Université Paris 1 Panthéon Sorbonne – Paris School of Economics

Thesis submitted for the degree of Doctor of Philosophy in Economics

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Financial Stress and the Business Cycle

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Introduction générale

Plus de dix ans ont passé depuis la crise financière de 2007 et les conséquences des récessions qui s'en sont suivies sont toujours palpables. Avec des niveaux de production de dix pour cent inférieurs à ceux impliqués par leurs tendances d'avant crise, les États-Unis, le Royaume-Uni, et la France n'ont toujours pas réalisé le rattrapage économique espéré.¹ Comment expliquer l'ampleur des crises financières, quel est le rôle des institutions dans leur transmission, comment identifier et prévoir une crise financière ? Ces questions de recherche ont marqué le champ de la macroéconomie de ces dernières années. L'objectif de cette thèse est de contribuer à l'éclaircissement de ces vastes problématiques avec le stress financier pour fil rouge.

Qu'est-ce que le stress financier ? Bernanke (1983), spécialiste des crises financières, le définit comme une hausse des coûts d'intermédiation du crédit. Si la définition suggérée est simple, les implications du stress financier pour l'activité économique et pour les décisions des firmes et des ménages sont en revanche multiples et complexes. En particulier, d'où provient le stress financier, et comment s'articule-t-il avec l'activité économique ? L'étude conjointe des sphères économiques et financières remonte au moins à Seligman (1908), dont les propos restent d'une actualité frappante : *"...every crisis inevitably involves a revolution in the conditions of credit. From this point of view, all crises may be declared to be financial crisis."* Comprendre les sources du stress financier c'est donc plus généralement s'intéresser aux sources du cycle économique et aux liens de causalité unissant ces deux ensembles. A ce sujet, notons tout d'abord que les sources du cycle des affaires, c'est-à-dire les fluctuations économiques de moyen terme, demeurent encore incertaines.

Un bref aperçu de la pensée macroéconomique moderne permet d'illustrer les va-et-vient qu'a connu ce champ et la place tardive qu'ont pris les facteurs financiers dans la compréhension du cycle des affaires. Ainsi, les années 1960 et 1970 sont dominées par

¹Barnichon, Matthes et Ziegenbein (2019).

deux courants de pensée, la théorie keynésienne et la théorie monétariste dans lesquelles les frictions financières ne jouent que peu de rôle. La théorie keynésienne explique les fluctuations économiques par des chocs de demande agrégée, tels que des chocs de dépense publique, tandis que la théorie monétariste les voit comme conséquences des changements de politique monétaire. La critique de Lucas (1976) vient bousculer cet ordre et ouvre la porte à la théorie des cycles d'affaires réels (RBC). Ce renouveau, menée par Kydland et Prescott (1982), est d'abord méthodologique : les modèles utilisés pour décrire l'économie se basent désormais sur des agents rationnels qui optimisent leurs décisions selon le cadre économique dans lequel ils opèrent. Ces modèles font la part belle aux chocs de technologie et les frictions financières y sont supposées inexistantes. L'article de Bernanke et Gertler (1989) marque un tournant dans la compréhension des cycles en intégrant au modèle RBC canonique une friction financière reliant les capacités d'endettement des firmes aux conditions macroéconomiques, c'est le mécanisme de l'accélérateur financier. La crise financière de 2007 vient renforcer cette tendance : dans de nombreux modèles d'équilibre général le secteur financier n'intervient plus seulement comme mécanisme d'amplification des cycles mais aussi comme source de chocs affectant directement les conditions de crédit.

Depuis, les techniques pour identifier le stress financier se sont diversifiées. Certains auteurs développent des stratégies empiriques permettant d'isoler les fluctuations des conditions de crédit indépendantes du cycle des affaires. C'est le cas de Gilchrist et Zakrajsek (2012a), Bassett, Chosak, Driscoll et Zakrajsek (2010) et Romer et Romer (2017) qui construisent des indices de stress financier basés sur l'observation des spreads obligataires, des conditions de crédit bancaire ou encore d'évidences historiques. D'autres, tels que Gerali, Neri, Sessa et Signoretti (2010), Christiano, Motto et Rostagno (2014) et Ajello (2016) développent des modèles théoriques dotés de frictions financières sophistiquées pour mettre en avant les propriétés particulières des chocs financiers. Aujourd'hui, de nombreuses interrogations demeurent concernant le secteur financier et ses interactions avec l'activité économique mais la plupart des économistes s'accordent néanmoins sur leur importance, les modèles attribuant généralement entre un tiers et la moitié du cycle des affaires aux chocs financiers.

Afin de contribuer à cette littérature, chacun des chapitres de cette thèse interroge un aspect particulier du stress financier. Le premier chapitre propose un choc affectant la ca-

pacité des banques à liquider le collatéral de leurs emprunteurs et permettant d'expliquer le cycle des affaires et notamment les fluctuations de la consommation. Le deuxième chapitre s'intéresse à la structure du secteur bancaire et à la manière dont celle-ci affecte la propagation des crises financières et leur impact sur l'activité économique. Enfin, le troisième chapitre revient sur les différentes techniques utilisées pour identifier les chocs financiers et propose une stratégie d'identification basée sur la structure de bilan des firmes non-financières.

Chapitre 1

Le premier chapitre de cette thèse a pour objet d'expliquer les fluctuations économiques et plus particulièrement les interactions entre le PIB, la consommation, l'investissement et l'emploi. Ce chapitre est co-écrit avec Yvan Bécard, assistant professeur à l'université PUC-Rio. Ce chapitre prend pour point de départ le niveau élevé de co-mouvements observés entre l'investissement et la consommation dans les économies des pays industrialisés. Depuis la crise financière de 2007 et la chute massive de l'activité économique qui s'en est suivie, de nombreux macroéconomistes ont désigné les facteurs financiers comme principales causes de la récession et plus généralement des fluctuations économiques de ces trente dernières années. Pourtant, malgré les arguments très convaincants mis en avant par la littérature économique, un élément central a résisté à la démonstration : les chocs financiers ne permettent pas d'expliquer les variations de la consommation.²

Comprendre les mouvements de la consommation est pourtant crucial. D'abord du point de vue du bien-être social, parce que les variations de la consommation ont des répercussions importantes sur l'emploi et le niveau de vie des individus. Ensuite du point de vue de la théorie, il semble douteux que les mouvements de deux séries aussi fortement liées que la consommation et l'investissement ne puissent être expliquées par des facteurs communs.

Pour mieux comprendre les liens unissant ces deux agrégats et ainsi mieux caractériser le cycle des affaires, ce chapitre met en avant plusieurs éléments saillants de l'économie américaine. Le premier élément concerne l'endettement des ménages américains et le fait que leur volume de dette bancaire ait triplé depuis les années 80, dépassant de beaucoup la dette bancaire des firmes. Le second élément est l'homogénéité des conditions

²Cette problématique remonte au moins à Barro and King (1984).

de crédits bancaires auxquelles ont fait face les firmes et les ménages depuis près de 20 ans, comme illustré par l'évolution similaire des niveaux de collatéral exigés par les banques à l'ensemble de leurs débiteurs, firmes et ménages confondus. Mis bout à bout, ces deux éléments offrent une explication financière des co-mouvements entre consommation et investissement cohérente avec les résultats de la littérature macroéconomique : parce que les banques ajustent indifféremment leurs conditions de crédit à l'ensemble de leurs débiteurs, les chocs financiers se répercutent à la fois sur l'endettement des firmes et des ménages, expliquant ainsi les variations simultanées de l'investissement et de la consommation.

Pour tester cette théorie et enquêter sur le rôle des conditions de crédit dans les fluctuations économiques, nous procédons en plusieurs étapes. Dans une première étape, nous construisons un modèle où les firmes et les ménages peuvent financer leur production et leur consommation en s'endettant auprès d'intermédiaires financiers, les banques. Parce que ces emprunteurs peuvent faire défaut sur leur dette, les banques se protègent d'éventuelles pertes en exigeant que l'ensemble de leurs prêts soit collatéralisé par des biens immobiliers ou par du capital productif. La deuxième étape consiste à incorporer au modèle un choc affectant simultanément les conditions de crédit des ménages et des firmes. Nous proposons pour cela un choc financier, le choc de collatéral, dont la particularité est de modifier les volumes d'actifs que les banques acceptent de recevoir comme collatéral.

La structure générale du modèle est plus conventionnelle et permet la comparaison du choc de collatéral aux différents chocs mis en avant par la littérature pour expliquer le cycle des affaires.³ Comme dans Christiano, Eichenbaum, and Evans (2005) et Smets and Wouters (2007), nous utilisons un modèle d'équilibre général néo-keynésien, c'est à dire caractérisé par la rigidité partielle des prix et des salaires. Le modèle incorpore aussi des frictions réelles telles que des coûts d'installations des biens d'investissement, et l'utilisation variable du capital productif. La partie financière du modèle reproduit le mécanisme d'accélérateur financier présenté par Bernanke and Gertler (1989) et Christiano, Motto, and Rostagno (2014) qui est aussi étendu aux ménages. Tous les crédits

³Pour reproduire les co-mouvements entre la consommation et l'investissement, la littérature a généralement recours à des chocs expliquant les fluctuations de ces deux séries de manière distincte. Cela pose le risque d'aboutir à des chocs corrélés entre eux, contredisant l'hypothèse généralement formulée d'indépendance des chocs et ignorant la possibilité d'une source commune aux variations de la consommation et de l'investissement.

sont intermédiés par des banques qui utilisent les dépôts des ménages créditeurs pour financer la consommation des ménages emprunteurs ainsi que l'investissement des firmes. Une hypothèse centrale du modèle est qu'en cas de défaut de leurs emprunteurs, les banques ne peuvent revendre le collatéral saisi aux ménages et aux firmes qu'après l'avoir préalablement converti en un actif liquide. Le choc de collatéral affecte la capacité de liquidation du collatéral des banques et donc les quantités de capital productif et de biens immobiliers que ces dernières sont prêtes à recevoir comme contreparties de leurs prêts aux firmes et aux ménages. Ainsi, une baisse de la capacité de liquidation des banques réduit la quantité d'actifs que ces dernières acceptent comme collatéral, rendant les prêts plus risqués et entraînant un resserrement des crédits accordés aux firmes et aux ménages.

Pour évaluer la capacité des chocs de collatéral à expliquer les fluctuations économiques des principaux agrégats, le modèle est estimé grâce à une procédure d'estimation bayésienne permettant de déterminer le modèle le plus vraisemblable et d'associer les variations des séries économiques à différents chocs structurels. L'estimation est réalisée sur données trimestrielles américaines pour la période 1985-2019 avec des séries macroéconomiques telles que le PIB, la consommation, l'investissement et les heures travaillées. Pour contrôler que l'impact des chocs de collatéral se transmet effectivement via leur impact sur l'accès au crédit, l'estimation inclut aussi les volumes de crédit bancaire accordés aux firmes et aux ménages et les taux d'intérêt associés à chacun de ces types de prêt. Les résultats d'estimation permettent de quantifier le rôle des différents chocs dans les variations des agrégats macroéconomiques et financiers au cours de ces trente dernières années.

Un résultat central tiré du modèle est que les chocs de collatéral expliquent la majeure partie des fluctuations du PIB, de la consommation, de l'investissement, et des heures travaillées ainsi que des volumes crédits bancaires et des taux leur correspondant. Les chocs de collatéral permettent aussi d'expliquer le haut niveau de corrélation entre consommation et investissement et accèdent l'idée selon laquelle les changements des conditions de crédit communs aux firmes et aux ménages expliquent les co-mouvements observés entre consommation et investissement.

La raison pour laquelle les chocs de collatéral sont favorisés par l'estimation relativement aux autres chocs s'explique naturellement par leur capacité à reproduire les carac-

téristiques du cycle des affaires pour toutes les séries considérées et en particulier les fluctuations observées durant la crise financière de 2007. Suite à un choc de collatéral, l'accès au crédit des firmes et des ménages est restreint, diminuant à la fois l'investissement et la consommation. La chute de la demande de capital et de biens immobiliers entraîne une baisse du prix des actifs et de leur valorisation en tant que collatéral. Les défauts des firmes et des ménages augmentent avec les primes de risque associées aux différents prêts bancaires et l'accès au crédit continue de se contracter. Cette spirale de contraction de la dette connue sous le nom d'accélérateur financier génère une forte chute de l'activité économique et une baisse de l'emploi s'accompagnant par une hausse supplémentaire des taux d'intérêt et des défauts. L'ensemble de ces réponses permet de reproduire les dynamiques propres à l'économie américaine pour la période d'estimation ce qui explique la prédominance des chocs de collatéral relativement aux autres types de chocs économiques pour expliquer les fluctuations économiques.

Afin de corroborer les résultats de l'estimation par des critères non-statistiques, nous procédons à une batterie d'exercices de validation externe en confrontant les implications du modèle à des données financières n'ayant pas été utilisées dans la procédure d'estimation. Dans un premier temps nous comparons les conditions de crédit impliquées par le modèle à des séries retraçant l'évolution des quantités de collatéral exigées par les banques pour leurs prêts aux ménages et aux firmes. Le niveau de corrélation très élevée entre les deux séries indique que le modèle est capable de capturer l'évolution des conditions de crédit des banques. Le même exercice est répété en comparant les chocs de collatéral à des indices de stress financiers tels que l'Excess Bond Premium, le VIX et le Chicago Fed National Financial Conditions. Ici encore, les deux types de séries sont fortement corrélées, le choc de collatéral permet de reproduire les mouvements de séries financières absentes de la procédure d'estimation et d'expliquer les sources du cycle des affaires aux États-Unis.

Chapitre 2

Le deuxième chapitre étudie l'impact de la compétition bancaire sur la transmission des politiques monétaires. Je m'y concentre plus particulièrement sur la façon dont le pouvoir de marché des banques affecte la capacité de la politique monétaire à stabiliser l'économie en réponse à des chocs financiers selon que le taux directeur avoisine la limite à taux zéro

ou pas. Au cours de ces 20 dernières années la zone euro a traversé plusieurs périodes de récession, la première fois suite à la crise financière aux États-Unis en 2008 et la seconde fois comme conséquence de la crise de la dette souveraine de 2010. Durant chacun de ces épisodes la banque centrale européenne a abaissé ses taux directeurs afin de limiter les risques de déflation et la baisse de l'activité économique.

L'étude des interactions entre le degré de compétition du système bancaire et l'efficacité de la politique monétaire est motivée par le fait que les fluctuations du PIB et du crédit bancaire observées ces 20 dernières années ont été plus faibles en France, un pays caractérisé par une forte concentration de son système bancaire, qu'en Allemagne et dans la zone euro durant les périodes où le taux directeur avoisinait la borne à taux zéro. La question que pose ce chapitre est donc de savoir si les divergences observées durant les périodes où le recours aux politiques monétaires dites conventionnelles est limité par la borne à taux zéro, peuvent s'expliquer par des degrés différents de concentration du secteur bancaire.

Pour répondre à cette question, je reprends et modifie le modèle exposé dans le premier chapitre en y intégrant un secteur bancaire organisé en compétition de monopole. Les banques présentes dans le modèle offrent des prêts différenciés à leurs clients, firmes et ménages, et n'ajustent que partiellement leurs taux de prêt aux changements du taux interbancaire mis en place par la banque centrale. Ce choix de modélisation du système bancaire permet de reproduire les niveaux et les dynamiques des taux d'intérêt observés en France pour différents types de prêts. J'utilise le modèle pour étudier dans quelle mesure la compétition bancaire affecte l'efficacité stabilisatrice de la politique monétaire en réponse à des chocs financiers. En particulier, je distingue les situations selon que la politique monétaire est limitée par le plancher à zéro du taux directeur ou pas. Dans ce modèle, la concentration bancaire se caractérise par deux effets opposés. D'un côté, une baisse du degré de compétition bancaire implique que la politique monétaire est moins efficace pour stabiliser l'économie en réponse à un choc financier : suite à la baisse du taux directeur, les banques n'ajustent que partiellement leurs taux de prêt, entraînant une hausse de leurs marges avec un faible impact stabilisateur pour les quantités de crédit alloué. En revanche, lorsque le secteur bancaire est faiblement compétitif, la demande de crédit bancaire est moins élastique et un changement de l'offre de crédit a un effet relativement moindre sur les volumes de crédits distribués.

J'utilise le modèle pour étudier la manière dont ces deux effets s'articulent selon la disponibilité de la politique monétaire. Le modèle est estimé sur des données trimestrielles françaises pour la période de 2003 à 2017. J'utilise les séries du PIB, de l'investissement, de la consommation ainsi que les séries du déflateur du PIB, d'un indice des prix de l'immobilier et d'un indice du coût du travail. L'estimation inclut aussi les séries de prêts bancaires aux ménages et aux firmes non-financières, les dépôts des ménages ainsi que les séries de taux d'intérêt correspondant à chacun de ces produits bancaires. L'estimation du modèle sur données françaises permet de confirmer les résultats obtenus dans le premier chapitre. Ici encore, les chocs de collatéral expliquent les fluctuations des variables économiques et financières du modèle et en particulier la consommation, l'investissement, les taux d'intérêt et les volumes de prêts et de dépôts bancaires. Les chocs de collatéral permettent de reproduire les dynamiques observées durant les deux dernières récessions en France, en particulier la hausse subite des spreads bancaires et la baisse progressive des volumes de prêts. Un résultat notable de l'estimation est le niveau élevé des paramètres déterminants la viscosité des taux d'intérêts pour les prêts aux firmes, les prêts aux ménages et les dépôts bancaires, permettant de reproduire la transmission retardée des changements du taux directeur aux taux de prêt bancaire.

Dans une seconde partie, j'utilise le modèle pour évaluer l'impact des chocs de collatéral durant les périodes où la politique monétaire est effectivement limitée par la borne à taux zéro pour différents degrés de concurrence du secteur bancaire. Dans le modèle estimé sur données françaises, la présence d'une limite à zéro du taux directeur amplifie fortement l'impact des crises financières sur l'activité économique. Suite à un choc de collatéral calibré pour répliquer la récession de 2008, le taux directeur atteint rapidement zéro, limitant de fait la baisse des taux de prêts et la stabilisation des volumes de crédit.

J'étudie ensuite l'impact de la borne à taux zéro pour différents niveaux de concentration du système bancaire. Je considère pour cela deux modèles différents. Le premier modèle correspond au modèle estimé sur données françaises et se caractérisant par une forte viscosité des taux d'intérêt bancaires et une faible élasticité de la demande de crédit des firmes et des ménages. Dans le second modèle, j'augmente significativement l'élasticité de la demande de crédit ainsi que la vitesse d'ajustement des taux bancaires au taux directeur.

Je trouve qu'un choc de collatéral a des effets plus faibles dans le modèle caractérisé

par un système bancaire compétitif lorsque la borne du taux zéro n'est pas prise en compte ou n'est pas atteinte par le taux directeur. Dans ce cas, la transmission de la politique monétaire sur les taux d'intérêt bancaires est plus rapide et vient limiter la chute des volumes de prêts alloués aux ménages et aux firmes ainsi que la baisse de la consommation, de l'investissement et de l'emploi. En revanche, lorsque la politique monétaire est limitée par la borne à zéro du taux directeur, l'impact récessif d'un choc de collatéral est plus prononcé dans l'économie où le secteur bancaire est compétitif. La raison est que dans ce cas, l'efficacité de la politique monétaire est tronquée par la borne du taux zéro tandis que la faible élasticité de la demande de crédits induite par la forte compétitivité du système bancaire réduit l'impact du choc de crédit sur les volumes de transaction, impliquant une chute des prêts moindre que dans cas où le secteur bancaire est faiblement compétitif. Cet exemple permet d'illustrer une situation où la concentration du système bancaire implique une stabilité accrue des encours de crédit et de l'activité économique.

Finalement, j'utilise le modèle pour montrer que la mise en place d'un coussin de capital contracyclique imposé aux banques et agissant via des pénalités sur leurs profits peut être substitué avantageusement à une politique monétaire expansionniste lorsque celle-ci est limitée par la borne à taux zéro.

Chapitre 3

Ce troisième chapitre revient sur les stratégies mises en place pour identifier les chocs financiers dans les chapitres précédents et plus généralement dans la littérature macro-financière. Une des particularités du système financier est sa capacité à agir à la fois comme source et comme vecteur de transmission des chocs économiques rendant particulièrement difficile la distinction entre les chocs financiers et les implications d'autres chocs économiques se propageant à travers le secteur financier. Bien que récente, une vaste littérature s'attache à quantifier l'impact des chocs financiers sur le cycle économique en utilisant des variables financières, prix des actifs financiers ou spreads de crédit, pour instrumenter les variations des conditions de crédit et en isoler la composante exogène, les chocs financiers.

L'objectif de ce chapitre est de proposer une méthode d'identification des chocs financiers qui soit robuste aux risques de misidentification liés aux caractéristiques des variables financières, leurs pro-cyclicalité et forward-lookingness les rendant particulière-

ment difficiles à séparer du cycle économique. Et d'autre part, se basant sur des critères exclusivement qualitatifs, moins sensibles aux spécifications du modèle que les critères quantitatifs utilisés dans les modèles DSGE pour identifier les chocs économiques.

Pour répondre à ces critères, je présente dans ce chapitre une stratégie d'identification se basant sur l'observation des choix de financement des firmes non-financières. L'idée est la suivante, une firme ayant accès à la fois aux financements bancaires et obligataires peut ajuster le volume et la composition de sa dette. Dans une première partie, je développe un modèle d'équilibre général me permettant d'étudier l'évolution de la dette des firmes en réponse à différents types de chocs. Je montre que seul le choix de dette des firmes permet de distinguer les chocs financiers des autres chocs macroéconomiques. Dans une seconde partie, je reprends les implications du modèle pour identifier les causes du cycle des affaires aux Etats-Unis à l'aide d'un modèle VAR identifié par la méthode des restrictions de signes.

Pour étudier l'évolution des niveaux de dettes bancaires et obligataires des firmes en réponse à différents types de choc, j'intègre le mécanisme de choix de dette présenté par De Fiore et Uhlig (2011) à un modèle néo-keynésien. Dans cette économie, les firmes peuvent choisir de financer leur production grâce à des emprunts bancaires ou obligataires en fonction de leurs caractéristiques individuelles. Les prêts bancaires sont plus coûteux que les prêts obligataires mais aussi plus flexibles puisqu'ils peuvent être renégociés par chaque firme en fonction de ses perspectives de profits. Le modèle implique que le choix de financement d'une firme dépende à la fois de ses caractéristiques individuelles mais aussi des conditions macroéconomiques dans lesquelles celle-ci opère.

Un résultat central du modèle est que seuls les chocs financiers impliquent une réponse opposée des prêts bancaires et des prêts obligataires. En modifiant directement l'attractivité des deux types de dettes, ces chocs incitent les firmes à réviser leur choix de financement. En revanche, les autres types de chocs modifient le niveau d'activité économique et par conséquent le niveau de dette requis par ces dernières pour produire, mais leurs effets sur les conditions de crédit des firmes sont faibles et indirects. En réponse à des chocs non-financiers, les firmes ajustent leur niveau d'emprunt de manière procyclique tout en laissant inchangée la composition de leur dette. Ces prédictions du modèle sont robustes à des paramétrisations très différentes.

Dans une seconde partie, j'utilise ces résultats pour informer un modèle empirique

et identifier les sources du cycle des affaires grâce aux données de bilan de firmes non-financières. Un avantage de cette stratégie d'identification est qu'il n'est pas nécessaire de considérer les chocs financiers comme des chocs de demande, une hypothèse communément formulée pour identifier les chocs financiers mais contraire aux évidences récentes mises en avant par Gilchrist et al. (2017). Le modèle empirique estimé est un modèle VAR identifié grâce à une méthode dite de restriction de signes. Cette méthode permet de classer les différents types de chocs structurels selon le signe de leur impact sur les différentes variables du modèle. L'estimation est réalisée avec des données américaines trimestrielles pour la période de 1985 à 2018, permettant de comparer les résultats obtenus à un vaste nombre d'études réalisées pour les États-Unis. Les séries utilisées pour l'estimation du modèle incluent les séries du PIB, de l'investissement, du déflateur du PIB et du taux directeur ainsi que les volumes de prêts bancaires et de prêts obligataires des corporations non-financières.

Conformément aux implications du modèle théorique, les chocs financiers sont identifiés comme les seuls chocs capables de générer des mouvements opposés pour les différents types de dette. Les autres types de chocs sont aussi identifiés selon le signe des réponses des différentes variables du modèle théorique qui sont robustes aux changements de paramétrisation.

Le modèle VAR estimé permet de caractériser l'impact des différents types de chocs considérés dans la littérature s'intéressant aux cycles des affaires. Je trouve qu'un choc financier expansionniste entraîne une hausse de l'investissement, du taux directeur et de l'inflation. Ces caractéristiques des chocs financiers sont cohérentes avec celles obtenues dans de nombreux modèles DSGE. Le modèle est ensuite utilisé pour étudier les contributions des différents chocs aux fluctuations économiques observées durant la période d'estimation. Je trouve que les chocs financiers expliquent plus d'un tiers de la variance du PIB mais que leur contribution est inégale au cours du cycle des affaires. Ainsi le modèle attribue les récessions du début des années 2000 et de 2008 à des chocs financiers mais ceux-ci ne jouent aucun rôle dans la récession du début des années 90. Malgré les restrictions minimales imposées pour identifier le modèle VAR, les caractéristiques des chocs financiers estimés sont cohérentes avec les résultats de la littérature macro-financière basés sur des techniques plus contraintes.

Dans la dernière partie de ce chapitre, je teste la stratégie d'identification en procè-

dant aux exercices suivants : le modèle néo-keynésien est estimé de sorte à minimiser la distance entre ses réponses impulsionnelles et celles générées par le modèle VAR. Je montre qu'avec une paramétrisation raisonnable, le modèle néo-keynésien est capable de répliquer les réponses du modèle empirique pour l'ensemble des chocs considérés.

Le modèle théorique estimé est ensuite utilisé pour recueillir les chocs financiers réalisés durant la période d'estimation du modèle VAR et calculer une mesure synthétisant le stress financier auquel ont été confrontées les firmes non-financières depuis les années 80. Je compare cette mesure à un proxy du stress financier, le spread obligataire - la différence entre les taux obligataires payés par les corporations américaines et le taux directeur. Les deux séries s'avèrent extrêmement proches en dépit du fait qu'aucune série de taux d'intérêt n'ait été utilisée dans l'estimation du modèle VAR. Enfin, je procède à un test dit de Granger-causalité permettant de déterminer laquelle de ces deux mesures du stress financier, celle impliquée par le modèle ou celle directement observée sur les marchés, permet de mieux prévoir l'autre. Je trouve que les chocs financiers identifiés grâce aux choix de financement des firmes permettent de prévoir les évolutions du spread obligataire. Ce résultat tend à suggérer que l'évolution relative des quantités de financement obligataire et de financement bancaire est un meilleur indicateur de stress financier que les spreads obligataires.

Chapter 1

Collateral Shocks

This chapter is co-authored with Yvan Bécard, Assistant Professor of Economics at PUC-Rio.

I. Introduction

Business cycles are characterized by positive comovements among output, consumption, investment, and employment. To understand what drives these comovements, a branch of macroeconomics develops and estimates quantitative general equilibrium models where candidate forces compete to generate responses that mimic actual business cycles. In the decade after the 2008 recession, a number of influential papers have come to the conclusion that financial shocks play a key role in driving economic fluctuations.¹ These findings are important because they are consistent with other strands of the empirical literature,² and ultimately help us understand how crises come and go.

Despite the recent progress, none of these studies proposes a single shock that generates the comovements observed in the data.³ Typically, the main financial impulse drives

¹See Gerali et al. (2010), Jermann and Quadrini (2012), Liu, Wang, and Zha (2013), Christiano, Motto, and Rostagno (2014), Gilchrist et al. (2014), Del Negro, Giannoni, and Schorfheide (2015), Iacoviello (2015), and Ajello (2016).

²Evidence using long-run time series includes Reinhart and Rogoff (2009) and Schularick and Taylor (2012). For vector autoregression evidence, see Gilchrist and Zakrajšek (2012b), Bassett et al. (2014), Prieto, Eickmeier, and Marcellino (2016), Furlanetto, Ravazzolo, and Sarferaz (2017), and Cesa-Bianchi and Sokol (2019). For univariate forecasting specifications, see López-Salido, Stein, and Zakrajšek (2017). For micro data evidence, see Peek and Rosengren (2000), Ashcraft (2005), Amiti and Weinstein (2011), Derrien and Kecskés (2013), Chodorow-Reich (2014), and Benmelech, Meisenzahl, and Ramcharan (2017).

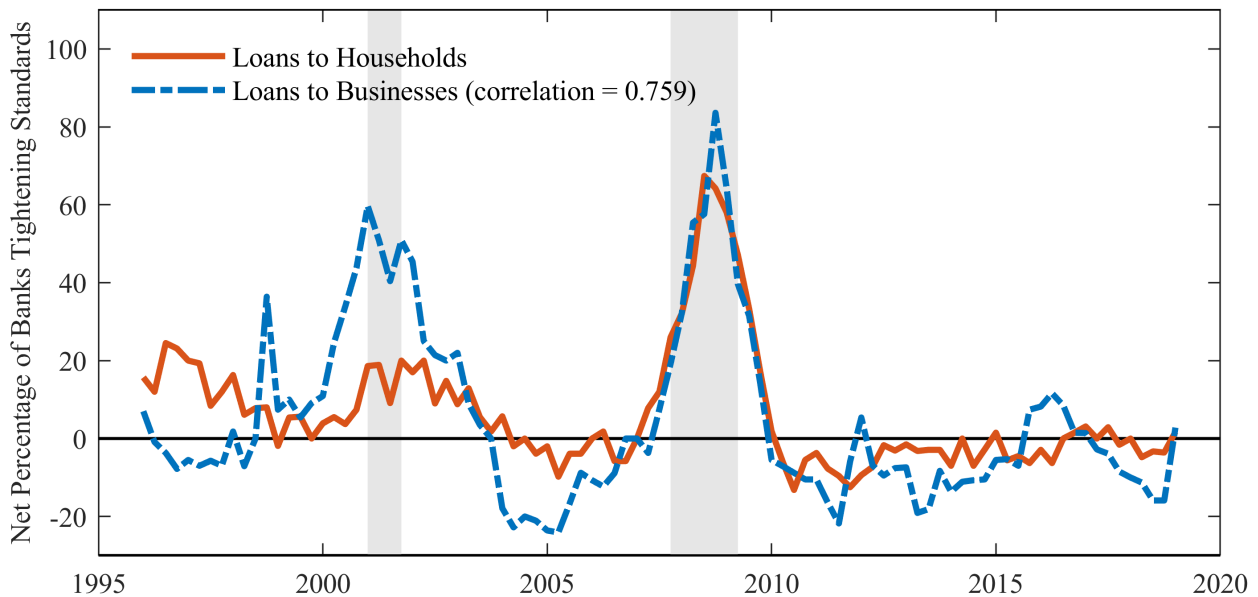
³Two dimensions matter for the comovements. The first one is qualitative: the candidate shock must

a large share of the variance in output, investment, and hours worked, but has very little impact on the dynamics of consumption. Since actual consumption is both highly correlated with and about two thirds as volatile as output, these papers must resort to a distinct source, generally a preference shock, to explain the movements in consumption. This is not satisfactory because the financial shock and the preference shock need to be correlated to fit the data, and this is at odds with their structural and independent nature.

In this paper, we identify a *single* disturbance that produces the comovements in all four aggregate variables, including consumption. This disturbance originates in the financial sector. In the United States, 80 percent of total private credit is bank-based; over half flows to households while the rest goes to businesses; most of it is secured by collateral. While these facts are well known, we believe an important feature of bank intermediation has been largely overlooked. When banks tighten or loosen their lending standards, they do so for both types of borrowers—households and firms alike. Figure 1.1 illustrates this point clearly. We plot two measures of lending standards, one for consumer loans and the other for business loans. The two series exhibit largely the same pattern. Right before the 2001 recession standards tightened, especially for firms. They subsequently eased, and from 2004 to 2007 banks were relaxing standards quarter after quarter (values are negative). Again, prior to the 2008 recession, banks abruptly increased lending requirements for both households and firms.

Motivated by this preliminary evidence, we develop a macroeconomic model with two main ingredients. First, a banking sector extends loans to households and firms. Second, the capacity of banks to absorb collateral simultaneously transmit to credit conditions for both types of loans. Our starting framework is the dynamic stochastic general equilibrium (DSGE) model of Christiano, Motto, and Rostagno (2014)—hereafter CMR. We augment this model by introducing heterogeneity among households. Some are net savers, or patient, while others are net borrowers, or impatient. We also add a banking sector subject to capital requirements by the regulator. Banks collect deposits from patient households and extend collateralized loans to impatient households and entrepreneurs. Impatient households use the loans to purchase housing and consume; entrepreneurs use

generate a positive correlation among output, consumption, investment, and employment. The second dimension is quantitative: the candidate shock must generate movements of the same magnitude as in the data. In this paper we emphasize the quantitative dimension because all the aforementioned papers struggle along this dimension for at least one variable— consumption.



Note: The grey bars indicate NBER recession dates. Source: Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOOS), Board of Governors of the Federal Reserve System.

Figure 1.1: Bank Tightening

the loans to purchase capital and rent it to productive firms.

Banks impose time-varying collateral requirements on their borrowers: we define the exogenous capacity of banks to liquidate collateral as the *collateral shock*, which we denote by ν_t . A collateral shock ν_t results in banks adjusting their lending requirements simultaneously on the two types of loans.⁴ In case of default, this fraction is seized by the bank, while borrowers keep the unpledged share. The collateral shock is meant to capture a broad set of developments in the financial sector. For instance, in the boom years preceding the last financial crisis, securitization enabled banks to demand lower downpayments. This would be captured in our model as a sequence of positive collateral shocks. Conversely, the sudden downgrading of securities used as collateral led banks to ask for higher haircuts. This would be captured as a steep negative collateral shock.

We ask whether the collateral shock can generate dynamics that resemble US busi-

⁴Kiyotaki and Moore (2018), Ajello (2016), and Del Negro et al. (2017) emphasize liquidity shocks through a resaleability constraint. Our collateral shock encompasses their disturbance, as the tightening of lending standards by banks in the last recession probably resulted from liquidity issues in wholesale credit markets. However, liquidity shocks in these papers affect only the financing of firms, and say nothing about household credit and house price dynamics, two central elements of the crisis.

ness cycles. The answer is yes. Using financial and macroeconomic data we estimate our model with Bayesian techniques and find that the collateral shock is the main driver of economic fluctuations over the past three decades. In particular, the collateral shock accounts for the bulk of the variance in output, consumption, investment, employment, business credit, household and business credit spreads, and a large share of the variance in household credit. To the best of our knowledge, our paper is the first to put forward a shock that explains the movements in all four main macroeconomic variables, including consumption, as well as in various financial series.⁵

The reason why our collateral shock is able to drive consumption on top of the other macro variables is simple and intuitive. Imagine confidence in the financial system drops and banks realize they can no longer absorb and resell as much collateral—a negative collateral shock. The first thing banks do is tighten collateral requirements on all their loans, regardless of the type of borrower. Both borrowing households and firms receive fewer loans. On the corporate side, firms cut back on capital expenditure, investment falls, and this provokes a fall in output and employment. On the consumer side, borrowing households cut back on housing and goods purchases, and this provokes a fall in consumption. To show the mechanism in a different way, we estimate a version of our model with no borrowing households (and no household credit). We find that the collateral shock is still the main driving force of the economy, but it fails to account for the movements in consumption.

We perform several out-of-sample exercises to study broader implications of the collateral shock. We confront the estimated collateral shock process against the series of bank lending standards presented in Figure 1.1. The match is good, and this provides a real-world interpretation to our theoretical object. The high correlation means our model generates realistic patterns for the two types of borrowers. We also compare the collateral shocks implied by the model with actual indexes of financial stress such as the VIX or the excess bond premium. We find that the collateral shocks is highly correlated and Granger cause these different measures of financial stress.

Our paper contributes to the literature that estimates quantitative models to under-

⁵Angeletos, Collard, and Dellas (2018b) recently argue that agents' heterogeneous beliefs about their trading partners' future productivity generate dynamics that resemble business cycles. Their confidence shock explains a large share of the movements in the four main macroeconomic variables, but is silent on financial variables, as the authors abstract from financial frictions.

stand the sources of business cycles. Angeletos, Collard, and Dellas (2019) motivate the search for a "main business-cycle shock" that generates strong short-run comovements among most macroeconomic variables but is disconnected from inflation and TFP.⁶ Justiniano, Primiceri, and Tambalotti (2010) demonstrate that shocks to the marginal efficiency of investment (MEI) can explain a large chunk of the business cycle, except for consumption. Their findings suggest financial factors might be at play.⁷ CMR show that once they add a financial accelerator to this setup and estimate it using financial series, the importance of the MEI shock nearly vanishes. Instead, shocks to the dispersion of firms' productivity, or risk shocks, become the main driver of economic fluctuations. The risk shock, however, is not able to account for much of the movements in consumption. We build on their approach and complement it by introducing bank lending to households. Our collateral shock is very similar to the risk shock on the entrepreneurial side, but it differs on the household side, and this allows us to match consumption. The collateral shock fits the narrative of the recent crisis, where ailing banks tightened credit to both consumers and businesses.

Our work is also related to a recent and growing line of research. The "credit supply view" argues that changes in the credit supply by banks, often unrelated to improvements in productivity or income, is the cause of debt booms and busts.⁸ Some of these studies highlight the direct causal link between household credit and consumption that our model displays. Mian and Sufi (2011) show that homeowners borrow vast amounts through refinancing and home equity loans as their house appreciates, a large fraction of which is used to consume. Mian, Rao, and Sufi (2013) find that the most credit-constrained households are those who cut consumption the most in bad times.

The article is organized as follows. Section I introduces the key mechanism and provides some intuition. Section II describes the full model and Section III discusses the data and estimation procedure. In Section IV we analyze the prominent role of the collateral

⁶Sargent and Sims (1977) and Giannone, Reichlin, and Sala (2004), among others, argue that US cycles are driven by two shocks, one for real variables and the other for nominal ones.

⁷Jermann and Quadrini (2012) estimate a model where firms raise intra-period loans to finance working capital. They find that financial shocks, *i.e.* tightening of the enforcement constraint by lenders, are the most important factor driving US business cycles, excluding consumption. Pfeifer (2016) disputes their result and argues that a more reliable estimation reproduces the findings of Justiniano, Primiceri, and Tambalotti (2010).

⁸Examples include Mian, Sufi, and Verner (2017), Justiniano, Primiceri, and Tambalotti (2018), and Rodano, Serrano-Velarde, and Tarantino (2018).

shock. Section V offers out-of-sample evidence in support of the collateral shock. Section VI concludes.

II. Intuition

This section provides intuition for the central mechanism of the paper. The purpose is twofold. First, we explain why financial shocks that emerge separately from the business and household sectors typically have counterfactual implications for consumption and investment. Second, we argue that a shock that emanates from banks and affects business and household loans simultaneously is able to overcome this issue and generate the comovements observed in the data.

A. The Comovement Puzzle

Our starting point is a standard business cycle model. The aggregate production function, the national income identity, and the optimal labor decisions of households and firms are respectively:

$$Y_t = F(K_t, L_t), \quad (1.1)$$

$$Y_t = C_t + I_t, \quad (1.2)$$

$$U_2(C_t, 1 - L_t) = W_t U_1(C_t, 1 - L_t), \quad (1.3)$$

$$W_t = \frac{1}{\lambda_t} F_2(K_t, L_t), \quad (1.4)$$

where Y_t is output, C_t consumption, I_t investment, K_t capital, L_t hours worked, W_t the real wage, λ_t the price markup over marginal cost, U utility, and F the production technology. We present two separate extensions to this simple framework.

Financial Friction and Financial Shock on Firms.—In the first extension, households do not own the capital stock directly. Instead, they save by purchasing debt B_t^e issued by firms (in the full model we call these firms entrepreneurs and use the superscript e) at rate R_t . Firms, in turn, use these funds to invest in the capital stock. For simplicity, $B_t^e = I_t$. Now, suppose there is a financial friction that limits the amount of debt firms can borrow from households. In particular, a borrowing constraint requires that the value of debt be a

fraction of the value of capital,

$$B_t^e \leq \phi_t^e K_t, \quad (1.5)$$

where ϕ_t^e is a loan-to-value ratio, taken as exogenous for now.

How does a negative financial shock, *i.e.* a drop in ϕ_t^e , affect the economy? The shock reduces firms' access to credit. Investment drops. Since capital is determined one period in advance, Equation (1.1) says that the response of output depends on the response of labor. With flexible prices, the demand for labor does not budge and output is largely unresponsive. From Equation (1.2), constant output and falling investment imply consumption must increase.⁹ To sum up, a financial shock on firms produces opposite movements in consumption and investment and fails to generate the comovements.

Financial Friction and Financial Shock on Households.—In the second extension, we suppose there are two types of households: patient (superscript p) and impatient (superscript i).¹⁰ Patient households are the usual saving households. They invest directly and without friction in the capital stock of firms to obtain return R_t^k and they buy debt B_t^i issued by impatient households at rate R_t . In equilibrium, they are indifferent between the two options, $R_t = E_t R_{t+1}^k$. Impatient households supply inelastic labor L^i at wage W_t , consume C_t^i , and obtain a loan B_t^i from patient households. Their budget constraint is $C_t^i + R_{t-1} B_{t-1}^i = W_t L^i + B_t^i$. They also own fixed housing H^i , whose sole purpose is to act as collateral for the loan. Similarly to firms in the first extension, impatient households are subject to a financial friction that limits the amount they can borrow. A borrowing constraint requires that the value of debt be a fraction of the value of housing,

$$B_t^i \leq \phi_t^i H^i, \quad (1.6)$$

where ϕ_t^i is a loan-to-value ratio, taken as exogenous for now. The budget constraint can be rewritten as:

$$C_t^i = W_t L^i + (\phi_t^i - R_{t-1} \phi_{t-1}^i) H^i. \quad (1.7)$$

⁹With sticky prices, it is possible to obtain a fall in consumption if 1) firms that cannot adjust their price reduce employment and output by a sufficiently large amount; 2) the central bank does not respond too much to inflation. This point is made by CMR and Basu and Bundick (2017), among others. However, under standard preferences the fall in consumption is typically much smaller and slower than the fall in output. As a result, when evaluated at business cycle frequency the financial shock accounts for a tiny fraction of the variance in consumption.

¹⁰This designation comes from Iacoviello (2005).

Aggregate consumption and labor are $C_t = C_t^p + C_t^i$ and $L_t = L_t^p + L_t^i$, respectively.

How does a negative financial shock, *i.e.* a drop in ϕ_t^i , affect the economy? The shock reduces impatient households' access to credit. From (1.7), their consumption C_t^i drops. The interest rate R_t immediately falls to clear the market for debt. This makes the return to capital relatively higher and induces patient households to move their savings towards capital. Investment goes up. Patient households might consume a bit more if a higher demand for labor increases their overall income, but this effect is small. Provided the share of impatient households in the economy is large enough, $|\Delta C_t^i| > |\Delta C_t^p|$, and aggregate consumption decreases. To sum up, a financial shock on households produces opposite movements in consumption and investment and fails to generate the comovements.

B. A Solution with Banks

We propose a simple way to solve the comovement problem with financial shocks. Consider a model where both firms and impatient households take on debt and are subject to financial frictions. Patient households remain the ultimate lenders in the economy. But now, a bank acts as an intermediate. The bank receives deposits D_t from patient agents and transforms them into loans for the two types of borrowers, $D_t = B_t^e + B_t^i$. The only interest rate is R_t , and thus the bank makes no profit or loss in the operation. However, borrowers can default on their loans. In such a case, the bank must seize their collateral, process it, refurbish it, and sell it back on the market.

This process takes times and is costly. Let $Z(\cdot)$ be the capacity of the bank to absorb and resell collateral, where $Z'(\cdot) > 0$ and $Z''(\cdot) < 0$. The bank builds an homogeneous collateral good A_t with capital and housing according to:

$$A_t = \nu_t Z(\phi_t^e K_t, \phi_t^i H_t).$$

Here, ϕ_t^e and ϕ_t^i are the share of capital and housing, respectively, in the collateral good, and ν_t is an efficiency variable, like technology in the production function. The bank chooses capital and housing intensities to solve:

$$\begin{aligned} & \max_{\phi_t^e, \phi_t^i} A_t - \phi_t^e K_t - \phi_t^i H_t, \\ & \text{subject to } A_t = \nu_t Z(\phi_t^e K_t, \phi_t^i H_t). \end{aligned}$$

The first-order conditions are:

$$\nu_t Z_1(\phi_t^e K_t, \phi_t^i H^i) = K_t, \quad (1.8)$$

$$\nu_t Z_2(\phi_t^e K_t, \phi_t^i H^i) = H^i. \quad (1.9)$$

The loan-to-value ratios ϕ_t^e and ϕ_t^i are endogenous and determined by the value of borrowers' collateralized assets and by the bank's absorbing capacity ν_t .

We assume that ν_t is an exogenous, stochastic variable that depends on unspecified market conditions. We refer to it as the *collateral shock*. For example, the sale of collateral requires to search for a buyer and then to bargain over the price. When market conditions deteriorate, the probability of finding a buyer and negotiating a good offer decreases. More generally, ν_t represents the risk-absorbing capacity of the financial sector, or put differently, confidence or optimism in financial markets.

How does a negative collateral shock affect the economy? Since Z is strictly concave, a lower ν_t decreases ϕ_t^e and ϕ_t^i for given K_t and H_t^i . Thus, the bank reacts by tightening the borrowing constraints of both firms and impatient households. Business and household credit fall, and so do investment and impatient household consumption. Provided that prices are sticky and output is demand-driven, the demand for labor falls and so does the wage. Thus, even though patient households want to consume more as they save less, their overall income is reduced and the movement in their consumption is relatively small. With a large enough share of impatient households in the economy, aggregate consumption falls. To sum up, a collateral shock leads to a fall in consumption, investment, output, hours, and credit, and thus generates the desired comovements.

III. The Model

We enrich the model of the previous section with several elements. First, we introduce risky debt and default, a la Bernanke, Gertler, and Gilchrist (1999), for each type of borrower. The reason is we want to match the quantity and price of debt, *i.e.* the interest rate on loans. This does not change the qualitative properties of our central mechanism. Second, we add a number of nominal and real frictions widely used in the literature, as in Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). To keep the presentation brief we relegate the complete derivation of the model to Online Appendix

Section A1.

A. *Patient Households*

A representative patient household contains a large number of workers who supply differentiated labor $l_{k,t}^p$, $k \in [0, 1]$. The household derives utility from consumption C_t^p and housing services H_t^p according to:

$$E_0 \sum_{t=0}^{\infty} \beta^{p,t} \left\{ \zeta_{c,t} \ln(C_t^p - b_c^p C_{t-1}^p) + \zeta_{h,t} \ln H_t^p - \psi_l \int_0^1 \frac{l_{k,t}^{p,1+\sigma_l}}{1+\sigma_l} dk \right\}, \quad b_c^p, \psi_l, \sigma_l > 0,$$

where $\beta^p \in (0, 1)$ is a discount factor, $\zeta_{c,t}$ is a consumption preference shock, and $\zeta_{h,t}$ is a housing preference shock. Housing services are provided one-for-one by the housing good \bar{H}_t^p whose price is Q_t^h . The budget constraint of the patient household writes:

$$(1 + \tau^c) P_t C_t^p + Q_t^h \bar{H}_t^p + P_t D_t \leq (1 - \tau^l) \int_0^1 W_{k,t}^p l_{k,t}^p dk + R_t P_{t-1} D_{t-1} + Q_t^h \bar{H}_{t-1}^p + \Delta_t^p + T_t^p,$$

where τ^c and τ^l are consumption and labor tax rates, P_t is the price of final goods, and $W_{k,t}^p$ is the nominal wage of worker k . The patient household allocates its budget on consumption, housing, and bank deposits D_t . Its revenues come from labor income, previous-period deposits, the sale of previous-period housing, dividends from entrepreneurs Δ_t^p , and a transfer from the government T_t^p .

B. *Impatient Households*

A representative impatient household comprises three types of members. A large number of workers supply differentiated labor $l_{k,t}^i$, $k \in [0, 1]$, consume, and choose housing services. A single real estate broker acquires housing goods and sells them to homeowners. Finally, a large number of homeowners borrow from banks to purchase housing goods and rent them to the workers.¹¹ The reason we split the impatient household in three is to ensure that the problem of the borrowing agent—the homeowner—is linear in net worth, which facilitates aggregation. There is perfect insurance in consumption goods and housing services within the household.

¹¹The separation of the impatient household program into workers and homeowners comes from Ferrante (2019).

Workers.—The impatient household has preferences similar to the patient one;

$$E_0 \sum_{t=0}^{\infty} \beta^{i,t} \left\{ \zeta_{c,t} \ln(C_t^i - b_c^i C_{t-1}^i) + \zeta_{h,t} \ln H_t^i - \psi_l \int_0^1 \frac{l_{k,t}^{i,1+\sigma_l}}{1+\sigma_l} dk \right\}, \quad b_c^i, \psi_l, \sigma_l > 0.$$

We impose $\beta^i < \beta^p$ to guarantee that the impatient household is a net borrower in equilibrium. The budget constraint of workers is:

$$(1 + \tau^c) P_t C_t^i + P_t r_t^h H_t^i \leq (1 - \tau^l) \int_0^1 W_{k,t}^i l_{k,t}^i dk + \Delta_t^i + T_t^i,$$

where r_t^h is the rental rate of housing and Δ_t^i denotes aggregate housing dividends coming from homeowners.

Real Estate Brokers.—A representative, competitive real estate broker acts as a middleman. He purchases housing goods from housing producers (described below) and sells them to the homeowners, who cannot bypass him. In the process of acquiring vast amount of real estate, the broker is subject to housing adjustment costs. These costs are important because they smooth the dynamics of housing and hence of household credit, which is an observable variable, and thus help our model fit the data. The problem of the real estate broker is to maximize profit:

$$E_0 \sum_{t=0}^{\infty} \beta^{i,t} \Lambda_{z,t}^i \left\{ Q_t^h \bar{H}_t^i - Q_t^h \bar{H}_t^i [1 + S^h(\bar{H}_t^i / \bar{H}_{t-1}^i)] \right\},$$

where $\Lambda_{z,t}^i$ is the impatient household's marginal utility of consumption and S^h is an increasing convex function, defined below.

C. Borrowers: Impatient Homeowners and Entrepreneurs

Impatient homeowners and entrepreneurs have similar programs and we thus describe them jointly in this subsection.

There is a continuum $j \in [0, 1]$ of borrowers of type $o \in \{i, e\}$, where $o = i$ if the type is homeowner and $o = e$ if the type is entrepreneur. In period t , borrower j of type o obtains a loan $B_{j,t}^o$ from the bank at interest rate R_t^o . She combines the loan with her net worth $N_{j,t}^o$ to purchase an asset $X_{j,t}$ at price Q_t^x , where $x \in \{h, k\}$. The asset is housing, $X_{j,t} = \bar{H}_{j,t}^i$

and $Q_t^x = Q_t^h$, if the borrower is a homeowner ($o = i$), or the asset is capital, $X_{j,t} = \bar{K}_{j,t}$ and $Q_t^x = Q_t^k$, if the borrower is an entrepreneur ($o = e$). The loan is risky, therefore the bank requires that the asset be pledged as collateral. The borrower can pledge only a fraction ϕ_t^o of her asset, decided by the bank. In case of default the bank seizes this fraction, while the borrower gets to keep the non-pledged share $1 - \phi_t^o$.

At the beginning of period $t + 1$, borrower j is hit by an idiosyncratic shock $\omega_{j,t+1}^o$ that converts the value of her asset $Q_t^x X_{j,t}$ into $\omega_{j,t+1}^o Q_t^x X_{j,t}$. We assume $\omega_{j,t+1}^o$ is a lognormal random variable distributed independently over time and across borrowers, with cumulative distribution function $F_t^o(\omega_{j,t+1}^o)$, and $E_t \omega_{j,t+1}^o = 1$. We denote by σ_t^o the exogenous standard deviation of $\ln \omega_{j,t+1}^o$. We call σ_t^i the household risk shock and σ_t^e the firm risk shock. The latter is what CMR simply refer to as the risk shock.

After receiving the idiosyncratic shock borrower j has the following net worth, which is simply the difference between assets and liabilities,

$$N_{j,t+1}^o = R_{j,t+1}^x \omega_{j,t+1}^o Q_t^x X_{j,t} - R_{j,t}^o B_{j,t}^o, \quad o \in \{i, e\}, x \in \{h, k\}.$$

Here, $R_{j,t+1}^x$ is the return on asset $X_{j,t}$. Let us separate momentarily the two types of borrowers. Impatient homeowner j obtains a return $R_{t+1}^h \equiv Q_{t+1}^h / Q_t^h$ on her housing, common to all homeowners.¹² She allocates her resources on new housing purchases and dividends to her household. She draws funds from her net worth, rental income, and a new loan from the bank. Her budget constraint is:

$$Q_{t+1}^h \bar{H}_{j,t+1}^i + \Delta_{j,t+1}^i = N_{j,t+1}^i + P_{t+1} r_{t+1}^h \bar{H}_{j,t+1}^i + B_{j,t+1}^i.$$

Entrepreneur j obtains the following return on capital:

$$R_{j,t+1}^k = [(1 - \tau^k)[u_{j,t+1} r_{t+1}^k - a(u_{j,t+1})] \Upsilon^{-(t+1)} P_{t+1} + (1 - \delta) Q_{t+1}^k + \tau^k \delta Q_{t+1}^k] / Q_t^k,$$

where τ^k is the tax rate on capital income. The entrepreneur chooses capital utilization rate $u_{j,t+1}$, pays utilization adjustment cost $a(u_{j,t+1})$, where a is defined below, and rents out capital services $u_{j,t+1} \omega_{j,t+1}^e Q_t^k \bar{K}_{j,t}$ to intermediate firms at rental rate r_{t+1}^k . After production, she sells her depreciated capital to capital producers at price Q_{t+1}^k . Depreciated

¹²This return excludes rental income which we assume cannot be seized by the bank.

capital benefits from a tax deduction. The entrepreneur allocates her resources on new capital purchases. Her sources of funds are her net worth and a new loan from the bank. Her budget constraint is:

$$Q_{t+1}^k \bar{K}_{j,t+1} = N_{j,t+1}^e + B_{j,t+1}^e.$$

Objective.—We return to the borrower j of type $o \in \{i, e\}$. The goal of borrower j is to maximize dividends if she is a homeowner, or expected net worth if she is an entrepreneur. Optimization is subject to the budget constraint and a bank participation constraint, defined below. In Online Appendix Section A1, we show that the objective function of the borrower is linear in current net worth. As a result, each borrower j receives a standard debt contract and strategically defaults whenever the cost of servicing debt exceeds the value of the assets she pledged to the bank as collateral. Let $\bar{\omega}_{j,t+1}^o$ be the default threshold, then,

$$R_{t+1}^x \bar{\omega}_{j,t+1}^o \phi_t^o Q_t^x X_{j,t} = R_{j,t}^o B_{j,t}^o, \quad o \in \{i, e\}, x \in \{h, k\}.$$

D. Banks

A representative, competitive bank uses patient household deposits to extend loans to impatient households and entrepreneurs. For every borrower j of type $o \in \{i, e\}$ the bank requires to break even. Thus, the participation constraint,

$$[1 - F_t^o(\bar{\omega}_{j,t+1}^o)] R_{j,t+1}^o B_{j,t}^o + (1 - \mu^o) \int_0^{\bar{\omega}_{j,t+1}^o} \omega_{j,t+1}^o dF_t^o(\omega_{j,t+1}^o) R_{t+1}^x \phi_t^o Q_t^x X_{j,t} \geq R_{t+1} B_{j,t}^o,$$

is always satisfied in period $t + 1$. Here μ^o is the cost paid by the bank to monitor defaulting borrowers.¹³ The first term on the left is the return from non-defaulting borrowers. The second term is the return on assets from defaulting borrowers whose assets are seized by the bank. As explained earlier, ϕ_t^o represents the value of the underlying asset—housing or capital—against which the bank is willing to lend, and which is therefore able to recover in case of bankruptcy.

As explained in Section I, processing and reselling collateral is no easy task. The bank

¹³In one version of the model, we allow the two monitoring costs to be time-varying exogenous variables. We find that the qualitative effects of these two shocks, μ_t^i and μ_t^e , are very similar to those of the two risk shocks, σ_t^i and σ_t^e , respectively, but that their quantitative effects are much less powerful.

produces an homogeneous collateral good A_t according to the production function:

$$A_t = \nu_t[\ln(\phi_t^i)\bar{H}_t^i + \ln(\phi_t^e)\bar{K}_t].$$

With this particular form, the optimal housing and capital intensities are

$$\begin{aligned}\phi_t^i &= \nu_t, \\ \phi_t^e &= \nu_t.\end{aligned}$$

E. Production, Government, Aggregation, Adjustment Costs, and Shocks

Goods Production.—A representative, competitive final good firm combines intermediate goods $Y_{j,t}$, $j \in [0, 1]$, to produce final output Y_t using the technology:

$$Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_{f,t}}} dj \right]^{\lambda_{f,t}},$$

where $\lambda_{f,t} \geq 1$ is a markup shock. Each intermediate good j is produced by a monopolist according to the production function:

$$Y_{j,t} = \max \left\{ \varepsilon_t (u_t K_{j,t-1})^\alpha (z_t l_{j,t})^{1-\alpha} - \theta z_t^*; 0 \right\}, \quad \alpha \in (0, 1),$$

where $K_{j,t-1}$ denotes capital services, $l_{j,t}$ is a homogeneous labor input, u_t is the aggregate utilization rate of capital, ε_t is a covariance stationary technology shock, and θ is a fixed cost. There are two sources of growth in the model. The first one is z_t , a shock to the growth rate of technology. The second one is an investment-specific shock $\mu_{\Upsilon,t}$ that changes the rate at which final goods are converted into $\Upsilon^t \mu_{\Upsilon,t}$ investment goods, with $\Upsilon > 0$. In equilibrium the price of investment goods is $P_t / (\Upsilon^t \mu_{\Upsilon,t})$. As in CMR, the fixed cost θ is proportional to z_t^* , which combines the two trends, $z_t^* = z_t \Upsilon^{(\frac{\alpha}{1-\alpha})t}$. The intermediate good producer faces standard Calvo frictions. Every period, a fraction $1 - \xi_p$ of intermediate firms sets their price $P_{j,t}$ optimally. The remaining fraction follows an indexation rule $P_{j,t} = \pi^\iota \pi_{t-1}^{1-\iota} P_{j,t-1}$, where $\iota \in (0, 1)$ and $\pi_t \equiv P_t / P_{t-1}$ is inflation. A variable without the subscript t denotes its steady-state value.

Labor Market.—A representative, competitive labor contractor aggregates specialized labor services $l_{k,t}^o$, where $k \in [0, 1]$ and $o \in \{p, i\}$, into homogeneous labor l_t^o using the technology:

$$l_t^o = \left[\int_0^1 l_{k,t}^{o, \frac{1}{\lambda_w}} dk \right]^{\lambda_w}, \quad o \in \{p, i\}, \lambda_w \geq 1.$$

Aggregate labor input is then defined as:

$$l_t = l_t^{p, \kappa} l_t^{i, 1-\kappa}, \quad \kappa \in (0, 1].$$

The share κ of patient labor income in total labor income is an important parameter; if $\kappa = 1$ we are back to a representative agent model.

Suppose that each worker of type k is represented by a monopoly union that sets its nominal wage rate $W_{k,t}^o$, where $o \in \{p, i\}$. All monopoly unions are subject to Calvo frictions in a similar fashion to intermediate firms. A fraction $1 - \xi_w$ of monopoly unions chooses their wage optimally. The remaining fraction follows an indexation rule $W_{k,t}^o = \mu_{z^*} \pi_t^{\iota_w} \pi_{t-1}^{1-\iota_w} W_{k,t-1}^o$, where $o \in \{p, i\}$, $\iota_w \in (0, 1)$, $\mu_{z^*} \equiv z^*/z_{-1}^*$ is the steady-state growth rate of the economy, and $\mu_{z^*, t}$ is a shock.

Capital and Housing Production.—A representative, competitive capital producer builds raw capital \bar{K}_t according to a standard technology:

$$\bar{K}_t = (1 - \delta)\bar{K}_{t-1} + [1 - S^k(\zeta_{I,t} I_t / I_{t-1})] I_t, \quad \delta \in (0, 1),$$

where I_t is investment, S^k is an increasing function defined below, and $\zeta_{I,t}$ is a shock to the marginal efficiency of investment. For simplicity, housing is in fixed supply and does not depreciate. The total housing stock is:

$$\bar{H} = \bar{H}_t^p + \bar{H}_t^i,$$

where \bar{H}_t^p and \bar{H}_t^i are the housing stocks of patient and impatient households, respectively, and $\bar{H}_t^i = \int_0^1 \bar{H}_{j,t}^i dj$.

Government.—The monetary authority follows a standard Taylor rule,

$$R_t - R = \rho_p(R_{t-1} - R) + (1 - \rho_p) [\alpha_\pi(E_t \pi_{t+1} - \pi) + \alpha_{\Delta y}(g_{y,t} - \mu_{z^*})] + \varepsilon_t^p,$$

where $\rho_p \in (0, 1)$ is a smoothing parameter, $\alpha_\pi > 0$ and $\alpha_{\Delta y} > 0$ are weight coefficients, and ε_t^p is a monetary policy shock. The variable $g_{y,t}$ is quarterly GDP growth in deviation from its steady state. The fiscal authority collects taxes to finance public expenditures G_t and make lump-sum transfers T_t to households:

$$G_t + T_t = ([u_t r_t^k - a(u_t)] \Upsilon^{-t} P_t - \delta Q_{t-1}^k) K_{t-1} \tau^k + (W_t^i l_t^i + W_t^p l_t^p) \tau^l + P_t C_t \tau^c.$$

Government spending is given by $G_t = z_t^* g_t$, where g_t is an exogenous-spending shock.¹⁴ Transfers are distributed to both types of households according to their respective share in total labor income, $T_t = \kappa T_t^p + (1 - \kappa) T_t^i$.

Aggregation.—Impatient households and entrepreneurs receive idiosyncratic shocks. Given their linear value function and our assumptions about perfect insurance, aggregation is simple. We provide details in Online Appendix Section A1. Aggregate consumption and debt are respectively:

$$C_t = C_t^p + C_t^i; \quad B_t = B_t^i + B_t^e.$$

Clearing in the goods market imposes

$$Y_t = G_t + C_t + I_t \Upsilon^{-1} \mu_{\Upsilon,t}^{-1} + a(u_t) \Upsilon^{-t} \bar{K}_{t-1} + D_t^b,$$

where D_t^b represents aggregate resources used by banks to monitor impatient households and entrepreneurs:

$$D_t^b = \phi_{t-1}^i \mu^i G_{t-1}^i (\bar{\omega}_t^i) R_t^h Q_{t-1}^h \bar{H}_{t-1}^i / P_t + \phi_{t-1}^e \mu^e G_{t-1}^e (\bar{\omega}_t^e) R_t^k Q_{t-1}^k \bar{K}_{t-1} / P_t.$$

Adjustment Costs.—Adjustment costs on investment and housing are similar,

$$S^o(x_t^o) = \exp \left[\sqrt{S^{o''}} / 2 (x_t^o - x^o) \right] + \exp \left[-\sqrt{S^{o''}} / 2 (x_t^o - x^o) \right] - 2, \quad o \in \{k, h\},$$

where $x_t^k \equiv \zeta_{I,t} I_t / I_{t-1}$ and $x_t^h \equiv H_t^i / H_{t-1}^i$. Note that $S^o(x^o) = S^{o'}(x^o) = 0$ for $o \in \{k, h\}$, and that $S^{k''}(x^k) = S^{k''}$ and $S^{h''}(x^h) = S^{h''}$ are parameters. The utilization adjustment cost

¹⁴This shock captures both changes in government expenditures and changes in net exports.

function is standard,

$$a(u_t) = r^k(\exp[\sigma_a(u_t - 1)] - 1)\sigma_a^{-1}, \quad \sigma_a > 0,$$

where r^k is the steady-state rental rate of capital. This function is such that in steady state utilization is equal to one, independently of the value of σ_a .

Shocks.—We consider 13 shocks: ε_t , ε_t^p , g_t , γ_t^e , $\lambda_{f,t}$, $\mu_{\gamma,t}$, $\mu_{z^*,t}$, ν_t , σ_t^i , σ_t^e , $\zeta_{c,t}$, $\zeta_{h,t}$, and $\zeta_{I,t}$. All have the same structure and follow a standard AR(1) process. Let x_t be a generic shock, then:

$$\ln(x_t/x) = \rho_x \ln(x_{t-1}/x) + \epsilon_t^x, \quad \epsilon_t^x \sim N(0, \sigma_x^2).$$

To solve the model, we stationarize it and we loglinearize it around the steady state. We list all the equations of the model in Online Appendix Section A2.

IV. Estimation

This section discusses the data and the calibration and estimation of parameters.

A. Data

We estimate our model on US quarterly data covering the period 1985Q1 to 2019Q1. These include seven standard macroeconomic variables: GDP, consumption, investment, hours worked, inflation, the federal funds rate, and the relative price of investment goods. In addition, we use four financial series: credit to households, credit to nonfinancial businesses, interest rate on household mortgage loans, and interest rate on business loans. The two rates enter as spreads relative to the federal funds rate. Online Appendix Section A3 gives a full description of the data and measurement equations.¹⁵ We treat the data as follows. In the case of GDP, consumption, investment, household credit, and business credit we express in real, per capita terms and we take the logarithmic first difference. For the price of investment goods we express in real terms and take the log first difference. We express hours in log levels. We measure inflation, the federal funds rate, and the two spreads in levels. We demean all variables to prevent low frequency movements from

¹⁵We use other data to calibrate parameters, match steady-state ratios, and perform out-of-sample exercises. See Online Appendix Tables A1 and A2.

interfering with the higher business cycle frequencies that interest us.

B. Calibrated and Estimated Parameters

The model has 58 parameters, including 33 structural ones and 25 related to shocks. We fix a number of them *a priori* based on our dataset and other sources and targets. We estimate the remaining 42 parameters using Bayesian methods.¹⁶ Online Appendix Section A5 provides a complete discussion. There, Table A3 reports the calibration, Table A4 the priors and posterior estimates, and Table A5 two measures of model fit.

V. The Collateral Shock

We begin this section by presenting quantitative evidence that suggests the collateral shock is the main driver of business cycles. We then explain why this is the case. Finally, we focus on the key element in our model that enables the collateral shock to account for the dynamics of consumption.

A. The Quantitative Role of the Collateral Shock

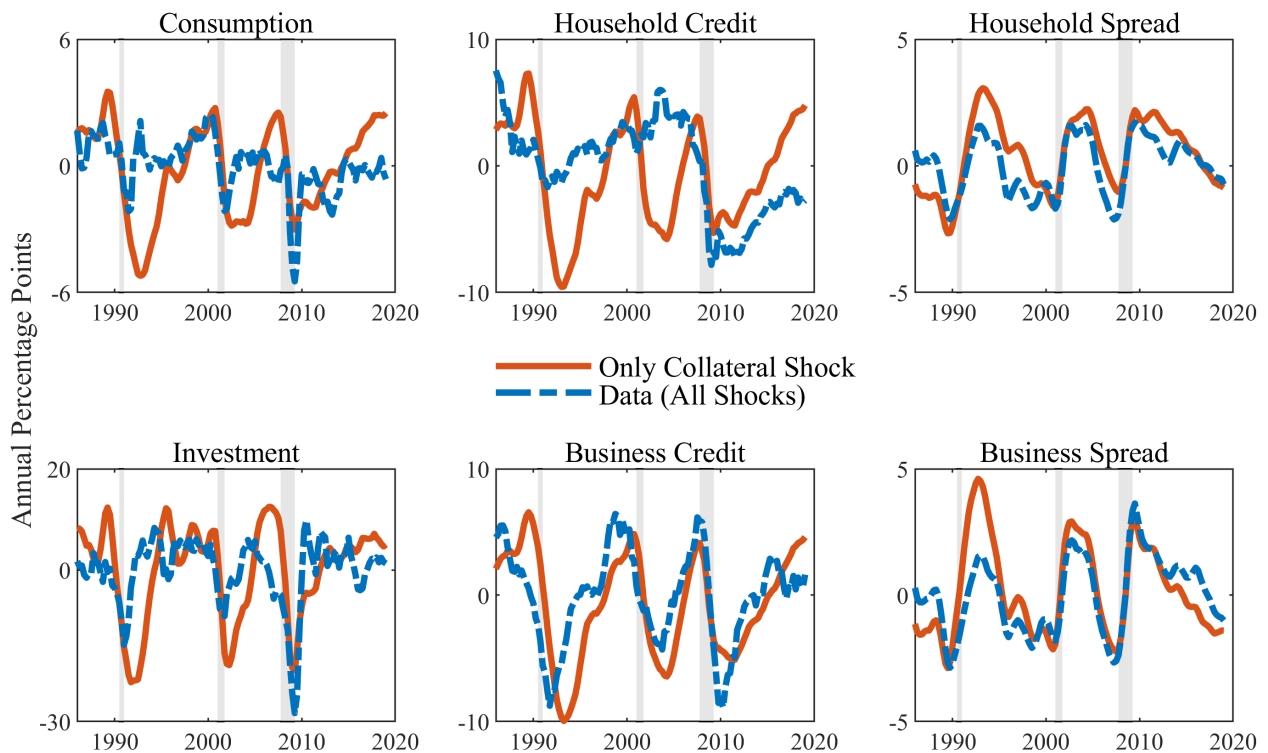
	Collateral Shock ν_t	Supply Shocks $\varepsilon_t, \mu_{z^*,t}, \mu_{\gamma,t}, \zeta_{I,t}, \lambda_{f,t}$	Demand Shocks $\zeta_{c,t}, \zeta_{h,t}, \sigma_t^i, \sigma_t^e, \varepsilon_t^g, \gamma_t^e, \varepsilon_t^p$
Output	50	25	25
Consumption	44	18	38
Investment	49	37	14
Hours	36	42	22
Household Credit	25	11	64
Household Spread	43	3	54
Business Credit	49	20	31
Business Spread	77	3	20

Notes: The variance decomposition is computed at the posterior mode. Business cycle frequency encompasses periodic components with cycles of 6-32 quarters.

Table 1.1: Variance Decomposition at Business Cycle Frequency

We start with our main result. Table 1.1 reports the percentage of the variance in key variables explained by the different shocks at business cycle frequency. We sum the

¹⁶All estimations are done using Dynare developed by Adjemian et al. (2018).



Notes: The solid line is the result of simulating the model with only the estimated collateral shock, while shutting off all other shocks. The dashed line is the data.

Figure 1.2: Isolating the Collateral Shock

contribution of five aggregate supply shocks in the column "Supply Shocks" and seven aggregate demand shocks in the column "Demand Shocks".

The collateral shock is the single most important force driving output, consumption, investment, and hours. It accounts for 50, 44, 49, and 36 percent of the variance in these macroeconomic variables, respectively. The collateral shock also explains a large chunk of the movements in financial variables. It is the main impulse behind business credit (49 percent of its variance), household and business spreads (43 and 77 respectively), and it drives a sizable share of the evolution in household credit (25). To the best of our knowledge, this is the first paper in the DSGE literature with multiple shocks that puts forward a single disturbance able to drive simultaneously the four main macro variables as well as several financial series.

Another way to assess the importance of the collateral shock is to conduct the following experiment. We simulate our model with all the estimated shocks at once. By

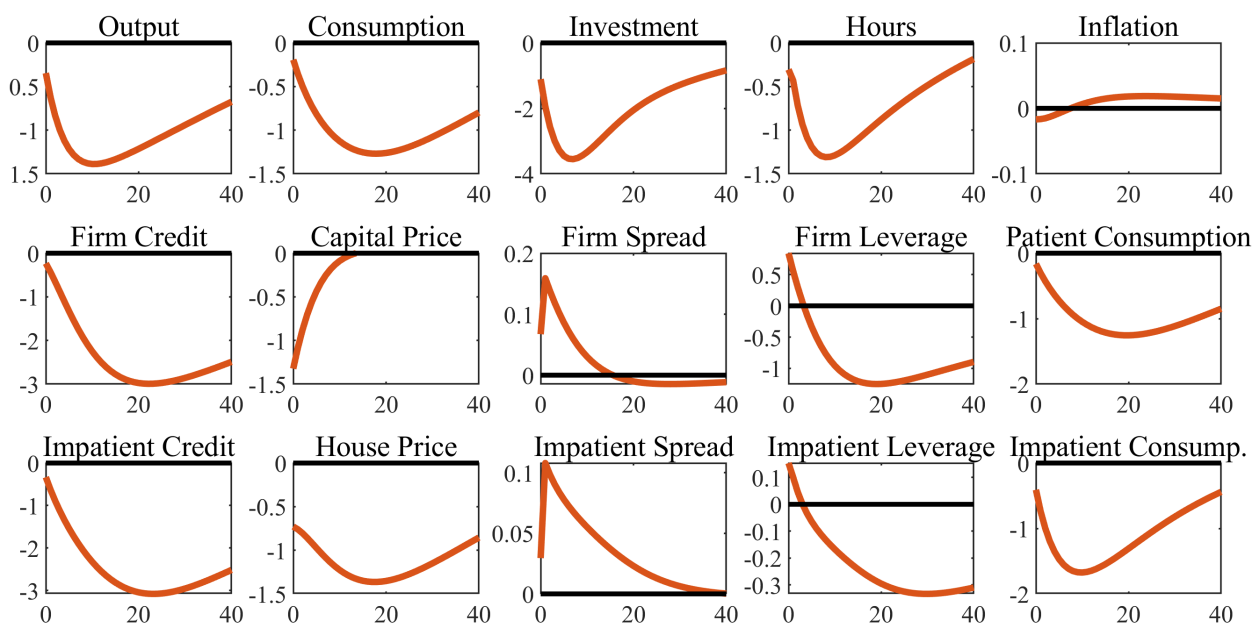
construction, this replicates the data exactly. Next, we simulate the model again but we shut down all shocks except the collateral shock. Figure 1.2 plots the results. In the case of investment, business credit, and the two spreads, the two lines track each other very closely. The match is also good for consumption and household credit, although the counterfactual series overshoot the actual ones in the first two recessions of the sample. The 2008-2009 recession highlights the leading role of the collateral shock. Overall, this exercise confirms that the collateral shock accounts for a large share of fluctuations in macroeconomic and financial variables over the past decades.

B. Explaining the Dominance of the Collateral Shock

The reason why our empirical analysis singles out the collateral shock is the following. When hit by a collateral shock, our model generates responses that mimic actual business cycles. Let us consider a negative realization, *i.e.* a fall in ν_t . We have in mind, for example, a sudden risk awareness in wholesale credit markets. This reduces liquidity in the financial sector and limits the appetite for collateral. Banks react by increasing collateral requirements on all their borrowers—households and entrepreneurs alike. Figure 1.3 displays the responses of key variables to such an event.

The first consequence is a fall in the volume of business loans (second row of Figure 1.3). This channel has been studied extensively in the literature and is relatively well understood. Entrepreneurs are forced to reduce their capital purchases. Investment and output drop, and intermediate firms respond by cutting down employment. The lower demand for capital generates a contraction in its price, reducing entrepreneurial net worth. This sets forth the standard financial accelerator. The fall in net worth causes a rise in leverage and makes entrepreneurs riskier. Banks charge them higher interest rates and the corporate spread shoots up. This, in turn, prevents entrepreneurs from borrowing, further reducing capital expenditures and output.

The second consequence of credit tightening is a fall in the volume of mortgage loans (third row of Figure 1.3). This channel has received less attention but is crucial in our story for the dynamics of consumption. Impatient households are forced to reduce their housing purchases. The price of housing falls and a second financial accelerator kicks in. As their net worth depreciates, impatient households become riskier. Banks charge them higher interest rates and the mortgage spread increases. This constrains borrowing even



Notes: Impulse responses to a one standard-deviation shock. All variables are expressed in percentage deviation from their steady state. The horizontal axis is time, one period is a quarter.

Figure 1.3: Dynamic Responses to a Negative Collateral Shock

further: after an initial spike in leverage, financially-constrained households are forced to deleverage.¹⁷

So what about consumption? The upshot is that indebted agents cut their goods purchases drastically. On impact, impatient household consumption drops by almost three times as much as patient household consumption. The dynamics also differ: impatient consumption plunges faster than patient consumption. As a result, aggregate consumption plummets, its dynamics mirroring those of output.

To sum up, the dynamics triggered by the collateral shock exhibit salient features of US business cycles: procyclical consumption, investment, employment, credit; countercyclical net worth, leverage, and credit spreads. Consumption, in particular, falls steeply and nearly as much and as fast as output. These elements explain why the estimation attributes such a large share of economic fluctuations to the collateral shock.

¹⁷The slow and painful debt deflation process is a stark feature of the last recession.

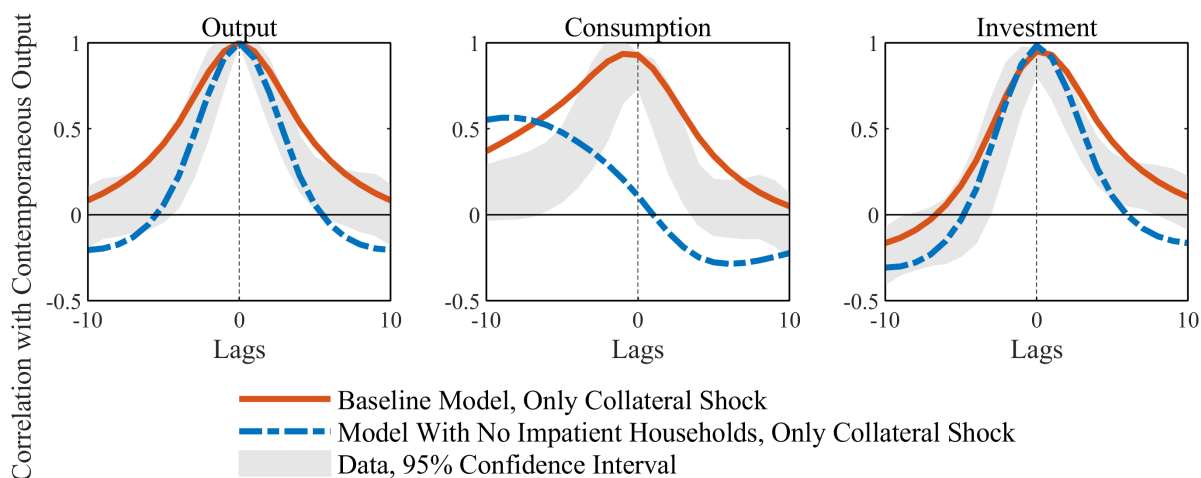


Figure 1.4: Cross Correlation with Output, Models Versus Data

C. The Collateral Shock and Consumption

The main contribution of this paper is to propose a financial shock that accounts for the dynamics of consumption on top of other macroeconomic and financial variables. This result rests on one fundamental ingredient—the presence of indebted households whose access to credit evolves over time. To see why, we estimate a version of the model without impatient households (equivalent to setting $\kappa = 1$). In a model with only one credit channel, from banks to entrepreneurs, the nature of the collateral shock changes. In fact it is no longer possible to distinguish it from a credit demand shock on the part of entrepreneurs, such as the firm risk shock (CMR’s risk shock).¹⁸

We compute dynamic cross-correlations between GDP today and three variables, for $L \in [-10, 10]$, where L is the number of lags. Figure 1.4 plots the results. The grey area corresponds to a 95 percent confidence interval centered around the actual correlations in the data. The solid line is the correlation implied by the baseline model when only the collateral shock is active, and all other shocks are switched off. The dashed line is the correlation implied by the model without impatient households when only the collateral shock is active.

Two results emerge from Figure 1.4. First, in both models the collateral shock alone generates factual correlations for output and investment at almost every lag. The reason

¹⁸In other words, since our functional form for the bank’s collateral production function implies $\phi_t^e = \nu_t$, then the collateral and firm risk shocks become observationally equivalent.

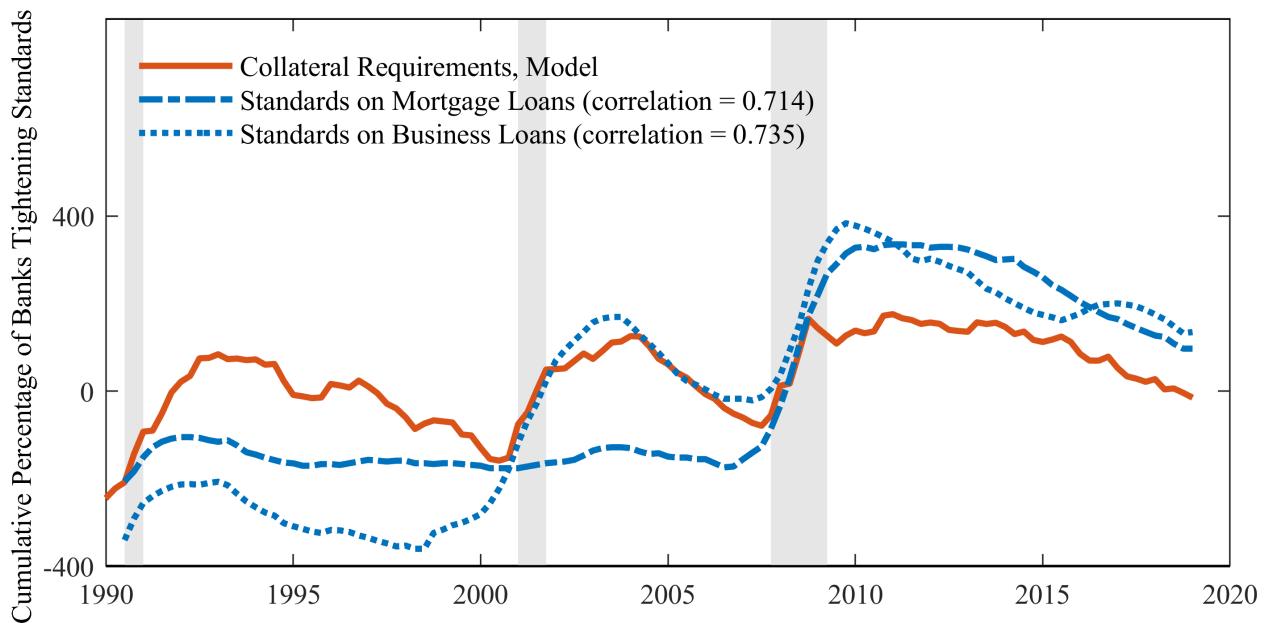
is simple. The shock reduces business credit, which causes investment and output to fall. These variables are hence highly correlated, as in the data. Second, in the model without impatient households the collateral shock fails dramatically on consumption. As explained in Section II, following a negative collateral shock patient agents, the only households in the economy, want to consume *more*, not less. In the estimation we find that counteracting general equilibrium effects dominate, in that a contracting economy (fewer hours, lower labor and capital income) ultimately forces patient households to reduce consumption. But these effects are not strong enough, and consumption ends up being weakly correlated with output, unlike in the data. In our baseline specification, on the other hand, the collateral shock reduces impatient household credit and consumption, enabling the model to match the procyclicality of aggregate consumption successfully.

VI. Discussion

Our analysis assigns a large role in business cycles to changes in the capacity of banks to absorb collateral. In our opinion, these changes are intrinsically linked to spirits or confidence, and we view the collateral shock as a measure of optimism or risk appetite in the financial sector. In this section we offer evidence regarding the nature of the collateral shock. We start by examining lending requirements, a variable that is arguably heavily influenced by banks' confidence on the economy. Lending standards implied by our estimated model are remarkably close to those observed in the data. We then go one step deeper by comparing the innovations of the collateral shock to several measures of financial stress. Here too, the match is good. We emphasize that none of the data presented in this section was used in the estimation of the model.

A. Lending Standards

Following a positive collateral shock ν_t , banks in our model respond by loosening collateral requirements on household and business loans. Banks tighten these requirements after a negative shock. To validate this channel, we plot our estimated collateral requirements $\phi_t^i = \phi_t^e$ against actual bank lending standards. These series come from the SLOOS, already discussed in the introduction. Note that in the survey banks are asked in a given quarter if they have tightened or loosened collateral requirements compared to the previous quarter. In the model, collateral requirements are expressed in deviation from steady



Notes: The solid line plots collateral requirements imposed by banks in the model. The dashed line is the cumulative sum of the net percentage of banks tightening standards for mortgage loans. The dotted line is the equivalent for commercial and industrial loans to large and middle-market firms. The two data series are demeaned.

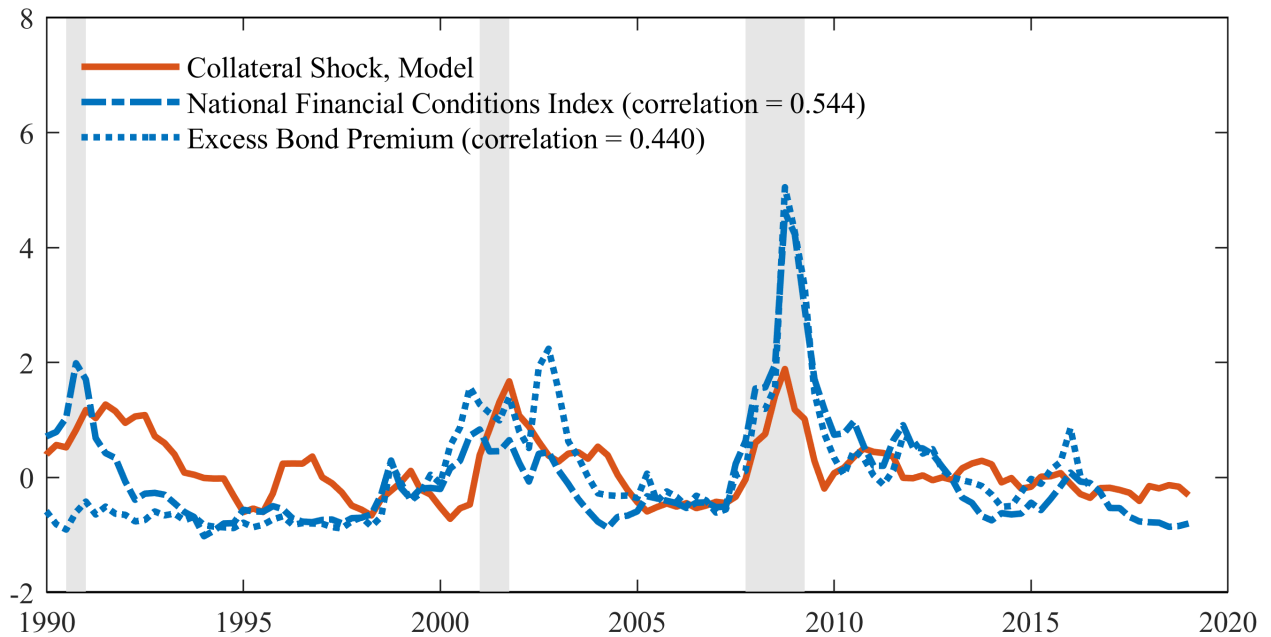
Figure 1.5: Bank Tightening, Model Versus Data

state. Therefore, to make the two objects comparable we take the cumulative sum of the survey series and remove their mean. Figure 1.5 shows the results. The observation period is shorter because the survey starts in 1990Q2.

The model and data series track each other very well. The correlation is 0.71 and 0.74 for household and business loans, respectively. Lending standards on firms tighten during each of the three recessions in our sample. Those on households harden in 1990, stay relatively stable during the mild 2001 recession, but tighten again dramatically in 2008. Thus the collateral shock, when fed to our model, produces changes in lending conditions that are actually observed, regardless of the borrower type. This lends further support to our story.

B. Financial Stress

Our second out-of-sample exercise looks at potential proxies for the collateral shock itself. We interpret the shock as the willingness of banks to ingest collateral. For the most



Notes: The solid line represents the inverted innovations to the estimated collateral shock. The dashed line is the Chicago Fed National Financial Conditions Credit subindex. The dotted line is the excess bond premium introduced by Gilchrist and Zakrajšek (2012b).

Figure 1.6: Financial Stress, Model Versus Data

part, this reflects confidence within the financial system. Thus, in Figure 1.6 we confront the (inverted) shock innovations to two measures of financial stress. The first one is the National Financial Conditions Index computed by the Chicago Fed. We are especially interested in the credit subindex, a composite of credit conditions. The second measure is the Gilchrist-Zakrajšek excess bond premium, an indicator of investors' risk appetite in the corporate bond market.

The main takeaway is that our shock correlates well with these two measures. All three spike at the eve of recessions before receding in the recovery and expansion phases. A test of predictive causality indicates that the collateral shock Granger causes the two data series at the five percent confidence level, at up to three lags. We also look at the Volatility Index (VIX) implied by S&P 500 index options and find very similar results: the collateral shock Granger causes the VIX at the one percent confidence level and the contemporaneous correlation is 0.44. We conclude that our theoretical object can be interpreted reasonably as a gauge of investor sentiment.

VII. Conclusion

We study the impact of changes in collateral requirements by banks on the economy. We build a macroeconomic model where banks must process the collateral of their defaulting borrowers in order to sell it back on the market. Their capacity to do so varies over time, and we call this variation the collateral shock. A negative collateral shock limits the amount of collateral banks can absorb, and these respond by tightening collateral requirements on their borrowers. We estimate our model on US data from 1985 to 2019 and find that the collateral shock is the main driver of the business cycle. It accounts for the bulk of the variance in output, consumption, investment, employment, business credit, household and business credit spreads, and a sizable share of the variance in household credit. The reason why the collateral shock matches the joint movements of consumption and other aggregates is because of the model's dual credit channel from banks to two types of borrowers—households and firms.

Technical Appendix to Collateral Shocks

This appendix is divided into five sections. Section VIII derives the full model. Section IX lists all equilibrium equations. Section X describes the data and observation equations. Section XI discusses the calibration and estimation of the parameters. Section XII presents additional results.

VIII. Derivation of the Baseline Model

A. Patient Households

The representative patient household maximizes utility subject to its budget constraint. The first-order conditions (FOCs) with respect to consumption C_t^p , housing $H_t^p = \bar{H}_t^p$, and deposits D_t are respectively:

$$\begin{aligned} 0 &= \Lambda_{z,t}^p (1 + \tau^c) P_t - \zeta_{c,t} / (C_t^p - b_c^p C_{t-1}^p) + b_c^p \beta^p E_t \zeta_{c,t+1} / (C_{t+1}^p - b_c^p C_t^p), \\ 0 &= \zeta_{h,t} / H_t^p - \Lambda_{z,t}^p Q_t^h + \beta^p E_t \Lambda_{z,t+1}^p Q_{t+1}^h, \\ 0 &= \Lambda_{z,t}^p P_t - \beta^p P_t E_t \Lambda_{z,t+1}^p R_{t+1}. \end{aligned}$$

B. Impatient Households

Workers.—The representative impatient household maximizes the utility of its workers subject to their budget constraint. The FOCs with respect to consumption C_t^i and housing services H_t^i are respectively:

$$\begin{aligned} 0 &= \Lambda_{z,t}^i (1 + \tau^c) P_t - \zeta_{c,t} / (C_t^i - b_c^i C_{t-1}^i) + b_c^i \beta^i E_t \zeta_{c,t+1} / (C_{t+1}^i - b_c^i C_t^i), \\ 0 &= \zeta_{h,t} / H_t^i - \Lambda_{z,t}^i P_t r_t^h. \end{aligned}$$

Real Estate Broker.—The real estate broker chooses a quantity of housing to maximize profit subject to the housing adjustment costs. The FOC with respect to \bar{H}_t^i is:

$$\Lambda_{z,t}^i Q_t^h = \Lambda_{z,t}^i Q_t^h \left[1 + S^h \left(\frac{\bar{H}_t^i}{\bar{H}_{t-1}^i} \right) + S^{h'} \left(\frac{\bar{H}_t^i}{\bar{H}_{t-1}^i} \right) \frac{\bar{H}_t^i}{\bar{H}_{t-1}^i} \right] - \beta^i E_t \Lambda_{z,t+1}^i Q_{t+1}^h S^{h'} \left(\frac{\bar{H}_{t+1}^i}{\bar{H}_t^i} \right) \left(\frac{\bar{H}_{t+1}^i}{\bar{H}_t^i} \right)^2.$$

Homeowners.—A non-defaulting homeowner j maximizes the present discounted value of dividends,

$$\begin{aligned} V_{j,t}^i &= \max_{\bar{H}_{j,t}^i, B_{j,t}^i} \{ \Delta_{j,t}^i + \beta^i E_t \Lambda_{z,t+1}^i / \Lambda_{z,t}^i \max\{0, V_{j,t+1}^i\} \}, \\ \text{subject to } N_{j,t}^i &= R_t^h \omega_{j,t}^i Q_{t-1}^h \bar{H}_{j,t-1}^i - R_{j,t-1}^i B_{j,t-1}^i, \\ Q_t^h \bar{H}_{j,t}^i + \Delta_{j,t}^i &= N_{j,t}^i + P_t r_t^h \bar{H}_{j,t}^i + B_{j,t}^i, \end{aligned}$$

and the bank participation constraint. Substitute the two constraints into the value function:

$$\begin{aligned} V_{j,t}^i &= \max_{\bar{H}_{j,t}^i, B_{j,t}^i} \{ R_t^h \omega_{j,t}^i Q_{t-1}^h \bar{H}_{j,t-1}^i - R_{j,t-1}^i B_{j,t-1}^i + P_t r_t^h \bar{H}_{j,t}^i + B_{j,t}^i - Q_t^h \bar{H}_{j,t}^i \\ &\quad + \beta^i E_t \Lambda_{z,t+1}^i / \Lambda_{z,t}^i \max\{0, V_{j,t+1}^i\} \}. \end{aligned}$$

Following Ferrante (2019), we define $\eta_{j,t}^i \equiv B_{j,t}^i / \bar{H}_{j,t}^i$ and $g_{j,t}^i \equiv \bar{H}_{j,t}^i / \bar{H}_{j,t-1}^i$. Since $V_{j,t}^i$ is linearly homogeneous in $\bar{H}_{j,t-1}^i$, we rewrite the scaled value function $v_{j,t}^i \equiv V_{j,t}^i / \bar{H}_{j,t-1}^i$:

$$\begin{aligned} v_{j,t}^i &= \max_{g_{j,t}^i, \eta_{j,t}^i} \left\{ R_t^h \omega_{j,t}^i Q_{t-1}^h - R_{j,t-1}^i \eta_{j,t-1}^i + P_t r_t^h g_{j,t}^i + \eta_{j,t}^i g_{j,t}^i - Q_t^h g_{j,t}^i \right. \\ &\quad \left. + g_{j,t}^i \beta^i E_t \frac{\Lambda_{z,t+1}^i}{\Lambda_{z,t}^i} \left[\int_{\bar{\omega}_{j,t+1}^i}^{\infty} v_{j,t+1}^i dF_t^i(\omega_{j,t+1}^i) + (1 - \phi_t^i) \int_0^{\bar{\omega}_{j,t+1}^i} R_{t+1}^h \omega_{j,t+1}^i Q_t^h dF_t^i(\omega_{j,t+1}^i) \right] \right\}. \end{aligned}$$

The FOCs with respect to $g_{j,t}^i$ and $\eta_{j,t}^i$ are respectively:

$$\begin{aligned} 0 &= P_t r_t^h + \eta_{j,t}^i - Q_t^h + \beta^i E_t \frac{\Lambda_{z,t+1}^i}{\Lambda_{z,t}^i} \int_0^{\infty} v_{j,t+1}^i dF_t^i(\omega_{j,t+1}^i), \\ 1 &= \beta^i E_t \frac{\Lambda_{z,t+1}^i}{\Lambda_{z,t}^i} [1 - F_t^i(\bar{\omega}_{j,t+1}^i)] \left(\frac{\partial R_{j,t}^i}{\partial \eta_{j,t}^i} \eta_{j,t}^i + R_{j,t}^i \right). \end{aligned}$$

Substitute the FOC for $g_{j,t}^i$ into the value function and multiply both sides by $\bar{H}_{j,t-1}^i$ to obtain the non-scaled value function:

$$V_{j,t}^i = \{R_t^h \omega_{j,t}^i Q_{t-1}^h \bar{H}_{j,t-1}^i - R_{j,t-1}^i B_{j,t-1}^i\} = N_{j,t}^i.$$

A default threshold $\bar{\omega}_{j,t}^i$ is such that the value of assets homeowner j pledged as collateral is lower than the cost of servicing debt. That is, homeowner j defaults when $\phi_{t-1}^i R_t^h \omega_{j,t}^i Q_{t-1}^h \bar{H}_{j,t-1}^i - R_{j,t-1}^i B_{j,t-1}^i = 0$, that is when $V_{j,t}^i(\bar{\omega}_{j,t}^i) = (1 - \phi_{t-1}^i) R_t^h \bar{\omega}_{j,t}^i Q_{t-1}^h \bar{H}_{j,t-1}^i$. This implies the following default threshold:

$$\bar{\omega}_{j,t}^i = R_{j,t-1}^i B_{j,t-1}^i / (R_t^h \phi_{t-1}^i Q_{t-1}^h \bar{H}_{j,t-1}^i).$$

Finally, compute the partial derivative $\partial R_{j,t}^i / \partial \eta_{j,t}^i$ using the bank participation constraint, and plug it into the FOC for $\eta_{j,t}^i$:

$$1 = \beta^i E_t \Lambda_{z,t+1}^i / \Lambda_{z,t}^i \{ R_{t+1}^a - (1 - \mu^i) R_{j,t}^i G_t^i(\bar{\omega}_{j,t+1}^i) + F_t^{i'}(\bar{\omega}_{j,t+1}^i) \bar{\omega}_{j,t+1}^i (1 - F_t^i(\bar{\omega}_{j,t+1}^i))^{-1} [R_{t+1}^a - (1 - \mu^i) G_t^i(\bar{\omega}_{j,t+1}^i) R_{t+1}^h \phi_t^i Q_t^h \bar{H}_{j,t}^i / B_{j,t}^i] \}.$$

C. Entrepreneurs

Following Christiano, Motto, and Rostagno (2014)—hereafter CMR—we define $\Gamma_t^e(\bar{\omega}_{j,t+1}^e)$ as the expected gross share of entrepreneurial returns going to banks:

$$\Gamma_t^e(\bar{\omega}_{j,t+1}^e) \equiv [1 - F_t^e(\bar{\omega}_{j,t+1}^e)] \bar{\omega}_{j,t+1}^e + G_t^e(\bar{\omega}_{j,t+1}^e), \quad G_t^e(\bar{\omega}_{j,t+1}^e) \equiv \int_0^{\bar{\omega}_{j,t+1}^e} \omega_{j,t+1}^e dF_t^e(\omega_{j,t+1}^e).$$

Using these variables and the definition of the default cutoff we rewrite expected net worth,

$$E_t[1 - \phi_t^e \Gamma_t^e(\bar{\omega}_{j,t+1}^e)] R_{t+1}^k Q_t^k \bar{K}_{j,t} = E_t[1 - \phi_t^e \Gamma_t^e(\bar{\omega}_{j,t+1}^e)] R_{t+1}^k L_{j,t}^e N_{j,t}^e,$$

where in the right side we use the definition of entrepreneurial leverage. The bank participation constraint is $[1 - F_t^e(\bar{\omega}_{j,t+1}^e)] R_{j,t}^e B_{j,t}^e + (1 - \mu^e) G_t^e(\bar{\omega}_{j,t+1}^e) R_{t+1}^k \phi_t^e Q_t^k \bar{K}_{j,t} = R_{t+1} B_{j,t}^e$. Using the definitions of the default cutoff and leverage we rewrite the constraint,

$$\phi_t^e [\Gamma_t^e(\bar{\omega}_{j,t+1}^e) - \mu^e G_t^e(\bar{\omega}_{j,t+1}^e)] = \frac{L_{j,t}^e - 1}{L_{j,t}^e} \frac{R_{t+1}}{R_{j,t+1}^k}.$$

The problem of entrepreneur j in period t is to choose leverage $L_{j,t}^e$ and cutoff $\bar{\omega}_{j,t+1}^e$ to maximize expected pre-dividend net worth in $t + 1$, subject to the bank participation constraint. Current net worth $N_{j,t}^e$ does not appear in the constraint and is present in the objective only as a factor of proportionality. Therefore, all entrepreneurs select the same $L_t^e = L_{j,t}^e$ and $\bar{\omega}_{t+1}^e = \bar{\omega}_{j,t+1}^e$ regardless of their net worth. The FOCs with respect to leverage L_t^e and default cutoff $\bar{\omega}_{t+1}^e$ are:

$$0 = E_t \left\{ \left[1 - \phi_t^e \Gamma_t^e(\bar{\omega}_{t+1}^e) \right] R_{j,t+1}^k N_{j,t}^e - \frac{\lambda_{j,t}^e}{(L_t^e)^2} \frac{R_{t+1}^a}{R_{j,t+1}^k} \right\},$$

$$0 = E_t \left\{ -\phi_t^e \Gamma_t^{e'}(\bar{\omega}_{t+1}^e) R_{j,t+1}^k L_t^e N_{j,t}^e + \lambda_{j,t}^e \phi_t^e \Gamma_t^{e'}(\bar{\omega}_{t+1}^e) - \lambda_{j,t}^e \phi_t^e \mu^e G_t^{e'}(\bar{\omega}_{t+1}^e) \right\},$$

where $\lambda_{j,t}^e$ is the multiplier on the constraint. Substituting out for $\lambda_{j,t}^e$ we obtain:

$$0 = E_t \left\{ \left[1 - \phi_t^e \Gamma_t^e(\bar{\omega}_{t+1}^e) \right] \frac{R_{j,t+1}^k}{R_{t+1}^a} + \frac{\Gamma_t^{e'}(\bar{\omega}_{t+1}^e)}{\Gamma_t^{e'}(\bar{\omega}_{t+1}^e) - \mu^e G_t^{e'}(\bar{\omega}_{t+1}^e)} \left(\frac{R_{j,t+1}^k}{R_{t+1}^a} \phi_t^e \left[\Gamma_t^e(\bar{\omega}_{t+1}^e) - \mu^e G_t^e(\bar{\omega}_{t+1}^e) \right] - 1 \right) \right\}.$$

Utilization Rate.—Entrepreneur j also determines the utilization rate of capital $u_{j,t}$. Since the market for capital services is competitive, the user cost function must equal the return on renting out capital services,

$$P_t \Upsilon^{-t} a(u_{j,t}) \omega_{j,t}^e \bar{K}_{j,t-1} = P_t \tilde{r}_t^k u_{j,t} \omega_{j,t}^e \bar{K}_{j,t-1}.$$

The FOC with respect to $u_{j,t}$ is:

$$a'(u_t) = \Upsilon^t \tilde{r}_t^k,$$

where optimal utilization $u_t = u_{j,t}$ depends only on aggregate variables and is therefore common to all entrepreneurs. The derivative of the utilization adjustment cost function is $a'(u_t) = r^k \exp(\sigma_a [u_t - 1])$, and the FOC can be rewritten as $\Upsilon^t \tilde{r}_t^k = r^k \exp(\sigma_a [u_t - 1])$.

D. Productive Sector

Final Good Producers.—The representative final good firm chooses the quantity of inputs $Y_{j,t}$ to maximize output Y_t subject to the following budget constraint:

$$\int_0^1 P_{j,t} Y_{j,t} dj = P_t Y_t.$$

The FOC with respect to intermediate good $Y_{j,t}$ is:

$$\left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_{f,t}}} dj \right]^{\lambda_{f,t}-1} Y_{j,t}^{\frac{1-\lambda_{f,t}}{\lambda_{f,t}}} = x P_{j,t},$$

where x is the multiplier on the budget constraint. Integrate over all goods, solve for x , rearrange, and obtain the demand function for a generic intermediate good:

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{\frac{\lambda_{f,t}}{1-\lambda_{f,t}}} Y_t.$$

Plug the demand function into the aggregator and obtain the aggregate price index:

$$P_t = \left[\int_0^1 P_{j,t}^{\frac{1}{1-\lambda_{f,t}}} dj \right]^{1-\lambda_{f,t}}.$$

Intermediate Good Producers: Production.—Intermediate good producer j makes the following profit:

$$P_{j,t} Y_{j,t} - W_t^p l_{j,t}^p - W_t^i l_{j,t}^i - P_t \tilde{r}_t^k u_t \bar{K}_{j,t-1},$$

where $P_t \tilde{r}_t^k$ represents the nominal rental rate of capital. The firm minimizes cost: subject to the production function. The FOCs with respect to capital services $u_t \bar{K}_{j,t-1}$, patient labor $l_{j,t}^p$, and impatient labor $l_{j,t}^i$ are respectively:

$$\begin{aligned} P_t \tilde{r}_t^k &= S_{j,t} \alpha \varepsilon_t (u_t \bar{K}_{j,t-1})^{\alpha-1} (z_t l_{j,t}^{p,\kappa} l_{j,t}^{i,1-\kappa})^{1-\alpha}, \\ W_t^p l_{j,t}^p &= S_{j,t} (1-\alpha) \kappa \varepsilon_t (u_t \bar{K}_{j,t-1})^\alpha (z_t l_{j,t}^{p,\kappa} l_{j,t}^{i,1-\kappa})^{1-\alpha}, \\ W_t^i l_{j,t}^i &= S_{j,t} (1-\alpha) (1-\kappa) \varepsilon_t (u_t \bar{K}_{j,t-1})^\alpha (z_t l_{j,t}^{p,\kappa} l_{j,t}^{i,1-\kappa})^{1-\alpha}, \end{aligned}$$

where $S_{j,t}$ is the multiplier on the production function and is interpreted as the marginal cost. Combine each of the two FOCs for labor with the FOC for capital services:

$$\frac{u_t \bar{K}_{j,t-1}}{l_{j,t}^p} = \frac{\alpha}{(1-\alpha)\kappa} \frac{W_t^p}{P_t \tilde{r}_t^k}; \quad \frac{u_t \bar{K}_{j,t-1}}{l_{j,t}^i} = \frac{\alpha}{(1-\alpha)(1-\kappa)} \frac{W_t^i}{P_t \tilde{r}_t^k}.$$

These two capital-to-labor ratios depend only on aggregate quantities and are therefore common to all intermediate producers. If firms pay the same factor prices, receive the same aggregate shocks, and choose the same quantities of inputs, then they have the same marginal cost $S_t = S_{j,t}$,

$$S_t = \frac{1}{\varepsilon_t} \left(\frac{P_t \tilde{r}_t^k}{\alpha} \right)^\alpha \left(\frac{W_t^{p,\kappa} W_t^{i,1-\kappa}}{(1-\alpha)\kappa^\kappa (1-\kappa)^{1-\kappa} z_t} \right)^{1-\alpha}.$$

Intermediate Good Producers: Prices.—Intermediate good producer j chooses a price $P_{j,t}$ to maximize the sum of future discounted profits from period t to $t+s$:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \beta^{p,s} \Lambda_{z,t+s}^p \left[P_{j,t} \Pi_{t,t+s} Y_{j,t+s} - W_{t+s}^p l_{j,t+s}^p - W_{t+s}^i l_{j,t+s}^i - P_{t+s} \tilde{r}_{t+s}^k u_{t+s} \bar{K}_{j,t-1+s} \right],$$

subject to a demand function. Here, $P_{t+s} = \pi_{t+s} \dots \pi_{t+1} P_t$, $\Pi_{t,t+s} \equiv \prod_{k=1}^s \tilde{\pi}_{t+k} = \tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1}$, and $\tilde{\pi}_t = \pi^t \pi_{t-1}^{1-t}$ is an indexation term. The firm discounts the future in the same way as the patient household it belongs to. Since the marginal cost equals the average variable cost we rewrite the problem as:

$$\max_{P_{j,t}} E_t \sum_{s=0}^{\infty} \xi_p^s \beta^{p,s} \Lambda_{z,t+s}^p Y_{j,t+s} (P_{j,t} \Pi_{t,t+s} - S_{t+s}),$$

subject to the demand function. The FOC with respect to price $P_{j,t}$ is:

$$0 = E_t \sum_{s=0}^{\infty} \xi_p^s \beta^{p,s} \Lambda_{z,t+s}^p Y_{t+s} \left(\frac{\tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1}}{\pi_{t+s} \dots \pi_{t+1}} \right)^{\frac{\lambda_{f,t+s}}{1-\lambda_{f,t+s}}} \left(\frac{\tilde{P}_t}{P_t} \right)^{\frac{\lambda_{f,t+s}}{1-\lambda_{f,t+s}}} \frac{1}{1-\lambda_{f,t+s}} \left[\tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1} - \lambda_{f,t+s} \frac{S_{t+s}}{\tilde{P}_t} \right],$$

where the optimal price $\tilde{P}_t \equiv P_{j,t}$ depends only on aggregate variables and is therefore common to all producers. Divide by $P_t = P_{t+s}/(\pi_{t+s} \dots \pi_{t+1})$ and rearrange,

$$\frac{\tilde{P}_t}{P_t} = \frac{E_t \sum_{s=0}^{\infty} \xi_p^s \beta^{p,s} P_{t+s} \Lambda_{z,t+s}^p Y_{t+s} \left(\frac{\tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1}}{\pi_{t+s} \dots \pi_{t+1}} \right)^{\frac{\lambda_{f,t+s}}{1-\lambda_{f,t+s}}} \frac{\lambda_{f,t+s}}{1-\lambda_{f,t+s}} \frac{S_{t+s}}{P_{t+s}}}{E_t \sum_{s=0}^{\infty} \xi_p^s \beta^{p,s} P_{t+s} \Lambda_{z,t+s}^p Y_{t+s} \left(\frac{\tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1}}{\pi_{t+s} \dots \pi_{t+1}} \right)^{\frac{1}{1-\lambda_{f,t+s}}} \frac{1}{1-\lambda_{f,t+s}}} \equiv \frac{K_{p,t}^p}{F_{p,t}^p}.$$

We know that $\frac{\tilde{\pi}_{t+s} \dots \tilde{\pi}_{t+1}}{\pi_{t+s} \dots \pi_{t+1}} = 1$ for $s = 0$. In addition, $\frac{\tilde{\pi}_{t+1+s} \dots \tilde{\pi}_{t+1+1}}{\pi_{t+1+s} \dots \pi_{t+1+1}} = \frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \frac{\tilde{\pi}_{t+1+s} \dots \tilde{\pi}_{t+1}}{\pi_{t+1+s} \dots \pi_{t+1}}$. Hence, we express the infinite sums $K_{p,t}^p$ and $F_{p,t}^p$ in recursive form:

$$\begin{aligned} K_{p,t}^p &= P_t \Lambda_{z,t}^p Y_t \frac{\lambda_{f,t}}{1-\lambda_{f,t}} \frac{S_t}{P_t} + \xi_p \beta^p E_t \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{\lambda_{f,t+1}}{1-\lambda_{f,t+1}}} K_{p,t+1}^p, \\ F_{p,t}^p &= P_t \Lambda_{z,t}^p Y_t \frac{1}{1-\lambda_{f,t}} + \xi_p \beta^p E_t \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda_{f,t+1}}} F_{p,t+1}^p. \end{aligned}$$

The aggregate price level is given by:

$$P_t = \left[(1 - \xi_p) \tilde{P}_t^{\frac{1}{1-\lambda_{f,t}}} + \xi_p (\tilde{\pi}_t P_{t-1})^{\frac{1}{1-\lambda_{f,t}}} \right]^{1-\lambda_{f,t}}.$$

Labor Contractors.—The representative labor contractor chooses the quantity of labor input $l_{k,t}^o$, $o \in \{p, i\}$ to maximize output l_t^o subject to the following budget constraint:

$$\int_0^1 W_{k,t}^s l_{k,t}^s dk = W_t^s l_t^o, \quad o \in \{p, i\}.$$

The FOC with respect to differentiated labor $l_{k,t}^o$ is:

$$\left[\int_0^1 l_{k,t}^{o, \frac{1}{\lambda_w}} dk \right]^{\lambda_w - 1} l_{k,t}^{o, \frac{1-\lambda_w}{\lambda_w}} = x W_{k,t}^o, \quad o \in \{p, i\},$$

where x is the multiplier on the budget constraint. Integrate over all inputs, solve for x , rearrange, and obtain the demand function for a generic labor input:

$$l_{k,t}^o = \left(\frac{W_{k,t}^o}{W_t^o} \right)^{\frac{\lambda_w}{1-\lambda_w}} l_t^o, \quad o \in \{p, i\}.$$

Plug the demand function into the Dixit-Stiglitz aggregator and obtain the aggregate wage index of patient and impatient workers:

$$W_t^o = \left[\int_0^1 W_{k,t}^{o, \frac{1}{1-\lambda_w}} dk \right]^{1-\lambda_w}, \quad o \in \{p, i\}.$$

Monopoly Unions.—Worker union k discounts the future in the same way as the household it represents. It chooses a wage $W_{k,t}^o$, $o \in \{p, i\}$, to maximize the sum of future utilities from period t to $t + s$:

$$E_t \sum_{s=0}^{\infty} \xi_w^s \beta^{o,s} \left[-\psi_l \int_0^1 \frac{l_{k,t+s}^{o, 1+\sigma_l}}{1+\sigma_l} dk + \Lambda_{z,t+s}^o W_{k,t}^o \Pi_{t,t+s}^w l_{k,t+s}^o \right], \quad o \in \{p, i\},$$

subject to $l_{k,t+s}^o = \left(\frac{W_{k,t}^o \Pi_{t,t+s}^w}{W_{t+s}^o} \right)^{\frac{\lambda_w}{1-\lambda_w}} l_{t+s}^o,$

where $W_{t+s}^o = \pi_{w,t+s} \dots \pi_{w,t+1} W_t^o$, $\Pi_{t,t+s}^w = \prod_{j=1}^s \mu_{z^*} \tilde{\pi}_{w,t+j}$, and $\tilde{\pi}_{w,t} = \pi^{l_w} \pi_{t-1}^{1-l_w}$ is an indexation term. The FOC with respect to wage $W_{k,t}^o$, $o \in \{p, i\}$, is:

$$0 = E_t \sum_{s=0}^{\infty} \xi_w^s \beta^{o,s} l_{t+s}^o \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\frac{\tilde{W}_t^o}{W_t^o} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\Lambda_{z,t+s}^o \frac{1}{1-\lambda_w} \Pi_{t,t+s}^w - \psi_l \frac{\lambda_w}{1-\lambda_w} \frac{1}{\tilde{W}_t^o} \left[\left(\frac{W_{k,t}^o \Pi_{t,t+s}^w}{W_{t+s}^o} \right)^{\frac{\lambda_w}{1-\lambda_w}} l_{t+s}^o \right]^{\sigma_l} \right).$$

The optimal wage $\tilde{W}_t^o \equiv W_{j,t}^o$ depends only on aggregate variables and is therefore common to all worker unions. That is, there is one optimal wage \tilde{W}_t^p for patient workers and another one \tilde{W}_t^i for impatient workers. Divide by $W_t^o = W_{t+s}^o / (\pi_{w,t+s} \dots \pi_{w,t})$ and rearrange:

$$\left(\frac{\tilde{W}_t^o}{W_t^o} \right)^{\frac{1-\lambda_w(1+\sigma_l)}{1-\lambda_w}} \frac{W_t^o}{P_t} \frac{1}{\psi_l} = \frac{E_t \sum_{s=0}^{\infty} \xi_w^s \beta^{o,s} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{\lambda_w}{1-\lambda_w} (1+\sigma_l)} l_{t+s}^{o, 1+\sigma_l}}{E_t \sum_{s=0}^{\infty} \xi_w^s \beta^{o,s} \frac{l_{t+s}^o}{\lambda_w} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{\pi_{w,t+s} \dots \pi_{w,t}}{\pi_{t+s} \dots \pi_t} \right) \Lambda_{z,t+s}^p P_{t+s}} \equiv \frac{K_{w,t}^o}{F_{W,t}^o}.$$

Express the infinite sums $K_{w,t}^o$ and $F_{W,t}^o$, $o \in \{p, i\}$, in recursive form:

$$\begin{aligned} K_{w,t}^o &= l_t^{o,1+\sigma_l} + \xi_w \beta^o E_t \left(\tilde{\pi}_{w,t+1} \pi_{w,t+1}^{-1} \mu_{z^*} \right)^{\frac{\lambda_w}{1-\lambda_w}(1+\sigma_l)} K_{w,t+1}^o, \\ F_{W,t}^o &= l_t^o \lambda_w^{-1} P_t \Lambda_{z,t}^o + \xi_w \beta^o E_t \left(\tilde{\pi}_{w,t+1} \mu_{z^*} \right)^{\frac{1}{1-\lambda_w}} \pi_{w,t+1}^{\frac{\lambda_w}{\lambda_w-1}} \pi_{t+1}^{-1} F_{W,t+1}^o. \end{aligned}$$

Therefore, the optimal wage writes:

$$\frac{\tilde{W}_t^o}{W_t^o} = \left[\frac{\psi_l}{W_t^o / P_t} \frac{K_{w,t}^o}{F_{W,t}^o} \right]^{\frac{1-\lambda_w}{1-\lambda_w(1+\sigma_l)}}, \quad o \in \{p, i\}.$$

The aggregate wage level of patient and impatient workers is given by:

$$W_t^o = \left[(1 - \xi_w) \tilde{W}_t^{o, \frac{1}{1-\lambda_w}} + \xi_w (\tilde{\pi}_{w,t} \mu_{z^*} W_{t-1}^o)^{\frac{1}{1-\lambda_w}} \right]^{1-\lambda_w, t}, \quad o \in \{p, i\}.$$

Divide by W_t^o and plug the expression into the optimal wage equation:

$$K_{w,t}^o = \frac{1}{\psi_l} \left[\frac{1 - \xi_w (\tilde{\pi}_{w,t} \pi_{w,t}^{-1} \mu_{z^*})^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w(1+\sigma_l)} \frac{W_t^o}{P_t} F_{W,t}^o, \quad o \in \{p, i\}.$$

Capital Producers.—The representative capital producer discounts the future in the same way as the patient household it belongs to. It chooses investment to maximize profit subject to its capital production technology. The FOC with respect to investment I_t is:

$$\begin{aligned} 0 &= \Lambda_{z,t}^p Q_t^k \left[1 - S \left(\zeta_{I,t} \frac{I_t}{I_{t-1}} \right) - \zeta_{I,t} \frac{I_t}{I_{t-1}} S^{k_I} \left(\zeta_{I,t} \frac{I_t}{I_{t-1}} \right) \right] \\ &\quad - \frac{\Lambda_{z,t}^p P_t}{\Upsilon^t \mu_{\Upsilon,t}} + \beta^p E_t \Lambda_{z,t+1}^p Q_{t+1}^k \zeta_{I,t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 S^{k_I} \left(\zeta_{I,t+1} \frac{I_{t+1}}{I_t} \right). \end{aligned}$$

E. Aggregation and Market Clearing

Productive Sector.—All intermediate goods producers have the same capital to labor ratio and the same marginal cost. Therefore, aggregate output writes:

$$Y_t = \varepsilon_t (u_t \bar{K}_{t-1})^\alpha (z_t^* l_t)^{1-\alpha} - \theta z_t^*.$$

Households.—Aggregate impatient homeowner debt is given by $B_t^i = \int_0^1 B_{j,t}^i dj$. Since the mean of $\omega_{i,t}^i$ is unity, aggregate homeowner housing stock writes:

$$\bar{H}_t^i = \int_0^1 \int_0^\infty \omega_{j,t}^i \bar{H}_{j,t}^i dF_{t-1}^i(\omega_{j,t}^i) dj.$$

The value function of homeowners is linear in housing net worth. This implies that all homeowners select the same leverage L_t^i and default cutoff $\bar{\omega}_{t+1}^i$ regardless of their housing net worth. Perfect insurance within the impatient household ensures all homeowners begin the next period with the same level of net worth. Aggregate net worth is given by:

$$N_t^i = \int_0^1 [1 - \phi_{t-1}^i \Gamma_{t-1}^i(\bar{\omega}_t^i)] R_t^h Q_{t-1}^h \bar{H}_{j,t-1}^i dj = [1 - \phi_{t-1}^i \Gamma_{t-1}^i(\bar{\omega}_t^i)] R_t^h Q_{t-1}^h \bar{H}_{t-1}^i.$$

Also, we assume government transfers are weighted according to households' respective labor in total labor income:

$$\begin{aligned} T_t^p &= \kappa T_t, \\ T_t^i &= (1 - \kappa) T_t. \end{aligned}$$

Entrepreneurs.—Market clearing requires that the quantity of physical capital produced by capital producers \bar{K}_t equal the quantity purchased by entrepreneurs, $\bar{K}_t = \int_0^1 \bar{K}_{j,t} dj$. As explained above, all entrepreneurs select the same utilization regardless of their idiosyncratic shock. Therefore, the return on capital $R_t^k = R_{j,t}^k$ is common to all entrepreneurs. Also, entrepreneurs choose the same leverage L_t^e and default cutoff $\bar{\omega}_{t+1}^e$. Using the previous equation and the fact that the mean of $\omega_{j,t}^e$ is unity, we determine the aggregate supply of capital services by entrepreneurs as:

$$K_{t-1} = \int_0^1 \int_0^\infty u_t \omega_{j,t}^e \bar{K}_{j,t-1} dF_{t-1}^e(\omega_{j,t}^e) = u_t \bar{K}_{t-1}.$$

Market clearing in capital services requires that the supply of capital services K_t by entrepreneurs equal the demand by intermediate good producers, $K_t = \int_0^1 K_{j,t} dj$. Perfect insurance among entrepreneurs *ex post* ensures they finish period t with the same level of

pre-dividend net worth. Aggregate net worth after dividend payments is given by:

$$\begin{aligned} N_t^e &= \gamma_t^e \left[\int_0^1 [1 - \phi_{t-1}^e \Gamma_{t-1}^e(\bar{\omega}_t^e)] R_t^k Q_{t-1}^k \bar{K}_{j,t-1} dj \right] - \delta^e N_t^e, \\ &= \gamma_t^e [1 - \phi_{t-1}^e \Gamma_{t-1}^e(\bar{\omega}_t^e)] R_t^k Q_{t-1}^k \bar{K}_{t-1} - \delta^e N_t^e. \end{aligned}$$

The aggregate balance sheet of entrepreneurs is:

$$Q_t^k \bar{K}_t = N_t^e + B_t^e,$$

where $B_t^e = \int_0^1 B_{j,t}^e dj$ is aggregate entrepreneurial debt.

IX. Summary of Equilibrium Conditions

In this section we list all the stationary equilibrium conditions of our baseline model. We also describe the alternative model specification mentioned in the main text.

A. Stationary Equilibrium in the Baseline Model

In order to solve our model, we need to stationarize it. Scaled variables are as follows

$$\begin{aligned}
 b_t &= B_t/(z_t^* P_t), & h_t^i &= \bar{H}_t^i/z_t^*, \\
 b_t^c &= B_t^c/(z_t^* P_t), & h_t^p &= \bar{H}_t^p/z_t^*, \\
 b_t^i &= B_t^i/(z_t^* P_t), & i_t &= I_t/(z_t^* \Upsilon^t), \\
 c_t &= C_t/z_t^*, & k_t &= \bar{K}_t/(z_t^* \Upsilon^t), \\
 c_t^i &= C_t^i/z_t^*, & \lambda_{z,t}^i &= \Lambda_{z,t}^i P_t z_t^*, \\
 c_t^p &= C_t^p/z_t^*, & \lambda_{z,t}^p &= \Lambda_{z,t}^p P_t z_t^*, \\
 d_t &= D_t/z_t^*, & n_t^e &= N_t^e/(z_t^* P_t), \\
 d_t^b &= D_t^b/z_t^*, & n_t^i &= N_t^i/(z_t^* P_t), \\
 F_{w,t}^i &= F_{W,t}^i z_t^*, & \tilde{p}_t &= \tilde{P}_t/P_t, \\
 F_{w,t}^p &= F_{W,t}^p z_t^*, & q_t^k &= Q_t^k \Upsilon^t/P_t, \\
 g_t &= G_t/z_t^*, & q_t^h &= Q_t^h/P_t, \\
 h_t &= \bar{H}_t/z_t^*, & r_t^k &= \Upsilon^t \tilde{r}_t^k, \\
 s_t &= S_t/P_t, & w_t^p &= W_t^p/(z_t^* P_t), \\
 t_t &= T_t/(z_t^* P_t), & y_{z,t} &= Y_t/z_t^*, \\
 t_t^i &= T_t^i/(z_t^* P_t), & y_t &= Y_t^{gdp}/z_t^*, \\
 t_t^p &= T_t^p/(z_t^* P_t), & \mu_{z^*,t} &= z_t^*/z_{t-1}^*, \\
 w_t &= W_t/(z_t^* P_t), & z_t^* &= z_t \Upsilon^{(\frac{\alpha}{1-\alpha})t}. \\
 w_t^i &= W_t^i/(z_t^* P_t), & &
 \end{aligned}$$

Prices.—Optimal price equations

$$F_{p,t}^p = \lambda_{z,t}^p y_{z,t} + \xi_p \beta^p E_t (\tilde{\pi}_{t+1} \pi_{t+1}^{-1})^{\frac{1}{1-\lambda_{f,t+1}}} F_{p,t+1}^p. \quad (1.10)$$

$$K_{p,t}^p = \lambda_{z,t}^p y_{z,t} \lambda_{f,t} s_t + \xi_p \beta^p E_t (\tilde{\pi}_{t+1} \pi_{t+1}^{-1})^{\frac{\lambda_{f,t+1}}{1-\lambda_{f,t+1}}} K_{p,t+1}^p. \quad (1.11)$$

$$K_{p,t}^p = \left(\left[1 - \xi_p (\tilde{\pi}_t \pi_t^{-1})^{\frac{1}{1-\lambda_{f,t}}} \right] (1 - \xi_p)^{-1} \right)^{1-\lambda_{f,t}} F_{p,t}^p. \quad (1.12)$$

Wages.—Optimal patient and impatient household wage equations and aggregate wage

$$F_{w,t}^p = \lambda_{z,t}^p l_t^p (1 - \tau^l) \lambda_w^{-1} + \beta^p \xi_w \mu_{z^*}^{\frac{1}{1-\lambda_w}} E_t \mu_{z^*,t+1}^{-1} \pi_{w,t+1}^{\frac{\lambda_w}{\lambda_w-1}} \tilde{\pi}_{w,t+1}^{\frac{1}{1-\lambda_w}} \pi_{t+1}^{-1} F_{w,t+1}^p. \quad (1.13)$$

$$K_{w,t}^p = l_t^{p,1+\sigma_l} + \xi_w \beta^p E_t (\tilde{\pi}_{w,t+1} \pi_{w,t+1}^{-1} \mu_{z^*})^{\frac{\lambda_w}{1-\lambda_w} (1+\sigma_l)} K_{w,t+1}^p. \quad (1.14)$$

$$K_{w,t}^p = \psi_l^{-1} \left(\left[1 - \xi_w (\tilde{\pi}_{w,t} \pi_{w,t}^{-1} \mu_{z^*})^{\frac{1}{1-\lambda_w}} \right] (1 - \xi_w)^{-1} \right)^{1-\lambda_w (1+\sigma_l)} w_t^p F_{w,t}^p. \quad (1.15)$$

$$F_{w,t}^i = \lambda_{z,t}^p l_t^i (1 - \tau^l) \lambda_w^{-1} + \beta^i \xi_w \mu_{z^*}^{\frac{1}{1-\lambda_w}} E_t \mu_{z^*,t+1}^{-1} \pi_{w,t+1}^{\frac{\lambda_w}{\lambda_w-1}} \tilde{\pi}_{w,t+1}^{\frac{1}{1-\lambda_w}} \pi_{t+1}^{-1} F_{w,t+1}^i. \quad (1.16)$$

$$K_{w,t}^i = l_t^{i,1+\sigma_i} + \xi_w \beta^i E_t (\tilde{\pi}_{w,t+1} \pi_{w,t+1}^{-1} \mu_{z^*})^{\frac{\lambda_w}{1-\lambda_w} (1+\sigma_i)} K_{w,t+1}^i. \quad (1.17)$$

$$K_{w,t}^i = \psi_l^{-1} \left(\left[1 - \xi_w (\tilde{\pi}_{w,t} \pi_{w,t}^{-1} \mu_{z^*})^{\frac{1}{1-\lambda_w}} \right] (1 - \xi_w)^{-1} \right)^{1-\lambda_w (1+\sigma_i)} w_t^i F_{w,t}^i. \quad (1.18)$$

$$w_t = (1 - \kappa) w_t^p + \kappa w_t^i. \quad (1.19)$$

Production.—Capital utilization and rental rate, patient and impatient labor demand, capital accumulation, return on capital and housing, and aggregate production function

$$r_t^k = r^k \exp(\sigma_a [u_t - 1]). \quad (1.20)$$

$$r_t^k = \alpha \varepsilon_t (\Upsilon \mu_{z^*,t} l_t)^{1-\alpha} (u_t k_{t-1})^{\alpha-1} s_t. \quad (1.21)$$

$$w_t^p l_t^p = (1 - \alpha) \kappa s_t \varepsilon_t \Upsilon^{-1} (\mu_{z^*,t}^{-1} u_t k_{t-1})^\alpha l_t^{1-\alpha}. \quad (1.22)$$

$$w_t^i l_t^i = (1 - \alpha) (1 - \kappa) s_t \varepsilon_t \Upsilon^{-1} (\mu_{z^*,t}^{-1} u_t k_{t-1})^\alpha l_t^{1-\alpha}. \quad (1.23)$$

$$k_t = (1 - \delta) \mu_{z^*,t}^{-1} \Upsilon^{-1} k_{t-1} + [1 - S(\zeta_{I,t} i_t \mu_{z^*,t} \Upsilon / i_{t-1})] i_t. \quad (1.24)$$

$$R_t^k = [(1 - \tau^k) [u_t r_t^k - a(u_t)] + (1 - \delta) q_t^k] \Upsilon^{-1} q_{t-1}^{k,-1} \pi_t + \tau^k \delta. \quad (1.25)$$

$$R_t^h = \pi_t q_t^h / q_{t-1}^h. \quad (1.26)$$

$$y_{z,t} = \varepsilon_t (\mu_{z^*,t}^{-1} \Upsilon^{-1} u_t k_{t-1})^\alpha l_t^{1-\alpha} - \theta. \quad (1.27)$$

Resource Constraints.—Aggregate output, consumption, hours, and housing; and GDP

$$y_{z,t} = g_t + c_t + i_t \mu_{\Upsilon,t}^{-1} + a(u_t) k_{t-1} \Upsilon^{-1} \mu_{z^*,t}^{-1} + d_t^b. \quad (1.28)$$

$$c_t = c_t^p + c_t^i. \quad (1.29)$$

$$l_t = l_t^{p,\kappa} l_t^{i,1-\kappa}. \quad (1.30)$$

$$h = h_t^p + h_t^i. \quad (1.31)$$

$$y_t = g_t + c_t + i_t \mu_{\Upsilon,t}^{-1}. \quad (1.32)$$

Government.—Monetary policy rule and government budget constraint

$$R_t - R = \rho_p (R_{t-1} - R) + (1 - \rho_p) [\alpha_\pi (E_t \pi_{t+1} - \pi) + \alpha_{\Delta y} (g_{y,t} - \mu_{z^*})] + \varepsilon_t^p, \quad (1.33)$$

$$g_t + t_t = ([u_t r_t^k - a(u_t)] \Upsilon^{-1} - \pi_t^{-1} \delta q_{t-1}^k) \mu_{z^*,t}^{-1} k_{t-1} \tau^k + (w_t^i l_t^i + w_t^p l_t^p) \tau^l + c_t \tau^c. \quad (1.34)$$

Capital Producers.—Optimal capital investment

$$0 = E_t \left\{ \lambda_{z,t}^p q_t^k [1 - S(\zeta_{I,t} \mu_{z^*,t} \Upsilon i_t / i_{t-1}) - \zeta_{I,t} \mu_{z^*,t} \Upsilon i_{t-1}^{-1} S^{k'}(\zeta_{I,t} \mu_{z^*,t} \Upsilon i_t / i_{t-1})] \right. \\ \left. - \lambda_{z,t}^p \mu_{\Upsilon,t}^{-1} + \beta^p \lambda_{z,t+1}^p q_{t+1}^k (\mu_{z^*,t+1} \Upsilon)^{-1} (\zeta_{I,t+1} \mu_{z^*,t+1} \Upsilon i_{t+1} / i_t)^2 S^{k'}(\zeta_{I,t+1} \mu_{z^*,t+1} \Upsilon i_{t+1} / i_t) \right\}. \quad (1.35)$$

Patient Households.—Optimal consumption, housing, and deposits

$$0 = \lambda_{z,t}^p (1 + \tau^c) - \zeta_{c,t} \mu_{z^*,t} / (\mu_{z^*,t} c_t^p - b_c^p c_{t-1}^p) + b_c^p \beta^p E_t \zeta_{c,t+1} / (\mu_{z^*,t+1} c_{t+1}^p - b_c^p c_t^p). \quad (1.36)$$

$$0 = \zeta_{h,t} / h_t^p - \lambda_{z,t}^p q_t^h + \beta^p E_t \mu_{z^*,t+1}^{-1} \lambda_{z,t+1}^p q_{t+1}^h. \quad (1.37)$$

$$0 = \lambda_{z,t}^p - \beta^p E_t (\pi_{t+1} \mu_{z^*,t+1})^{-1} \lambda_{z,t+1}^p R_{t+1}. \quad (1.38)$$

Impatient Households.—Optimal consumption, housing services, physical housing, leverage; budget constraint, bank participation constraint, default cutoff, net worth, leverage, and spread

$$0 = \lambda_{z,t}^i(1 + \tau^c) - \zeta_{c,t}\mu_{z^*,t}/(\mu_{z^*,t}c_t^i - b_c^i c_{t-1}^i) + b_c^i \beta^i E_t \zeta_{c,t+1}/(\mu_{z^*,t+1}c_{t+1}^i - b_c^i c_t^i). \quad (1.39)$$

$$0 = \zeta_{h,t}\psi_h^i/h_t^i - \lambda_{z,t}^i r_t^h. \quad (1.40)$$

$$0 = \lambda_{z,t}^i(r_t^h h_t^i + b_t^i) - \lambda_{z,t}^i q_t^h h_t^i [1 + S^h(\mu_{z^*,t}h_t^i/h_{t-1}^i) + \mu_{z^*,t}h_t^i h_{t-1}^{i,-1} S^{h'}(\mu_{z^*,t}h_t^i/h_{t-1}^i)] \quad (1.41)$$

$$+ \beta^i E_t \lambda_{z,t+1}^i/(\pi_{t+1}\mu_{z^*,t+1}) [q_{t+1}^h(\mu_{z^*,t}h_{t+1}^i/h_t^i)^2 S^{h'}(\mu_{z^*,t+1}h_{t+1}^i/h_t^i) + [1 - \Gamma_t^i(\bar{\omega}_{t+1}^i)] R_{t+1}^h q_t^h h_t^i].$$

$$0 = \lambda_{z,t}^i - \beta^i E_t \lambda_{z,t+1}^i (\pi_{t+1}\mu_{z^*,t+1})^{-1} \left[R_{t+1}^a - (1 - \mu^i) R_t^i G_t^{i'}(\bar{\omega}_{t+1}^i) \right. \quad (1.42)$$

$$\left. + \bar{\omega}_{t+1}^i F_t^{i'}(\bar{\omega}_{t+1}^i) [1 - F_t^i(\bar{\omega}_{t+1}^i)]^{-1} (R_{t+1}^a - (1 - \mu^i) G_t^i(\bar{\omega}_{t+1}^i) R_{t+1}^h \phi_t^i q_t^h h_t^i / b_t^i) \right].$$

$$0 = (1 - \tau^l) w_t^i l_t^i + (\pi_t \mu_{z^*,t})^{-1} [1 - \Gamma_{t-1}^i(\bar{\omega}_t^i)] R_t^h q_{t-1}^h h_{t-1}^i + b_t^i + t_t^i - (1 + \tau^c) c_t^i - q_t^h h_t^i. \quad (1.43)$$

$$0 = R_{t+1} b_t^i - [1 - F_t^i(\bar{\omega}_{t+1}^i)] R_t^i b_t^i - (1 - \mu^i) G_t^i(\bar{\omega}_{t+1}^i) R_{t+1}^h \phi_t^i q_t^h h_t^i. \quad (1.44)$$

$$\bar{\omega}_t^i = R_{t-1}^i b_{t-1}^i / (R_t^h q_{t-1}^h h_{t-1}^i). \quad (1.45)$$

$$n_t^i = (\pi_t \mu_{z^*,t})^{-1} [1 - \Gamma_{t-1}^i(\bar{\omega}_t^i)] R_t^h q_{t-1}^h h_{t-1}^i. \quad (1.46)$$

$$L_t^i = q_t^h h_t^i / n_t^i. \quad (1.47)$$

$$S_t^i = R_t^i / R_t. \quad (1.48)$$

Entrepreneurs.—FOC, bank participation constraint, default cutoff, net worth, leverage, debt, and spread

$$0 = E_t \left\{ [1 - \phi_t^e \Gamma_t^e(\bar{\omega}_{t+1}^e)] R_{t+1}^k / R_{t+1}^a + \Gamma_t^{e'}(\bar{\omega}_{t+1}^e) [\Gamma_t^{e'}(\bar{\omega}_{t+1}^e) - \mu^e G_t^{e'}(\bar{\omega}_{t+1}^e)]^{-1} \right. \quad (1.49)$$

$$\left. (R_{t+1}^k R_{t+1}^{a,-1} \phi_t^e [\Gamma_t^e(\bar{\omega}_{t+1}^e) - \mu^e G_t^e(\bar{\omega}_{t+1}^e)] - 1) \right\}.$$

$$0 = R_{t+1} b_t^e - [1 - F_t^e(\bar{\omega}_{t+1}^e)] R_t^e b_t^e - (1 - \mu^e) G_t^e(\bar{\omega}_{t+1}^e) R_{t+1}^k \phi_t^e q_t^k k_t. \quad (1.50)$$

$$\bar{\omega}_t^e = R_{t-1}^e b_{t-1}^e / (R_t^k q_{t-1}^k k_{t-1}). \quad (1.51)$$

$$n_t^e = \gamma_t^e (\pi_t \mu_{z^*,t})^{-1} [1 - \Gamma_{t-1}^e(\bar{\omega}_t^e)] R_t^k q_{t-1}^k k_{t-1} - \delta^e n_t^e. \quad (1.52)$$

$$L_t^e = q_t^k k_t / n_t^e. \quad (1.53)$$

$$b_t^e = q_t^k k_t - n_t^e. \quad (1.54)$$

$$S_t^e = R_t^e / R_t. \quad (1.55)$$

Banks.—Optimal housing and capital requirements and total bank credit

$$\phi_t^i = \nu_t. \quad (1.56)$$

$$\phi_t^e = \nu_t. \quad (1.57)$$

$$b_t = b_t^i + b_t^e. \quad (1.58)$$

B. Auxiliary Expressions

Prices and Wages.—Price and wage indexation and wage inflation

$$\tilde{\pi}_t = \pi^{\iota_p} \pi_{t-1}^{1-\iota_p}. \quad (1.59)$$

$$\tilde{\pi}_{w,t} = \pi^{\iota_w} \pi_{t-1}^{1-\iota_w}. \quad (1.60)$$

$$\pi_{w,t} = \pi_t \mu_{z^*,t} w_t / w_{t-1}. \quad (1.61)$$

Adjustment Costs.—Utilization, investment, and housing adjustment costs

$$a(u_t) = r^k (\exp[\sigma_a(u_t - 1)] - 1) \frac{1}{\sigma_a}. \quad (1.62)$$

$$S^k(\zeta_{I,t} \mu_{z,t}^* \Upsilon i_t / i_{t-1}) = e^{\sqrt{\frac{S^k \mu}{2}} \Upsilon (\zeta_{I,t} \mu_{z^*,t} \frac{i_t}{i_{t-1}} - \mu_z^*)} + e^{-\sqrt{\frac{S^k \mu}{2}} \Upsilon (\zeta_{I,t} \mu_{z^*,t} \frac{i_t}{i_{t-1}} - \mu_z^*)} - 2. \quad (1.63)$$

$$S^h(\mu_{z^*,t} h_t^i / h_{t-1}^i) = e^{\sqrt{\frac{S^h \mu}{2}} (\mu_{z^*,t} \frac{h_t^i}{h_{t-1}^i} - \mu_z^*)} + e^{-\sqrt{\frac{S^h \mu}{2}} (\mu_{z^*,t} \frac{h_t^i}{h_{t-1}^i} - \mu_z^*)} - 2. \quad (1.64)$$

Distribution Functions.—Default probability, bank monitoring returns, and gross share of profits going to banks

$$F_{t-1}^i(\bar{\omega}_t^i, \sigma_{t-1}^i) = \Phi([\ln(\bar{\omega}_t^i) + (\sigma_{t-1}^i)^2/2]/\sigma_{t-1}^i), \quad (1.65)$$

$$G_{t-1}^i(\bar{\omega}_t^i, \sigma_{t-1}^i) = \Phi([\ln(\bar{\omega}_t^i) + (\sigma_{t-1}^i)^2/2]/\sigma_{t-1}^i - \sigma_{t-1}^i), \quad (1.66)$$

$$\Gamma_{t-1}^i(\bar{\omega}_t^i, \sigma_{t-1}^i) = \bar{\omega}_t^i [1 - F_{t-1}^i(\bar{\omega}_t^i, \sigma_{t-1}^i)] + G_{t-1}^i(\bar{\omega}_t^i, \sigma_{t-1}^i), \quad (1.67)$$

$$F_{t-1}^e(\bar{\omega}_t^e, \sigma_{t-1}^e) = \Phi([\ln(\bar{\omega}_t^e) + (\sigma_{t-1}^e)^2/2]/\sigma_{t-1}^e), \quad (1.68)$$

$$G_{t-1}^e(\bar{\omega}_t^e, \sigma_{t-1}^e) = \Phi([\ln(\bar{\omega}_t^e) + (\sigma_{t-1}^e)^2/2]/\sigma_{t-1}^e - \sigma_{t-1}^e), \quad (1.69)$$

$$\Gamma_{t-1}^e(\bar{\omega}_t^e, \sigma_{t-1}^e) = \bar{\omega}_t^e [1 - F_{t-1}^e(\bar{\omega}_t^e, \sigma_{t-1}^e)] + G_{t-1}^e(\bar{\omega}_t^e, \sigma_{t-1}^e), \quad (1.70)$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution.

Banks.—Aggregate resources for monitoring impatient households and entrepreneurs

$$d_t^b = (\pi_t \mu_{z^*,t})^{-1} [\mu^i G_{t-1}^i(\bar{\omega}_t^i) R_t^h \phi_{t-1}^i q_{t-1}^h h_{t-1}^i + \mu^e G_{t-1}^e(\bar{\omega}_t^e) R_t^k \phi_{t-1}^e q_{t-1}^k k_{t-1}]. \quad (1.71)$$

C. Alternative Model with No Impatient Households and No Collateral Shocks

In the paper, we compare our baseline model to an alternative model without impatient households and without collateral shock. This model is close to the CMR model. With respect to our baseline model, the differences are as follows. All equations related to impatient households and housing drop: (1.16), (1.17), (1.18), (1.23), (1.26), (1.31), (1.34), (1.37), (1.39), (1.40), (1.43), (1.41), (1.42), (1.44), (1.45), (1.46), (1.47), (1.48), (1.56), (1.64), (1.65), (1.66), (1.67), and (1.71). In addition, the following equations change: aggregate wage (1.19), aggregate consumption (1.29), aggregate hours (1.30), and total bank credit (1.58)

$$w_t = w_t^p; \quad c_t = c_t^p; \quad l_t = l_t^{p,\kappa}; \quad b_t = b_t^e.$$

Regarding parameters, the share κ of patient labor in total labor is equal to one, while β^i , b_c^i , $F^i(\bar{\omega}^i)$, μ^i , and $S^{h'}$ drop. Parameters associated to the collateral, housing risk, and housing preference shocks, ρ_ν , σ_ν , ρ_{σ^i} , σ_{σ^i} , ρ_{ζ_h} , and σ_{ζ_h} , also drop.

Chapter 1. Collateral Shocks

Mnemonic	Description	Unit	Source
<i>A. Macroeconomic Series</i>			
GDP	Gross domestic product	\$bn	BEA
GDPDEF	Gross domestic product: implicit price deflator	idx	BEA
PCND	Personal consumption expenditures: nondurables	\$bn	BEA
PCESV	Personal consumption expenditures: services	\$bn	BEA
PCDG	Personal consumption expenditures: durables	\$bn	BEA
GPDI	Gross private domestic investment	\$bn	BEA
A006RD3Q086SBEA	Gross private domestic investment: price deflator	idx	BEA
HOANBS	Nonfarm business sector: hours of all persons	idx	BEA
FEDFUNDS	Effective federal funds rate	%	BOG
CNP16OV	Civilian noninstitutional population	ppl	BLS
LABSHPUSA156NR	Share of labor compensation in GDP, annual	%	UoG
<i>B. Financial Series</i>			
CMDEBT	Households & nonprofits: debt securities & loans	\$bn	BOG
MORTGAGE30US	30-year fixed rate mortgage average in the US	%	FHLMC
TBSDODNS	Nonfinancial business: debt securities & loans	\$bn	BOG
BAA	Moody's seasoned Baa corporate bond yield	%	Moody's
TABSNNCB	Nonfinancial corporate business: total assets	\$bn	BOG
TNWMVBSNNCB	Nonfinancial corporate business: net worth	\$bn	BOG
TABSNNB	Nonfinancial noncorporate business: total assets	\$bn	BOG
TNWSNNB	Nonfinancial noncorporate business: net worth	\$bn	BOG
NCBREMV	Nonfinancial corporate business: real estate	\$m	BOG
NNBREMV	Nonfinancial noncorporate business: real estate	\$bn	BOG
H0SUBLPDHMSNQ	Net % of banks tightening standards for mortgages	%	BOG
DRTSPM	Net % of banks tightening standards for prime mtgs.	%	BOG
DSUBLPDHMSENQ	Net % of banks tightening standards for GSE mtgs.	%	BOG
DRTSCILM	Net % of banks tightening standards for C&I loans	%	BOG
NFCICREDIT	Chicago Fed national financial conditions credit	idx	FRBC
<i>C. Tax Series</i>			
1100	Taxes on income, profits, & capital gains of individuals	\$bn	OECD
1200	Taxes on income, profits, & capital gains of corporates	\$bn	OECD
2000	Social security contributions	\$bn	OECD
2200	Employers social security contributions	\$bn	OECD
3000	Taxes on payroll and workforce	\$bn	OECD
4400	Taxes on financial and capital transactions	\$bn	OECD
5110	General taxes on goods and services	\$bn	OECD
5121	Excises	\$m	OECD
P31NC	Final consumption expenditures of households	\$m	OECD
P3CG	Final consumption expenditure, general government	\$m	OECD
D1CG	Total compensation of government employees	\$m	OECD
SB3G	Mixed income, gross	\$m	OECD
NFD4R	Property income	\$m	OECD
NFB4G	Entrepreneurial income, gross	\$m	OECD
NFD11P	Wages and salaries	\$m	OECD
SB2GB3G	Operating surplus and mixed income, gross	\$m	OECD

Notes: BEA: Bureau of Economic Analysis; BLS: Bureau of Labor Statistics; BOG: Board of Governors; FHLMC: Freddie Mac; FRBC: Federal Reserve Bank of Chicago, UoG: University of Groningen.

Table 1.2: Data Sources

X. Data and Observation Equations

A. Data Sources

All macroeconomic and financial data are extracted from the Federal Reserve Economic Data (FRED) database. To compute effective tax rates, we use annual data from the Organization for Economic Co-operation and Development (OECD). Table 1.2 lists all the series and their associated mnemonic.

B. Data Treatment

Table 1.3 shows how we construct our observable variables. We also construct additional variables to match steady-state ratios and provide out-of-sample evidence. To compute effective tax rates, we follow the methodology developed by Mendoza, Razin, and Tesar (1994). The formulas are theirs; we use OECD mnemonics reported in Table 1.2.

C. Observation Equations

We specify the model observation equations that match our treatment of the data. The superscript *obs* denotes an observable variable.

Gross domestic product:	$y_t^{obs} = 1 + \ln(y_t \mu_{z^*,t} / y_{t-1}) - \ln \mu_{z^*} = y_t \mu_{z^*,t} / (y_{t-1} \mu_{z^*}).$
Consumption:	$c_t^{obs} = c_t \mu_{z^*,t} / (c_{t-1} \mu_{z^*}).$
Investment:	$i_t^{obs} = i_t \mu_{z^*,t} / (i_{t-1} \mu_{z^*}).$
Hours:	$l_t^{obs} = 1 + \ln l_t - \ln l = l_t / l.$
Inflation:	$\pi_t^{obs} = 1 + \ln \pi_t - \ln \pi = \pi_t / \pi.$
Nominal interest rate:	$R_t^{obs} = R_t - R.$
Price of investment:	$\mu_{\Upsilon,t}^{obs} = \mu_{\Upsilon,t} / \mu_{\Upsilon,t-1}.$
Household credit:	$b_t^{i,obs} = b_t^i \mu_{z^*,t} / (b_{t-1}^i \mu_{z^*}).$
Household spread:	$S_t^{i,obs} = R_t^i - R_t - (R^i - R).$
Business credit:	$b_t^{e,obs} = b_t^e \mu_{z^*,t} / (b_{t-1}^e \mu_{z^*}).$
Business spread:	$S_t^{e,obs} = R_t^e - R_t - (R^e - R).$

Constructed Series	Formula	Remark
Population	= HPfilter(CNP16OV, $\lambda = 10\,000$)	To remove breaks
<i>A. Observable Variables</i>		
GDP	= GDP/(GDPDEF \times Population)	First diff, demean
Consumption	= (PCND + PCESV)/(GDPDEF \times Population)	First diff, demean
Investment	= (PCDG + GPDI)/(GDPDEF \times Population)	First diff, demean
Hours	= HOANBS/Population	Demean
Inflation	= $\ln(\text{GDPDEF}) - \ln(\text{GDPDEF})_{-1}$	Demean
Price of investment	= $\ln(\text{A006RD3Q086SBEA}_t) - \ln(\text{GDPDEF})$	Demean
Nominal interest rate	= FEDFUNDS/4	Demean
Household credit	= CMDEBT/(GDPDEF \times Population)	First diff, demean
Household spread	= (MORTGAGE30US – FEDFUNDS)/4	Demean
Business credit	= TBSDODNS/(GDPDEF \times Population)	First diff, demean
Business spread	= (BAA – FEDFUNDS)/4	Demean
<i>B. Other Variables</i>		
Exogenous spending	= GDP – Consumption – Investment	Avg 1985–2019
Capital share	= 100 – LABSHPUSA156NRUG	Avg 1985–2017
Total credit	= Household credit + Business credit	Avg 1985–2019
Productive capital	= $\frac{\text{TABSNNCB} + \text{TABSNNB} - \text{NCBREM} - \text{NNBREM}}{\text{GDPDEF} \times \text{Population}}$	Avg 1985–2019
Business leverage	= $\frac{\text{TABSNNCB} + \text{TABSNNB}}{\text{TNWMVBSNNCB} + \text{TNWBSNNB}}$	Avg 1985–2019
Lending standards H	= H0SUBLPDHMSNQ; DRTSPM; DSUBLPDHMSENQ	Merge 3 series
Lending standards B	= DRTSCILM	
Consumption tax	= (5110 + 5121)/(P31NC + P3CG – D1CG – 5110 – 5121)	Methodology developed by
Household tax rate	= 1100/(SB3G + NFD4R – NFB4G + NFD11P) $\equiv \tau^h$	Mendoza, Razin,
Labor income tax	= (τ^h D1CG + 2000 + 3000)/(D1CG + 2200)	and Tesar (1994)
Capital income tax	= [τ^h (SB3G + NFD4R + NFB4G) + 1200 + 4400]/SB2GB3G	

Table 1.3: Data Treatment

XI. Bayesian Estimation, Complement

This section complements Section II of the main text. We discuss successively the set of parameters we calibrate, the set of parameters we estimate, a measure of model fit, and estimates for the two other model specifications.

A. Calibrated Parameters

Table 1.4 reports the calibrated parameters. For those in Panel A, we use our data set directly. The share of capital in production α averages 0.39 between 1985 and 2019. The steady-state government spending-to-GDP ratio η_g equals 0.16, the mean in our sample. Annualized steady-state inflation π^* is set to 2.14%, the average over the period. The

Par.	Description	Value	Target / Source
<i>A. Parameters Calibrated Using Our Data Set</i>			
α	Capital share in production	0.3906	Sample mean
η_g	Steady state gov. spending-GDP ratio	0.1648	Sample mean
π^*	Steady state inflation, annual	2.1369	Sample mean
μ_z^*	Growth rate of the economy, annual	1.4987	Sample mean
Υ	Trend rate of IST change, annual	0.9268	Sample mean
τ^c	Tax rate on consumption	0.0476	Sample mean
τ^k	Tax rate on capital income	0.2290	Sample mean
τ^l	Tax rate on labor income	0.2005	Sample mean
δ^e	Entrepreneurial dividend share	0.0335	$L^e = 1.7479$
<i>B. Other Parameters</i>			
δ	Depreciation rate of capital	0.0250	10% annual
σ_l	Labor supply elasticity	1.0000	CMR
β^p	Patient discount factor	0.9993	$R = 3.95\%$ annual
β^i	Impatient discount factor	0.9700	Krusell and Smith (1998)
λ_f	Steady state price markup	1.2000	CMR
λ_w	Steady state wage markup	1.0250	CMR
ψ_l	Disutility weight on labor	0.7608	Hours $l = 1$

Table 1.4: Calibrated Parameters

mean growth rate of real per capita GDP μ_z^* is fixed at 1.50% on an annual basis. We set the annualized rate of investment-specific technological change Υ to 0.93%, which corresponds to the average rate of decline in the relative price of investment goods over the period. The tax rates on consumption τ^c , capital income τ^k , and labor income τ^l are computed following the methodology developed by Mendoza, Razin, and Tesar (1994). Over the 1985-2019 period, we find $\tau^c = 0.048$, $\tau^k = 0.229$, and $\tau^l = 0.200$. The dividend paid by entrepreneurs δ^e is set to match the average business sector leverage of 1.75 in our sample.

We calibrate the remaining parameters, in Panel B, as follows. We set the depreciation rate δ to 0.025 to match an annual rate of 10%. The labor supply elasticity σ_l equals 1. The patient household discount factor β^p is fixed at 0.9993, which pins down the annualized fed funds rate R to 3.95%. The impatient household discount factor β^i must be lower than β^p . We put it at 0.97, which lies between the values used by Iacoviello (2005) (0.95) and Krusell and Smith (1998) (0.99). Following CMR we calibrate the steady-state price markup λ_f at 1.20 and the steady-state wage markup λ_w at 1.025. The disutility weight on labor ψ_l is fixed so that total hours worked are normalized to one in steady state.

B. Estimated Parameters

Table 1.5 reports the estimated parameters. In Panel A we collect the structural ones. Many of these parameters are standard in the DSGE literature, and we apply similarly standard priors.¹⁹ These include the Taylor rule coefficients, $a_{\Delta y}$, a_{π} , and ρ_p , the Calvo price and wage stickiness parameters, ξ_p and ξ_w , the indexation coefficients, ι_p , and ι_w , and the curvature parameters for utilization and investment, σ_a and $S^{k''}$. For most of these parameters we find posterior modes close to those of CMR. One exception is the lower utilization cost function curvature (1.33 compared to their 2.54) which implies larger fluctuations in capital utilization in our model. We also find a smaller investment adjustment cost curvature $S^{k''}$ (4.80 compared to their 10.78), but our value is not too far from the 5.48 found by Smets and Wouters (2007). Our estimate of the Calvo price stickiness, at 0.88, entails a Phillips curve with a slope coefficient of 0.008.²⁰

We now discuss the less habitual parameters. The cost of adjusting housing $S^{h''}$ is essential to smooth the dynamics of impatient household housing, and hence household debt, a variable we observe. Because it is costly to sell housing immediately, impatient households react more slowly to adverse shocks. The posterior mode of $S^{h''}$, at 4.37, is close to the mode of $S^{k''}$. Next, we set the prior mean of the steady-state default probability of households and entrepreneurs, $F^i(\bar{\omega}^i)$ and $F^e(\bar{\omega}^e)$, to an annual percentage rate of 3.2 and 2.95, respectively.²¹ We find a higher posterior value for both, implying our model overshoots the actual default rates of households and firms. The two monitoring costs, μ^i and μ^e , have a prior mean of 0.3. It is difficult to measure precisely the cost of bankruptcy. Alderson and Betker (1995) estimate it at 36 percent for firms. Our posterior estimates (40 and 20 percent, respectively) are not too far from this value. Another important coefficient is the share κ of patient labor in total labor. We set its prior to 0.5 based on the observation that at least half of households in the US hold a form of collateralized debt.²² We find a

¹⁹We refer to Smets and Wouters (2007), Justiniano, Primiceri, and Tambalotti (2010), and CMR.

²⁰Mavroeidis, Plagborg-Møller, and Stock (2014) find that the slope coefficient of the New Keynesian Phillips curve varies from 0.001 to 0.141 according to different model specifications and estimation methods. This is a fairly wide range and the authors warn of specification uncertainty and weak identification issues.

²¹These values correspond to the average delinquency rates on consumer loans and the average delinquency rates on commercial and industrial loans, respectively, over the period 1987-2019.

²²According to The Pew Charitable Trusts (2015), eight in ten Americans hold some form of debt. The most frequently held forms are mortgage debt (44%), unpaid credit card balances (39%), car loans (37%), and student loans (21%). In our model debt is backed by collateral, so that corresponds to all mortgage debt as well as a large share of auto loans.

posterior mode of 0.82, implying 18 percent of households are debt-constrained. This is slightly lower than the 20-25 percent share of hand-to-mouth households estimated by Kaplan, Violante, and Weidner (2014) with micro data.

Finally, we turn to the exogenous processes. Panel B of Table 1.5 reports their values. We fix the autoregressive parameter of the monetary policy shock ρ_{ep} to zero. We find that several shocks are highly persistent, including the collateral shock, with an estimated autocorrelation coefficient of 0.981. The estimated standard deviation of the collateral shock is relatively large, at 0.021. The housing preference shock also has a high standard deviation (0.30) to capture the fact that house prices went through a large boom and bust episode in the 2000s.

C. Model Fit

We ask whether our estimated model is a reliable representation of the US economy by comparing its steady-state properties to the data. Panel A of Table 1.6 reports key model variables and ratios evaluated at the posterior mode along with their empirical counterpart. Overall, the model and data match well. This is the case by construction for the ratio of government spending to GDP, inflation, and nonfinancial firm leverage. One exception to the good fit is the ratio of debt to GDP, which is too low in the model.

As a second measure of model fit, we compute moments of selected variables when the model is at its posterior mode, and we confront them to the data. Since model variables are stationary, we need to stationarize the data as well, and we do that using a standard HP filter (we find similar results using a bandpass filter). Panel B of Table 1.6 reports the results. Overall, the fit is good. The model, however, falls short of matching the volatility of business credit.

Chapter 1. Collateral Shocks

Param.	Description	Prior			Posterior	
		Distrib.	Mean	SD	Mode	SD
<i>A. Economic Parameters</i>						
$a_{\Delta y}$	Taylor rule output	normal	0.12	0.1	0.5128	0.0480
a_{π}	Taylor rule inflation	normal	1.5	0.25	2.0335	0.1225
ρ_p	Taylor rule smoothing	beta	0.85	0.1	0.8637	0.0120
ξ_p	Calvo price stickiness	beta	0.5	0.125	0.8808	0.0358
ξ_w	Calvo wage stickiness	beta	0.5	0.125	0.9159	0.0185
l_p	Price indexation on inflation	beta	0.5	0.2	0.9611	0.0284
l_w	Wage indexation on inflation	beta	0.5	0.2	0.6507	0.2093
σ_a	Capital utilization cost	normal	1	0.5	1.3266	0.2492
$S^{k''}$	Investment adjustment cost	normal	2	1	4.8008	0.4740
$S^{h''}$	Housing adjustment cost	normal	2	1	4.3734	0.4652
b_c^p	Patient consumption habit	beta	0.65	0.1	0.8288	0.0363
b_c^i	Impatient consumption habit	beta	0.65	0.1	0.8600	0.0435
$F^i(\bar{\omega}^i)$	Impatient default probability	beta	0.008	0.003	0.0181	0.0032
$F^e(\bar{\omega}^e)$	Entrepreneur default probability	beta	0.007	0.003	0.0277	0.0042
μ^i	Impatient monitoring cost	beta	0.3	0.15	0.3991	0.0629
μ^e	Entrepreneur monitoring cost	beta	0.3	0.15	0.1971	0.0552
κ	Share of patient in total labor	beta	0.5	0.2	0.8215	0.0676
<i>B. Shock Parameters</i>						
ρ_{ε}	Autocorr. stationary technology	beta	0.5	0.2	0.9166	0.0143
ρ_g	Autocorr. government spending	beta	0.5	0.2	0.9574	0.0367
ρ_{γ^e}	Autocorr. entrepreneur equity	beta	0.5	0.2	0.3398	0.0619
ρ_{λ_f}	Autocorr. price markup	beta	0.5	0.2	0.8166	0.0827
$\rho_{\mu_{\Upsilon}}$	Autocorr. investment technology	beta	0.5	0.2	0.9478	0.0156
$\rho_{\mu_{z^*}}$	Autocorr. technology trend	beta	0.5	0.2	0.2954	0.1053
ρ_{ν}	Autocorr. collateral	beta	0.5	0.2	0.9807	0.0070
ρ_{σ^i}	Autocorr. household risk	beta	0.5	0.2	0.9614	0.0189
ρ_{σ^e}	Autocorr. entrepreneur risk	beta	0.5	0.2	0.1052	0.0215
ρ_{ζ_c}	Autocorr. consumption preference	beta	0.5	0.2	0.2688	0.0724
ρ_{ζ_h}	Autocorr. housing preference	beta	0.5	0.2	0.7544	0.0480
ρ_{ζ_i}	Autocorr. marginal eff. investment	beta	0.5	0.2	0.4556	0.0656
σ_{ε}	SD stationary technology	invg2	0.01	1	0.0046	0.0004
σ_{ε^p}	SD monetary policy	invg2	0.01	1	0.0011	0.0001
σ_g	SD government spending	invg2	0.01	1	0.0174	0.0012
σ_{γ^e}	SD equity	invg2	0.01	1	0.0048	0.0003
σ_{λ_f}	SD price markup	invg2	0.01	1	0.0314	0.0231
$\sigma_{\mu_{\Upsilon}}$	SD investment technology	invg2	0.01	1	0.0045	0.0003
$\sigma_{\mu_{z^*}}$	SD technology trend	invg2	0.01	1	0.0026	0.0014
σ_{ν}	SD collateral	invg2	0.01	1	0.0215	0.0029
σ_{σ^i}	SD household risk	invg2	0.01	1	0.0145	0.0027
σ_{σ^e}	SD entrepreneur risk	invg2	0.01	1	0.0103	0.0013
σ_{ζ_c}	SD consumption preference	invg2	0.01	1	0.0186	0.0043
σ_{ζ_h}	SD housing preference	invg2	0.01	1	0.3161	0.0652
σ_{ζ_i}	SD marginal efficiency investment	invg2	0.01	1	0.0226	0.0018

Note: SD stands for standard deviation, invg2 for the inverse gamma distribution of type 2.

Table 1.5: Estimated Parameters

<i>A. Steady-State Variables</i>		Model	Data
c/y	Consumption-to-GDP ratio	0.63	0.58
i/y	Investment-to-GDP ratio	0.21	0.26
g/y	Government-spending-to-GDP ratio	0.16	0.16
$k/(4y)$	Productive-capital-to-GDP ratio	1.64	2.09
$b/(4y)$	Debt-to-GDP ratio	0.85	1.36
π	Inflation, annual rate	2.14	2.14
R	Fed funds rate, annual rate	3.95	3.62
L^e	Entrepreneurial leverage	1.75	1.75

<i>B. Dynamic Variables</i>	Corr. with GDP		Standard Deviation		Autocorrelation	
	Model	Data	Model	Data	Model	Data
GDP	1	1	1	1	0.94	0.88
Consumption	0.84	0.81	0.64	0.71	0.94	0.84
Investment	0.93	0.91	3.28	4.39	0.94	0.91
Hours	0.90	0.87	1.25	1.64	0.93	0.95
Household Credit	0.27	0.51	1.62	1.31	0.94	0.92
Household Spread	-0.45	-0.62	0.11	0.21	0.90	0.87
Business Credit	0.37	0.31	1.09	2.60	0.94	0.96
Business Spread	-0.37	-0.7	0.13	0.27	0.90	0.89

Notes: The sample period is 1985Q1–2019Q1. In Panel A data values show the sample mean. Model values are computed at the posterior mode. In Panel B data variables are detrended with a HP filter to permit comparison with stationary model variables.

Table 1.6: Static and Dynamic Properties, Model Versus Data

XII. Additional Result

	Collateral Shock ν_t	Consumption Preference Shock $\zeta_{c,t}$
<i>A. Baseline Model</i>		
Output–Consumption	51	9
Output–Investment	52	0
Consumption–Investment	58	1
<i>B. Model with No Impatient Households and No Collateral Shock</i>		
Output–Consumption	0	46
Output–Investment	29	3
Consumption–Investment	– 4	14

Notes: The covariance decomposition is computed at the posterior mode. Business cycle frequency encompasses periodic components with cycles of 6-32 quarters.

Table 1.7: Covariance Decomposition at Business Cycle Frequency

This section presents an additional result. We report in Table 1.7 the percentage of the covariance between output, consumption, and investment that is explained by the collateral and consumption preference shocks, at business cycle frequency. We break down the table into two panels, one for the baseline model (Panel A) and the other for the model without impatient households (Panel B). Two results emerge. First, in the baseline model the collateral shock explains a large share of the covariance between the three pairs of variables. Second, in the model without impatient households the collateral shock is unable to account for the covariance between consumption and output and consumption and investment. Instead, it is the consumption preference shock that fills the gap.

Chapter 2

Bank Competition and the Financial Crisis, the French Example

I. Introduction

This paper aims at identifying the causes of business cycles fluctuations in France and to assess whether financial factors have been as pregnant there as in the USA and the Eurozone these past 20 years. While studies of the business cycle using general equilibrium models focus largely on the US economy and the Euro area, the Great Recession in 2008 followed by the Eurozone crisis in 2010 have had strong impacts in France both at macroeconomic and financial levels. I present a general equilibrium model able to replicate the key features of the French economy during the last two recessions, the model is used to study the implications of the zero lower bound (ZLB) depending on the structural characteristics of the economy and more precisely on the degree of bank competition characterized here by both markups and stickiness in loan and deposit interest rates. The model is estimated and used to build counter-factual scenarios of the crisis and study potential impacts of structural reforms in the banking system.

I find that much of the fall in investment, consumption, labor and loan volumes, as well as the rise in bank spreads, can be imputed to shocks occurring in the banking sector. Also, while the ZLB substantially increases the recessive impact of financial shocks, a high degree of bank concentration in France may have mitigated some of its adverse effects on real activity. The intuition is as follows. In an economy characterized by a monopolistic banking sector, the monetary policy pass-through is weaker if banks adjust

only slowly lending rates to changes in the policy rate. Accordingly, monetary policy is less efficient at stabilizing activity and adverse shocks may end up in worse economic outcomes. On the other hand, concentration in the banking sector also implies that shifts in credit supply have relatively less impact on loan volumes and economic activity as the credit demand curve is steeper. Importantly, these two effects can play differently depending on the availability of monetary policy. When the ZLB is not binding, the first effect likely dominates so that the economy is more resilient to credit supply shocks if the banking sector is competitive with a strong monetary pass-through. However, in periods when no recourse to monetary policy is possible, a lower elasticity of credit demand due to weak bank competition implies smaller response in loans following financial disturbances and overall a mitigated impact on real activity.

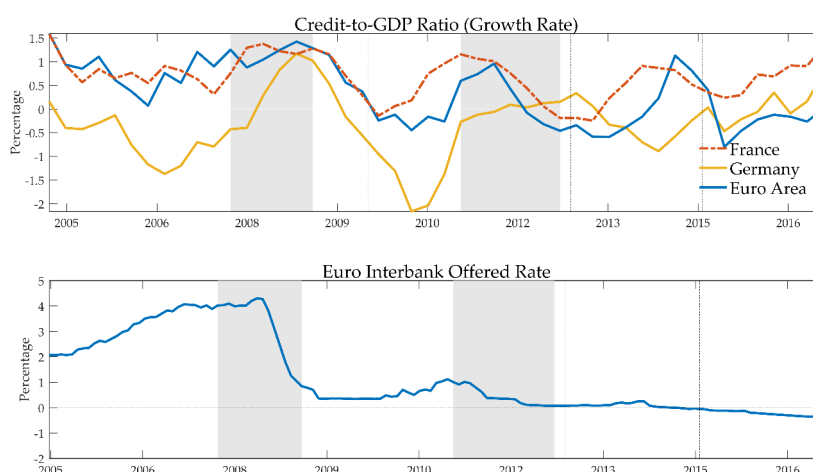


Figure 2.1: Credit and the Interbank Rate

Note: This figure depicts the evolution of the credit-to-GDP ratio for France, Germany and the Euro area in the upper panel and the annualized 6 months Euribor in the lower panel.

Figure 2.1 plots the evolution of the credit-to-GDP ratio for France, Germany, and the Eurozone as well as the Euribor since 2005. Overall, the credit-to-GDP ratios for the different entities appear to have experienced similar movements for the past 10 years. All growth rates fall in the aftermath of the recessions and pick up within a few years. An important feature underlined here by the dot black lines is the fact that following periods when the Euribor rate reaches a local minimum, the growth rate of the credit-to-GDP ratio

in the Eurozone is weak and delayed relative to its French counterpart. The difference between France and Germany is even more pronounced. The periods of low Euribor rate stressed in this graph correspond to periods of negative shadow rate as pointed in Wu and Xia (2017). This figure suggests different impacts of the ZLB on credit-to-GDP ratios in France and the Eurozone or Germany when the Euribor rate is low.¹

II. Literature Review

In this paper, I focus on the case of France to study the macroeconomic implications of bank competition when conventional monetary policy is impeded due to a binding ZLB. Several authors have stressed the concentrated nature of the French banking sector. For instance, Leuvensteijn, Sørensen, Bikker, and Rixtel (2008) provide evidence that the banking sector in France was the least competitive in the Eurozone at the outset of the Great Recession. Bikker and Spierdijk (2008) identify a negative trend in bank competition for France since the '90s. A vast literature investigates the effects of bank competition on monetary policy pass-through, Corvoisier and Gropp (2002) explain the difference between bank retail interest rates and money market rates using bank product-specific concentration indices. They find that bank market power explains high levels of lending rates and low levels of deposit rates. Borio and Fritz (1995) also find a significant effect of bank monopoly power on the monetary transmission mechanism. In particular, they show that the response of lending rates to changes in the policy rate is delayed in France relative to other developed countries. Using an index of deregulation, constructed by Gual (1999), Mojon (2001) finds that higher competition in the Euro area contributes positively to the adjustment speed of lending rates to changes in money market rates. Leuvensteijn, Sørensen, Bikker, and Rixtel (2008) find that competition significantly reduces bank spreads for consumer loans, mortgage loans, and short term business loans.

Several papers have studied the implications of bank competition with DSGE models. Using a general equilibrium version of the spatial monopolistic competition model of Salop (1979), Andrés and Arce (2012) show that banking competition gives rise to a trade-off between the long-run level of economic activity and stability over the business cycle

¹The credit volume corresponds to the outstanding volume of credit provided by banks, all other sectors of the economy and non-residents to the private non-financial sector. The credit-to-GDP ratio growth rate is computed as a moving average over two quarters. I find similar results when taking separately real GDP and credit to non-financial sector for the different areas.

as macroeconomic variables are more responsive to exogenous shocks when banks are competitive. In contrast, Stebunovs (2008) shows that a low degree of competition in the banking system increases funding costs for borrowers and reduces the number of non-financial producing firms as well as the aggregate level of production. He further shows that concentration in the banking sector amplifies the impact of technology shocks on real activity relative to a competitive banking sector environment. Recent papers have studied the impact of economic reforms in the context of binding ZLB. Cacciatore, Duval, Fiori, and Ghironi (2017) study the impact of goods and labor market reforms during recessions and show that the adverse effects of the ZLB can be mitigated by inflationary economic policies. Using a New Keynesian model, Eggertsson, Ferrero, and Raffo (2014) find that the impact of reforms that would be expansionary in normal times becomes a priori ambiguous, and possibly contractionary, in periods of binding ZLB.

The model I use to study the impact of bank competition for the transmission of financial shocks is a modified version of the financial accelerator model of Bernanke, Gertler, and Gilchrist (1999) including nominal frictions for prices and wages as in Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). Following Iacoviello (2005) and Iacoviello and Neri (2010), the model embeds impatient households to study the dynamics of household debt, credit spreads, and housing. I build on the framework from Gerali et al. (2010) which analyses the implications of credit-supply factors on business cycle fluctuations while allowing for imperfect financial intermediation.² On the supply side, imperfectly competitive banks set a time-varying markup on loans that increases credit costs and limits borrowing for both entrepreneurs and households. On the demand side, access to debt for households and entrepreneurs is subject to collateral requirements. To this benchmark, I add the possibility of strategic default for households and entrepreneurs in a costly-state verification setting: borrowers have limited liability and the value of their collateral get hit by idiosyncratic shocks, making the borrowers heterogeneous ex-post.³ Because collateral is uninsurable due to the incompleteness of financial markets this gives rise to the possibility of strategic default on both mortgage and corporate loans. Similar to Pariès, Sørensen, and Rodriguez-Palenzuela (2011), only

²See also Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2014) and Angelini, Neri, and Panetta (2014) as examples of frameworks that build on a similar specification of the banking structure.

³See Bernanke, Gertler, and Gilchrist (1999), Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2014) and Bécard and Gauthier (2018).

a fraction of banks can modify interest rates in response to changes in the policy rate. This specification of the banking structure allows replicating the sluggish adjustments of bank loan and deposit rates in response to shifts in monetary policy. The model is estimated with Bayesian techniques using french macroeconomic and financial data over the 2003 - 2017 period.

The rest of the paper is organized as follows. Section III describes the structural model. Section IV presents the data used for estimation and model calibration. Section V discusses the results of the Bayesian estimation. Section VI explores the implications of both bank competition and CCyB at the ZLB. Section VII concludes.

III. The Model

There are three main types of agents in the model. Households that work and consume final goods, firms which hire labor and rent capital to produce and sell goods and financial intermediaries that channel funds from depositors to borrowing firms and households. There is no direct finance and all transactions are intermediated by the banking sector. I start with the presentation of the non-financial sector.

A. Non-Financial Sector

The economy is populated by three types of agent - patient households, impatient households, and entrepreneurs. Households maximize their utility subject to their respective resource constraint. Both patient households, indexed by P , and impatient households, indexed by I , work, consume and save or borrow. Entrepreneurs rent capital services to intermediate good producers, their objective is to maximize their expected net worth. Households have different discount factors ($\beta^I < \beta^P$) so that locally around the steady-state patient households are savers and impatient households are borrowers.⁴

Patient Households

The economy is populated by a large number of identical households. Each patient household contains every types of differentiated labor $l_{i,t}^P$ for $i \in [0, 1]$. The problem of a house-

⁴I follow Iacoviello (2005), Gerali et al. (2010) and Angelini, Neri, and Panetta (2014) in assuming that because shocks to the economy are local, patient households always hold positive savings and impatient households and entrepreneurs always hold a positive debt.

hold is to select her levels of consumption c_t^P , housing stock h_t^P and deposit d_t in order to maximize her inter-temporal utility defined as:

$$U_P(c_t^P, h_t^P) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1 - a^P) \varepsilon_t^z \log(c_t^P - a^P c_{t-1}^P) + \varepsilon_t^h \psi_h^P \log(h_t^P) - \psi_l \int_0^1 \frac{l_{i,t}^{P, 1+\phi}}{1+\phi} di \right], \quad (2.1)$$

where ϕ is the inverse Frisch-Waugh elasticity of labour supply and parameter a^P defines patient degree of consumption habits. In addition both ψ_l and ψ_h^P are weight parameters for leisure and housing utility.⁵ Variables ε_t^z and ε_t^h are exogenous shocks on consumption and housing preferences.

Patient households supply differentiated labor $l_{i,t}^P$. For each type of labor i there exists a monopolistic union which sets the corresponding wage rate $w_{i,t}^P$. Previous period real deposits of patient households d_{t-1} are remunerated at a real rate $(1 + r_{t-1}^d)/\pi_t$ per unit of saving, where $\pi_t = P_t/P_{t-1}$ defines the current rate of inflation and P_t is the price of the consumption good. Patient household budget constraint writes as:

$$(1 + \tau^c) c_t^P + q_t^h (h_t^P - h_{t-1}^P) + d_t = (1 - \tau^l) \int_0^1 w_{i,t}^P l_{i,t}^P di + (1 + r_{t-1}^d) \frac{d_{t-1}}{\pi_t} + \frac{Tr_t^P}{\pi_t}, \quad (2.2)$$

where q_t^h is the real price of the housing good and $Tr_t^P = \delta_t^E n_{t-1}^E + \delta^B n_{t-1}^B + G_t^P$ corresponds to lump-sum transfers including dividends from entrepreneurs δ_t^E and dividends from banks δ^B expressed as fractions of n_{t-1}^E and n_{t-1}^B , respectively past period entrepreneur and bank net worths. Parameters τ^c and τ^l are taxation rates on consumption spending and labor income. Finally, variable G_t^P corresponds to lump-sum transfers from the government.

Impatient Households

The model assumes the existence of a continuum of impatient households $j \in [0, 1]$. Each impatient household contains every types of differentiated labor $l_{i,t}^I$ for $i \in [0, 1]$ and max-

⁵In the utility function, consumption is weighted by $1 - a^P$ to produce the same steady-state marginal utility of consumption as in a model without habits.

imizes her inter-temporal utility defined as:

$$U_I(c_{j,t}^I, h_t^I) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_I^t \left[(1 - a^I) \varepsilon_t^z \log(c_{j,t}^I - a^I c_{j,t-1}^I) + \varepsilon_t^h \psi_h^I \log(h_{j,t}^I) - \psi_l \int_0^1 \frac{l_{j,i,t}^I}{1 + \phi} di \right]. \quad (2.3)$$

Impatient households are borrowers at the margin, at least in the neighborhood of the steady-state. Real term borrowing is denoted by $b_{j,t}^I$, which households obtain by pledging a fraction of their housing stock $h_{j,t}^I$ as collateral. In period t , each impatient household j is hit by an idiosyncratic shock $\xi_{j,t}^I > 0$ that affects the value of her housing. In applications $\xi_{j,t}^I$ follows a lognormal distribution centered to one with cumulative density function denoted $F_t^I(\xi^I)$ and standard deviation σ_t^I .⁶ Since the distribution assumed for this shock is symmetric and impatient households have a unit mass, the value of the aggregate stock of collateral does not change within a time period. As for entrepreneurs in Christiano, Motto, and Rostagno (2014), the dispersion of household collateral value σ_t^I is assumed to be an exogenous $AR(1)$ process. In period t , after observing the shock to her collateral $\xi_{j,t}^I$, the ex-post value of housing for household j is $q_t^h \xi_{j,t}^I h_{j,t-1}^I$. Because an impatient household has limited liability, she chooses to strategically default whenever the real value of the debt to be repaid is larger than the residual value of the collateral she pledged, that is if:

$$(1 + r_{j,t-1}^{bI}) \frac{b_{j,t-1}^I}{\pi_t} \geq \Phi_{t-1}^I q_t^h \xi_{j,t}^I h_{j,t-1}^I, \quad (2.4)$$

where Φ_{t-1}^I is defined as the loan-to-value (LTV) ratio set by the regulator or by the market for households. In application, it is assumed that this ratio is subject to exogenous fluctuations. Here, the right hand side of this equation corresponds to the effective value of collateral pledged by impatient household j while the left hand side corresponds to the actualized value of her debt. Denoting $\bar{\xi}_{j,t}^I$, the threshold value of the idiosyncratic shock under which household j chooses to default, this yields:

$$\bar{\xi}_{j,t}^I = \frac{(1 + r_{j,t-1}^{bI}) b_{j,t-1}^I / \pi_t}{\Phi_{t-1}^I q_t^h h_{j,t-1}^I}.$$

⁶This structure can be interpreted as uncertainty on the quality of the housing collateral with a magnitude controlled by an exogenous shock process σ_t^I .

After aggregating over the continuum of impatient households, aggregate net worth in housing writes:

$$\begin{aligned}
 n_t^I &= \int_{-\infty}^{\infty} \max \left\{ 0, \xi^I \Phi_{t-1}^I q_t^h h_{j,t-1}^I - (1 + r_{t-1}^{bI}) \frac{b_{j,t-1}^I}{\pi_t} \right\} dF_t^I(\xi^I), \\
 &= \int_{\bar{\xi}_{j,t}^I}^{\infty} \left[\xi^I \Phi_{t-1}^I q_t^h h_{j,t-1}^I - (1 + r_{t-1}^{bI}) \frac{b_{j,t-1}^I}{\pi_t} \right] dF_t^I(\xi^I), \\
 &= \left(1 - \int_{-\infty}^{\bar{\xi}_{j,t}^I} \xi^I dF_t^I(\xi^I) \right) \Phi_{t-1}^I q_t^h h_{j,t-1}^I - \left(\bar{\xi}_{j,t}^I \int_{\bar{\xi}_{j,t}^I}^{\infty} dF_t^I(\xi^I) \right) \Phi_{t-1}^I q_t^h h_{j,t-1}^I, \\
 &= \Phi_{t-1}^I q_t^h h_{j,t-1}^I [1 - S_t^I(\bar{\xi}_{j,t}^I) - \bar{\xi}_{j,t}^I F_t^I(\bar{\xi}_{j,t}^I)].
 \end{aligned}$$

Here F_t^I denotes the cumulative distribution function for ξ_t^I , and the probability of default for impatient household j writes $F_t^I(\bar{\xi}_{j,t}^I)$. Accordingly, $S_t^I(\bar{\xi}_t^I) \equiv \int_{-\infty}^{\bar{\xi}_t^I} \xi^I dF_t^I$ is the fraction of aggregate housing seized by the bank. The aggregate budget constraint for impatient households writes:

$$\begin{aligned}
 (1 + \tau^c) c_t^I + \left[1 + S_h \left(\frac{h_t^I}{h_{t-1}^I} \right) \right] q_t^h h_t^I + (1 + r_{t-1}^{bI}) (1 - F_t^I(\bar{\xi}_t^I)) \frac{b_{t-1}^I}{\pi_t} \\
 = (1 - \tau^l) \int_0^1 w_{i,t}^I l_{i,t}^I di + b_t^I + q_t^h h_{t-1}^I (1 - \Phi_{t-1}^I S_t^I(\bar{\xi}_t^I)), \quad (2.5)
 \end{aligned}$$

where S_h is an adjustment cost function defined bellow.

I assume the existence of risk-neutral retail branches that channel funds from banks to impatient households and entrepreneurs conditional on making positive expected profits. This implies an endogenous LTV constraint which caps the borrowing capacities of households. Assuming that banks are fully-diversified across borrowers and operate in perfectly competitive markets, the participation constraint for bank retail branches is always binding and writes as:

$$\mathbb{E} \left\{ (1 + r_{j,t}^{bI}) (1 - F_t^I(\bar{\xi}_{j,t+1}^I)) \frac{b_{j,t}^I}{\pi_{t+1}} + (1 - \mu^I) \Phi_t^I S_t^I(\bar{\xi}_{j,t+1}^I) q_{t+1}^h h_{j,t}^I \right\} \geq \mathbb{E} \left\{ (1 + R_{t+1}^{bI}) \frac{b_{j,t}^I}{\pi_{t+1}} \right\}, \quad (2.6)$$

where R_t^{bI} corresponds to the funding rate for commercial branches providing loans to

households. The description of the banking sector is postponed after the description of entrepreneurs.

Entrepreneurs

Entrepreneurs are modeled as in Bernanke, Gertler, and Gilchrist (1999). At the end of period t , each entrepreneur j (superscript E) receives a loan $b_{j,t+1}^E$ from banks which is combined with her net worth $n_{j,t}^E$ to purchase raw capital $k_{j,t+1}^E$ from competitive capital goods producers at price q_t^k :

$$q_t^k k_{j,t+1}^E = n_{j,t}^E + b_{j,t+1}^E.$$

After having purchased capital, each entrepreneur is subject to an idiosyncratic shock $\xi_{j,t}^E$, which converts her raw capital $k_{j,t+1}^E$ into efficiency units $\xi_{j,t+1}^E k_{j,t+1}^E$. As for impatient households, ξ^E is assumed to be a unit-mean lognormal random variable distributed independently over time and across entrepreneurs, where σ_t^E is the standard deviation of $\log \xi_t^E$ and follows an exogenous $AR(1)$ process.⁷ After observing period $t + 1$ aggregate rates of return and prices, each entrepreneur chooses her capital utilization rate $u_{j,t+1}$ and rents out capital services $u_{j,t+1} \xi_{j,t+1}^E k_{j,t+1}^E$ to firms at rental rate $r_{j,t+1}^k$. After production is realized, entrepreneurs sell back their depreciated capital to households at price q_{t+1}^k . Entrepreneur rate of return defines as:

$$1 + R_{j,t+1}^k = \frac{(1 - \tau^k)[u_{j,t+1} r_{j,t+1}^k - \psi(u_{j,t+1})] + (1 - \delta^k)q_{t+1}^k + \delta^k \tau^k q_t^k}{q_t^k},$$

where $\psi(\cdot)$ is an increasing and convex function utilization adjustment cost function, defined below and τ^k denotes the tax rate on capital income where capital can be deducted at historical cost. The default threshold $\bar{\xi}_{j,t+1}^E$ of an entrepreneur j is:

$$\bar{\xi}_{j,t}^E = \frac{(1 + r_{j,t-1}^{bE}) b_{j,t-1}^E / \pi_t}{(1 + R_{j,t}^k) \Phi_{t-1}^E q_{t-1}^k k_{j,t-1}^E},$$

where $r_{j,t}^{bE}$ is the net nominal interest rate paid by entrepreneur j on her debt. This rate is predetermined in period t , and therefore not contingent on period $t + 1$ state. If an entrepreneur draws $\xi_{j,t+1}^E < \bar{\xi}_{j,t+1}^E$, she becomes bankrupt in which case her pledged assets

⁷This shock corresponds to the risk shock studied by Christiano, Motto, and Rostagno (2014).

are seized by the banks. The problem of an entrepreneur is to maximize expected pre-dividend net worth defined as:

$$E_t \left\{ \int_{\bar{\xi}_{j,t+1}^E}^{\infty} \left[(1 + R_{j,t+1}^k) \xi^E q_t^k k_{j,t}^E - (1 + r_t^{bE}) \frac{b_{j,t}^E}{\pi_t} \right] dF(\xi^E) \right\} = E_t [1 - \Gamma_{t+1}(\bar{\xi}_{j,t+1}^E)] (1 + R_{t+1}^k) L_{j,t}^E n_{j,t}^E,$$

subject to a bank participation constraint which is defined below. Here, L_t^E denotes the entrepreneurial leverage such that:

$$L_{j,t}^E \equiv \frac{q_t^k k_{j,t}^E}{n_{j,t}^E},$$

and $\Gamma_{t+1}(\bar{\xi}_{j,t+1}^E)$ is the expected gross share in pledged assets' earnings going to banks and defined as:

$$\Gamma_t(\bar{\xi}_{j,t+1}^E) \equiv [1 - F_t^E(\bar{\xi}_{j,t+1}^E)] \bar{\xi}_{j,t+1}^E + G_t(\bar{\xi}_{j,t+1}^E), \text{ with } G_t(\bar{\xi}_{j,t+1}^E) = \int_0^{\bar{\xi}_{j,t+1}^E} \xi^E dF_t^E(\xi^E).$$

Here $1 - F_t^E(\bar{\xi}_{j,t+1}^E)$ denotes the share of entrepreneurs who repay their debt and $G_t(\bar{\xi}_{j,t+1}^E)$ corresponds to the monitoring returns seized from defaulting entrepreneurs. Thus, $1 - \Gamma_t(\bar{\xi}_{j,t+1}^E)$ is the share of earnings that entrepreneurs keep to themselves. Finally, entrepreneurs are required to pay exogenously determined dividends δ_t^E to patient households at the end of each period in exchange for perfect consumption insurance. This is to ensure that they never accumulate enough net worth to the point where they stop relying on banks for funding. Entrepreneurial net worth writes:

$$n_{j,t}^E = [1 - \Gamma_t(\bar{\xi}_{j,t}^E)] (1 + R_t^k) q_{t-1}^k k_{j,t-1}^E - \delta_t^E n_{j,t-1}^E.$$

As for impatient households, net worth maximization by entrepreneurs is subject to a bank participation constraint:

$$\mathbb{E} \left\{ (1 + r_{j,t}^{bE}) (1 - F_{t+1}^E(\bar{\xi}_{j,t+1}^E)) \frac{b_{j,t}^E}{\pi_{t+1}} + (1 - \mu^E) \Phi_t^E (1 + R_{j,t+1}^k) S_{t+1}^E(\bar{\xi}_{j,t+1}^E) q_t^k k_{j,t}^E \right\} \geq \mathbb{E} \left\{ (1 + R_{t+1}^{bE}) \frac{b_{j,t}^E}{\pi_{t+1}} \right\}, \quad (2.7)$$

where Φ_{t-1}^E is the loan-to-value ratio for corporate loans set by the regulator or by the mar-

ket and R_t^{bE} is the funding rate for commercial branches providing loans to entrepreneurs.

Credit and Deposit Demands

The three types of agents interact differently with the monopolistically competitive financial intermediaries. Namely, each bank has a certain degree of market power and is able to differentiate customers depending on their type. Assuming a Dixit-Stiglitz structure for the credit market, ε^d , ε^{bI} , and ε^{bE} , correspond to the elasticities of substitution for the different types of loan respectively for patient households, impatient households and entrepreneurs. Individual demands for loans to households $b_{j,t}^I$, loans to entrepreneurs $b_{j,t}^E$ and deposits $d_{j,t}$, hinge on overall credit and deposit volumes and on individual prices charged by banks relative to their aggregate counterparts:

$$b_{j,t}^I = \left(\frac{R_{j,t}^{bI}}{R_t^{bI}} \right)^{-\varepsilon^{bI}} b_t^I, \quad b_{j,t}^E = \left(\frac{R_{j,t}^{bE}}{R_t^{bE}} \right)^{-\varepsilon^{bE}} b_t^E,$$

$$d_{j,t} = \left(\frac{R_{j,t}^d}{R_t^d} \right)^{-\varepsilon^d} d_t. \quad (2.8)$$

The next subsection details the structure of the banking sector which combines deposits from patient households with bank equity to provide collateralized loans to impatient households and entrepreneurs.

B. Banking Sector

The structure of the banking system follows the one described in Pariès, Sørensen, and Rodriguez-Palenzuela (2011). There is a continuum of identical bank holdings of type $j \in [0, 1]$, constituted of three branches each.⁸ Each perfectly competitive bank holding distributes loans and gets funds using deposits d_t from patient households and by issuing bank equity n_t^B . The balance-sheet constraint for a wholesale branch writes:

$$b_t^I + b_t^E = d_t + n_t^B. \quad (2.9)$$

⁸As the equilibrium will be symmetric, the j index is dropped for notational convenience when there is no ambiguity.

Each of the two other types of branch, the deposit and loan branches, are divided into two units which operate under monopolistic competition and set interest rates for deposits and loans according to the elasticities of substitution ε^d , ε^{bI} and ε^{bE} .

Wholesale Branch

The wholesale branch operates as a link between the different retail branches and combines bank capital and deposits to issue loans. Bank equity capital is sluggish in that bank capital n_t^B accumulates only through retained earnings as implied by:

$$n_t^B = (1 - \delta^B) \frac{n_{t-1}^B}{\pi_t} + \frac{J_{t-1}^B}{\pi_t} + \Lambda_t^{bI} + \Lambda_t^{bE}. \quad (2.10)$$

The parameter δ^B corresponds to the fraction of equity paid as dividends by the bank to patient households and J_t^B corresponds to the consolidated profits of the bank. Variables Λ_t^{bI} and Λ_t^{bE} are possible losses endured by the commercial household and firm loan units. As in Angelini, Neri, and Panetta (2014), the parameter δ^B can be interpreted as a fixed cost for managing equity or dividends and prevents capital from growing without bound while allowing for strictly positive steady-state profits. While this structure captures the slow-movement of bank equity capital in the data, it is important to note it also rules out other options for recapitalization that may be available to the bank. The absence of other sources of equity financing most likely overstates the sluggishness of bank equity capital. I also consider the presence of a target bank leverage requirement ν_t resulting from market discipline or regulatory constraint. Discussion of this instrument is postponed to subsection 6.3. A wholesale banking branch chooses d_t and B_t , the overall loan volume, so as to maximize its sum of future cash flows:

$$\begin{aligned} \max_{\{B_t, d_t\}} \mathbb{E}_0 \sum_{s=0}^{\infty} \lambda_{t+s}^P & \left[(1 + R_{t+s}^b) B_{t+s} - B_{t+1+s} + d_{t+1+s} - (1 + R_{t+s}^d) d_{t+s} + \Delta n_{t+1+s}^B \right. \\ & \left. - \frac{\kappa^B}{2} \left(\frac{n_{t+s}^B}{B_{t+s}} - \nu_{t+s} \right)^2 n_{t+s}^B \right], \\ \text{s.t. } B_t &= d_t + n_t^B, \end{aligned} \quad (2.11)$$

where both the net wholesale loan rate R_t^b , and the net wholesale deposit rate R_t^d are taken as given and λ_t^P is the marginal value of non-housing consumption for patient households.

Bank capital position.—The first order conditions for the wholesale branch give the following relation between its funding costs and the price it sets for loans:

$$R_t^b = R_t^d - \theta^B \left(\frac{n_t^B}{B_t} - \nu_t \right) \left(\frac{n_t^B}{B_t} \right)^2. \quad (2.12)$$

As an unlimited source of finance is assumed for a given monetary policy rate R_t , the wholesale deposit rate R_t^d is pinned down in the interbank market such that $R_t^d = R_t$. Using (14), the wholesale spread S_t^w is defined as:

$$S_t^w \equiv R_t^b - R_t = -\theta^B \left(\frac{n_t^B}{B_t} - \nu_t \right) \left(\frac{n_t^B}{B_t} \right)^2. \quad (2.13)$$

As a result, the wholesale branch chooses its capital-to-asset ratio and distance from the regulatory requirement only relative to the difference between R_t^b the rate paid by loan branches for one unit of loan and R_t the rate paid to the deposit branch for one unit of deposit. The interest rate spread is the key variable which drives wholesale banks' decision to tighten lending conditions in case it fails to satisfy leverage requirements. In the estimation, a constant capital target ν is assumed. This assumption is relaxed when studying the implications of a counter-cyclical capital buffer at the ZLB in section VI.

Loan Branches

Loan branches are modeled in two parts. Retail units get funds from their wholesale branch and resell funds to commercial loan units. The model assumes a continuum $j \in [0, 1]$ of retail units operating under monopolistic competition. Each unit decides its lending rate for entrepreneurs $R_{j,t}^{bE}$ or for impatient households $R_{j,t}^{bI}$, subject to rigidity à la Calvo (1983). A unit j of type $s \in \{I, E\}$ maximizes the discounted sum of its

expected profits subject to the following demand schedules:

$$\begin{aligned} \max_{\{R_{j,t}^{bS}\}} \mathbb{E}_0 \sum_{s=0}^{\infty} (\beta_P \xi^{bS})^{t+s} \lambda_{t+s}^P [(1 + R_{j,t}^{bS}) b_{j,t+s}^S - (1 + R_t^b) b_{j,t+s}^S], \\ \text{s.t. } b_{j,t+s}^S = \left(\frac{R_{j,t+s}^{bS}}{R_{t+s}^{bS}} \right)^{-\varepsilon^{bS}} b_{t+s}^S. \end{aligned}$$

Analogously to Calvo staggered contracts for prices, $1 - \xi^{bS}$ corresponds to the fraction of retail banks able to reset their price each period. Funds are then sold to commercial loan units that operate on competitive markets and provide secured loans to defaulting borrowers. Each period, commercial loan units recover non-defaulting loans and the proceeds from selling the collateral of non-repaying borrowers. A fraction μ^S of the value of the collateral is lost in bankruptcy proceedings and seizure costs, such that the loan branches ultimately recover a fraction $1 - \mu^S$ of the pledged assets.

Because retail loan rates r_t^{bE} and r_t^{bI} are non-contingent, both types of loan commercial units endure losses or gains depending on the realizations of aggregate shocks. Defining Λ_t^{bI} and Λ_t^{bE} respectively as the losses for the household commercial unit and for the entrepreneur commercial unit and aggregating across all branches yields:

$$\Lambda_t^{bI} \equiv [(1 + r_{t-1}^{bI})(1 - F_{t-1}^I(\bar{\xi}_t^I)) - (1 + R_t^{bI})] \frac{b_{t-1}^I}{\pi_t} + (1 - \mu^I) \Phi_{t-1}^I S_{t-1}^I(\bar{\xi}_t^I) q_t^h h_{t-1}^I,$$

$$\Lambda_t^{bE} \equiv [(1 + r_{t-1}^{bE})(1 - F_{t-1}^E(\bar{\xi}_t^E)) - (1 + R_t^{bE})] \frac{b_{t-1}^E}{\pi_t} + (1 - \mu^E) \Phi_{t-1}^E S_{t-1}^E(\bar{\xi}_t^E) (1 + R_t^k) q_{t-1}^k k_{t-1}^E.$$

The losses of the branches are passed on banks profits J_t^B .

Deposit Branches

As for loan branches, there is a continuum $j \in [0, 1]$ of deposit branches that collect deposits $d_{j,t}$ from households at a rate $R_{j,t}^d$ and sell them to their wholesale branch at a rate R_t . Only a fraction $1 - \xi^{bP}$ of branches are able to adjust interest rates each period. Deposit

branches solve the following program:

$$\begin{aligned} \max_{\{R_{j,t}^d\}} \mathbb{E}_0 \sum_{s=0}^{\infty} (\beta_p \xi^{bP})^{t+s} \lambda_{t+s}^P [(1 + R_t) d_{j,t+s} - (1 + R_{j,t+s}^d) d_{j,t+s}], \\ \text{s.t. } d_{j,t+s} = \left(\frac{R_{j,t+s}^d}{R_{t+s}^d} \right)^{-\varepsilon_{t+s}^d} d_{t+s}, \end{aligned}$$

subject to the deposit demand schedule in equation (2.8). Note that without Calvo rigidity, the bank pricing equations boil down to:

$$\begin{aligned} R_t^{bI} &= \frac{\varepsilon_t^{bI}}{\varepsilon_t^{bI} - 1} R_t^b, \\ R_t^{bE} &= \frac{\varepsilon_t^{bE}}{\varepsilon_t^{bE} - 1} R_t^b, \\ R_t^d &= \frac{\varepsilon_t^d}{\varepsilon_t^d - 1} R_t. \end{aligned}$$

In this setup interest rates on loans and deposits are simply set as markups over the marginal cost. Finally, the consolidated real profits of banks J_t^B are defined as the sum of net earnings from the retail branches and the wholesale branch and strictly positive at the steady state to ensure banks' participation.

C. Rest of the economy

Final Good Producers.—Perfectly competitive final good firms produce a final consumption good Y_t by combining a continuum of intermediate goods $Y_{j,t}$ according to the following Dixit-Stiglitz technology:

$$Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_{f,t}}} dj \right]^{\lambda_{f,t}},$$

where $\lambda_{f,t} \geq 1$ is an exogenous price markup shock.

Intermediate Good Producers.—A monopolistic producer builds intermediate good j according to the production function:

$$Y_{j,t} = \max \{ \varepsilon_t^a (u_t k_{j,t-1}^E)^\alpha (l_{j,t})^{1-\alpha} - \bar{\Phi}; 0 \},$$

where α is the capital income share, $k_{j,t-1}^E$ corresponds to capital services, $l_{j,t}$ is an homogeneous labor input, u_t is the utilization rate of capital, and ε_t^a is defined as a stationary technology shock. As in Christiano, Motto, and Rostagno (2014), intermediate good producer profits are set to zero at the steady-state by assuming a fixed cost for production $\bar{\Phi}$. The intermediate good producer faces standard Calvo frictions. Each period, a fraction $1 - \xi_p$ of intermediate firms can set their price $P_{j,t}$ optimally. The remaining fraction follows the indexation rule:

$$P_{j,t} = (\pi)^{\iota_p} (\pi_{t-1})^{1-\iota_p} P_{j,t-1},$$

where ι_p with $0 < \iota_p < 1$ is an indexation parameter, $\pi_{t-1} = P_{t-1}/P_{t-2}$ is inflation, P_t is the price of the final good Y_t , and π is the steady-state rate of inflation.

Labor Contractors.—There exists two types of labor, one type for each type of household $s \in \{P, I\}$. Perfectly competitive labor contractors combine specialized labor services $h_{i,t}^s$ into homogeneous labor l_t^s sold to intermediate firms using the following technology:

$$l_t^s = \left[\int_0^1 h_{i,t}^s \frac{1}{\lambda_w} di \right]^{\lambda_w},$$

where $\lambda_w \geq 1$ is a wage markup that does not depend on the labor type.

Monopoly Unions.—For each type s of household, unions represent workers by type i and optimally set their wage rate $W_{i,t}^s$. As in Erceg, Henderson, and Levin (1999), unions are subject to Calvo frictions in a similar fashion to intermediate firms. Each period a fraction $1 - \xi_w$ of monopoly unions can adjust wage to their optimal wage. The remaining fraction follows the following indexation rule:

$$W_{i,t}^s = (\pi)^{\iota_w} (\pi_{t-1})^{1-\iota_w} W_{i,t-1}^s,$$

where ι_w is an indexation parameter with $0 < \iota_w < 1$.

Labor Packers.—Labor packers combine the two types of labor into an homogeneous labor input l_t sold in competitive markets to the intermediate good producers. Aggregation of

different labor types is made through a Cobb-Douglas function:

$$l_t = (l_t^P)^\kappa (l_t^I)^{1-\kappa},$$

where parameter κ corresponds to the steady-state income share of patient households.

Central bank.—Monetary policy is introduced via a standard Taylor rule which sets the interest rate R_t on the interbank market:

$$1 + R_t = (1 + R)^{(1-\phi_r)} (1 + R_{t-1})^{\phi_r} \left(\frac{E\pi_{t+1}}{\pi} \right)^{\phi_\pi(1-\phi_r)} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y(1-\phi_r)} \exp(\epsilon_t^m), \quad (2.14)$$

where ϵ_t^m is a Gaussian white noise corresponding to monetary policy shocks and ϕ_r is a smoothing parameter in the policy rule. In addition ϕ_π and ϕ_y are the Taylor rule coefficients for the quarterly rate of expected inflation and for the quarterly GDP growth.

Capital goods producers.—Capital goods producers buy the depreciated capital left after production and replenish capital units by investing I_t^k , transforming final goods into new productive capital sold back to entrepreneurs at the end of the period. They operate in competitive markets and are subject to adjustment costs. The intertemporal problem of capital goods producers is to maximize their sum of profits discounted using patient household discount factor:

$$\max_{\{q_t^k, I_t^k\}} \mathbb{E}_0 \sum_{s=0}^{\infty} \lambda_{t+s}^P [q_{t+s}^k k_{t+s}^E - q_{t+s}^k (1 - \delta^k) k_{t-1+s}^E - I_{t+s}^k], \quad (2.15)$$

and subject to the following production technology:

$$k_t^E = (1 - \delta^k) k_{t-1}^E + \left[1 + S_k \left(\varepsilon_t^{ik} \frac{I_t^k}{I_{t-1}^k} \right) \right] I_t^k, \quad (2.16)$$

where ε_t^{ik} is an exogenous disturbance to capital goods production. The adjustment costs function for capital investment writes:

$$S_k \left(\varepsilon_t^{ik} \frac{I_t^k}{I_{t-1}^k} \right) = \exp \left(\sqrt{S_k''/2} (\varepsilon_t^{ik} \frac{I_t^k}{I_{t-1}^k} - 1) \right) + \exp \left(-\sqrt{S_k''/2} (\varepsilon_t^{ik} \frac{I_t^k}{I_{t-1}^k} - 1) \right) - 2. \quad (2.17)$$

The utilization cost function is defined as in Christiano, Motto, and Rostagno (2014):

$$\psi(u_t) = r^k \frac{\exp(\sigma^a(u_t - 1)) - 1}{\sigma^a},$$

where r^k is the steady-state level for capital returns and σ^a is a parameter defining the curvature of the utilization cost function. The adjustment cost function for impatient housing is defined as:

$$S_h(\varepsilon_t^h h_t^I / h_{t-1}^I) = \exp\left(\sqrt{S_h''/2}(\varepsilon_t^h h_t^I / h_{t-1}^I - 1)\right) + \exp\left(-\sqrt{S_h''/2}(\varepsilon_t^h h_t^I / h_{t-1}^I - 1)\right) - 2. \quad (2.18)$$

Market clearing.—The markets for labor, credit, housing and consumption goods clear. Output is consumed, invested, or lost in monitoring activity. It follows that the aggregate budget constraint of the economy is:

$$y_t = c_t + I_t^k + g_t + \psi_t k_{t-1}^E(u_t) + C_t^b,$$

where C_t^b corresponds to losses from monitoring costs defined as:

$$C_t^b = \mu^E \Phi_{t-1}^E q_{t-1}^k (1 + R_t^k) S_t^E k_t^E + \mu^I \Phi_{t-1}^I q_t^h S_t^I h_t^I,$$

and c_t is the aggregate consumption, $c_t = c_t^P + c_t^I$. Finally, g_t denotes government consumption which is assumed to follow a stationary stochastic process.

Shock Processes.—I summarize here the exogenous variables considered in the model and used to match the data. The model embeds a preference shock on consumption goods ζ_t^c , a preference shock on housing goods ζ_t^h , a shock to the marginal efficiency of investment ε_t^{Ik} , a technology shock ε_t^a , a price markup shock λ_t^f and a government consumption shock g_t . To capture the evolution of credit conditions not specific to the borrower types, I follow Bécard and Gauthier (2018) and consider the possibility of common shifts in leverage ratios Φ_t^I and Φ_t^E labeled as collateral shocks. A collateral shock corresponds to a change in the pledgeability of both housing and capital goods. It is modeled by simply assuming that the two loan-to-value ratios share a common $AR(1)$ process. The model also embeds specific risk shocks σ_t^I and σ_t^E which modify the dispersion of idiosyncratic productivity

for entrepreneurs and impatient households respectively. Similar to Christiano, Motto, and Rostagno (2014), an equity shock δ_t^E exogenously shifts the value of entrepreneurs equity. All the exogenous variables follow $AR(1)$ processes. Hence, for a generic process x_t :

$$x_t = \rho_x x_{t-1} + \epsilon_t^x \text{ where, } \epsilon_t^x \sim N(0, \sigma_x^2).$$

Innovations to the monetary policy rule ϵ_t^m are modeled as Gaussian white noises with variance σ_m^2 .

IV. Model Solution and Parametrization

A linear approximation of the policy functions around the steady state is used to characterize the likelihood. The model is estimated using Bayesian techniques.⁹

A. Data

The model is estimated with 12 quarterly time series for France over the period 2003 to 2017. The dataset includes quarterly growth rates for GDP, consumption, and investment. For the different price series, I use the GDP deflator, the residential real house price index, and a labor cost index.¹⁰ Financial series are the interest rate series for corporate loans, household loans, and deposits, as well as the quarterly growth rates for outstanding corporate loans and household loans. Deposits are defined as the sum of overnight deposits, deposits redeemable at notice and deposits with an agreed maturity up to two years. The interest rate for deposits corresponds to a weighted average of the interest rates for each of these products. I take the 6 months Euribor as a measure of the interbank market rate. The series used for the estimation are expressed in first difference - except for lending rates, and demeaned. The data used in the estimation are displayed in figure 2.2.

⁹Given the size of the model, I do not explore a global solution method and stick to the more common local approach as in Angelini, Neri, and Panetta (2014), Gerali, Neri, Sessa, and Signoretti (2010), and Iacoviello (2005). See Lopez (2015) for a global solution of a stripped-down general equilibrium model with a banking structure.

¹⁰The housing price series corresponds to the price index of second-hand dwellings for metropolitan France and the labor cost series is the wage index.

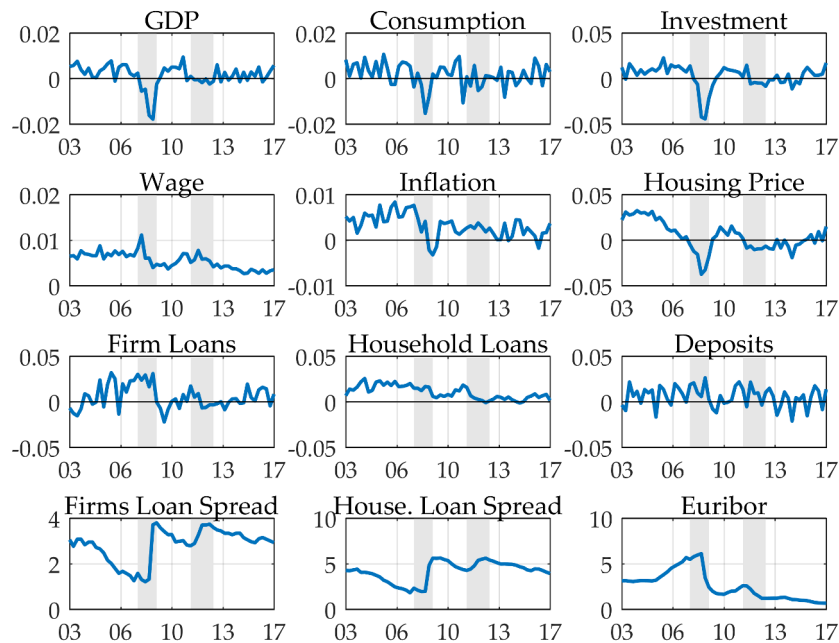


Figure 2.2: Estimation Data Set.

Note: All series are expressed in quarterly growth rates, except for spreads and the Euribor rate which are annualized. Spreads are expressed in basis points. Series are deflated using the GDP deflator.

B. Calibrated Parameters

There are 62 parameters in the model, 46 are estimated. This section presents the calibrated parameters. The discount factor for patient households β_P is set to 0.997, to calibrate the annualized steady-state interest rate r_d close to the average rate for deposits observed for France. The impatient discount rate is set to 0.9875, in the range used by Iacoviello and Neri (2010) and in order to match the household loan-to-value ratio Φ^I from the model to the one inferred by Calza, Monacelli, and Stracca (2009) for France at 0.70. Parameter α and the capital depreciation rate δ^k are set respectively to 0.30 and 0.025 to match the average labor income share and the investment-to-output ratio in France over the estimation period. Values for price and labor-elasticities ε^y and ε^l are set to 5 and 6 to target a markup of 20 percent in the good market and a markup of 15 percent in the labor

market, similar to the values used in Gerali, Neri, Sessa, and Signoretti (2010).¹¹ The loan-to-value ratio for constrained entrepreneurs is set to 0.5, what corresponds to the average ratio of loan-over-equity for the non-financial corporate sector observed over the estimation period. Taxation rates τ^l , τ^c and τ^k are set in order to match the investment-to-GDP and the consumption-to-GDP ratios to their observed counterparts. Finally, I calibrate η_g , the steady-state value of government-spending over GDP, to match the share of GDP neither invested or consumed at 0.23. Parameters related to the banking sector are cali-

Parameters	Description	Value
β_P	Patient households' discount factor	0.997
β_I	Impatient households' discount factor	0.987
ϕ	Inverse Frisch elasticity	1
τ^c	Taxation on consumption purchase	0.3
τ^l	Taxation on wage rate	0.25
τ^k	Taxation on capital rental rate	0.05
Φ^I	Households' LTV ratio	0.7
Φ^E	Entrepreneurs' LTV ratio	0.5
α	Capital income share	0.3
δ^k	Depreciation rate of physical capital	0.025
δ^E	Dividend rate for entrepreneurs	0.0109
δ^B	Dividend rate for banks	0.015
π	Steady-state inflation rate	1
r	Steady-state interest rate (Annualized)	1.56
$\frac{\varepsilon^y}{\varepsilon^y - 1}$	Steady-state markup in the goods market	1.25
$\frac{\varepsilon^l}{\varepsilon^l - 1}$	Steady-state markup in the labor market	1.2
$\frac{\varepsilon^{bI}}{\varepsilon^{bI} - 1}$	Steady state markup on rate on loans to households	2.73
$\frac{\varepsilon^{bE}}{\varepsilon^{bE} - 1}$	Steady state markup on rate on loans to firms	1.55
$\frac{\varepsilon^d}{\varepsilon^d - 1}$	Steady state markdown on deposit rate	1.2

Table 2.1: Calibrated Parameters

brated to match stylized facts from the financial series in the dataset. To do so I compute the quarterly average spreads using interest rates for loans to firms and households, rates for deposits and the Euribor. Since the steady-state equations give a direct relationship between interest rates and the elasticities of substitution for the different types of loan, I set accordingly ε^d , ε^{bI} and ε^{bE} to match the average observed spreads. Finally, dividends

¹¹The markup in the good sector for France lies within European average close to 20 percent, between Finland and Italy (see Trésor-Economics n°27 – January 2008 for more details).

δ^E and δ^B are calibrated respectively to 0.01 and 0.0145 to match a steady-state share of entrepreneur loans over total loans to 0.56 and a deposits-to-GDP ratio to 0.4. Table 2.1 lists the values of the calibrated parameters. The rest of the parameters are estimated.

Variable	Description	Model	Data
c/y	Consumption to GDP ratio	0.56	0.547
i/y	Investment to GDP ratio	0.21	0.219
g/y	Government spending to GDP ratio	0.23	0.234
$b^I/(4y)$	Household loans to annual GDP ratio	0.53	0.47
$b^E/(4y)$	Firms loans to annual GDP ratio	0.2	0.361
b^I/b	Household debt to total debt ratio	0.72	0.563
$d/(4y)$	Bank deposits to annual GDP ratio	0.35	0.395
R	Euribor (APR)	1.6	1.59
L^B	Bank leverage	1.9	1.92
Spr^E	Spread Entrepreneur	1.9	1.83
Spr^I	Spread Impatient	3.2	3.2

Notes: All data values are computed as the sample average over the period 2003Q1–2016Q4. Model values are computed for the parameters evaluated at their posterior mode.

Table 2.2: Steady-State Properties, Model Versus Data

C. Estimated Parameters

Prior densities for the estimated parameters are summarized in table 3.6 along with the modes and confidence intervals obtained from the estimation procedure. Most of the estimated parameters are standard in the literature and are assigned prior densities corresponding to those used in the DSGE literature.¹² These include the Taylor rule coefficients, ϕ_π , ϕ_π , and ρ_p , the Calvo price and wage stickiness parameters, ξ_p and ξ_w , the price and wage indexation coefficients, ι_p , and ι_w , and the curvature parameters for utilization and investment, σ_a and S_k'' .

The model also includes less usual parameters as the ones characterizing household debt contracts and the housing adjustment cost function. The curvature for housing adjustment costs S_h'' is important to smooth the dynamics of housing and debt for impatient households. Parameters characterizing the investment and housing adjustment cost curvatures evolve in opposite directions relative to their prior means. For most of the param-

¹²See for instance Smets and Wouters (2007), Gerali, Neri, Sessa, and Signoretti (2010), Justiniano, Primiceri, and Tambalotti (2011), and Christiano, Motto, and Rostagno (2014) for similar estimation procedures.

Param.	Description	Prior			Posterior		
		Dist.	Mean	SD	Mode	5%	95%
κ	Share of patient in total labor	beta	0.5	0.15	0.169	0.0637	0.265
a^P	Consumption habit patient	beta	0.65	0.1	0.457	0.295	0.646
a^I	Consumption habit impatient	beta	0.65	0.1	0.569	0.399	0.695
F^I	Probability of default impatient	beta	0.008	0.005	0.00627	0.00495	0.00875
F^E	Probability of default entrepreneur	beta	0.008	0.005	0.00885	0.00702	0.0118
μ^I	Monitoring cost impatient	beta	0.4	0.1	0.0759	0.055	0.149
μ^E	Monitoring cost entrepreneur	beta	0.4	0.1	0.121	0.0869	0.22
ψ_h^I	Impatient housing weight in utility	beta	0.3	0.1	0.107	0.0664	0.216
ψ_h^P	Patient housing weight in utility	beta	0.3	0.1	0.269	0.12	0.448
ξ^{bE}	Calvo entrepreneur rate stickiness	beta	0.3	0.2	0.757	0.678	0.799
ξ^{bI}	Calvo household rate stickiness	beta	0.3	0.2	0.9	0.881	0.909
ξ^{bP}	Calvo deposit rate stickiness	beta	0.3	0.2	0.946	0.908	0.963
ξ_p	Calvo price stickiness	beta	0.5	0.1	0.905	0.891	0.932
ξ_w	Calvo wage stickiness	beta	0.6	0.1	0.779	0.7	0.853
S_k''	Investment adjust. cost curvature	normal	4	2	2.26	2.26	4.95
S_h''	Housing adjust. cost curvature	normal	4	2	9.87	7.23	12.3
ϕ_π	Taylor rule inflation coefficient	gamma	2.5	0.5	3.23	2.71	4.18
ϕ_y	Taylor rule output coefficient	normal	0.4	0.1	0.365	0.203	0.54
ρ_p	Taylor rule smoothing	beta	0.75	0.1	0.779	0.729	0.833
ι_p	Price indexation on inflation target	beta	0.5	0.15	0.882	0.685	0.976
ι_w	Wage indexation on inflation target	beta	0.5	0.15	0.447	0.235	0.705
σ_a	Utilization cost curvature	normal	1	0.25	0.772	0.316	0.993
θ^B	Bank penalty coefficient	gamma	0.3	0.2	0.174	0.0261	0.165

Table 2.3: Estimated Parameters

eters, the posterior modes obtained are in line with results from Gerali, Neri, Sessa, and Signoretti (2010) and Christiano, Motto, and Rostagno (2014). A noticeable exception is the high level of price stickiness at 0.90, implying a mean duration for price adjustment of 10 quarters. Nonetheless, price rigidity is attenuated by the high level of price indexation with a ι_p at 0.88. Parameter S_k'' to 2.26 is also smaller than the value at 7 found in Smets and Wouters (2003). The mode for S_h'' on the other hand rises to 9.87. A high S_h'' reduces the possibility for impatient households to smooth consumption and increases the impact of financial shocks on consumption. The two monitoring cost parameters, μ^I and μ^E , are assigned prior means at 0.4 as is standard in the literature. Monitoring cost parameter values decrease sharply relative to their prior mean, to 0.08 for households and to 0.12 for entrepreneurs. This implies lower leverages for both types of borrower what limits the impact of financial shocks on loans. Next, the steady-state probability of household

default $F^I(\bar{\xi}^I)$ and entrepreneurial default $F^E(\bar{\xi}^E)$ are set to obtain annualized rate of default at 3 percent, close to the share of non-performing loans observed over the estimation period for France. Estimated values for default rates increase for firms and decrease for households relative to their prior specifications. Parameter κ corresponds to the share of non credit-constrained agents in labor income. Its prior mean is set to 0.5 following Iacoviello and Neri (2010). The posterior mode for this parameter falls to 0.17, implying a large share of credit-constraint households. A higher value is found by Darracq Pariès and Notarpietro (2008) and Iacoviello and Neri (2010). As impatient households are more sensitive to financial shocks than patient households, a low κ implies a tighter link between households borrowing and consumption, allowing to replicate the strong correlation between the two series. The housing weights for impatient and patient utilities ψ_h^I and ψ_h^P are assigned prior means at 0.30, in order to target a steady-state share of household debt in total debt of approximately two thirds. The posterior mode for the housing weight parameter in patient utility ψ_h^P stays relatively close to the value of its prior mean. The posterior mode for the housing weight in impatient utility ψ_h^I falls to 0.11 implying smaller weight on housing in the utility function of impatient households relative to the prior mean. Overall, much of the estimated parameters that characterize the financial friction for households are in line with results from Bécard and Gauthier (2018) who use US data to estimate a model with impatient households. The bank penalty coefficient θ^B is assigned a prior similar to the one in Gerali, Neri, Sessa, and Signoretti (2010) taking into account the different definitions of bank leverage. The prior distributions for bank rate stickiness parameters, ξ^{bE} , ξ^{bI} and ξ^{bP} , come from Pariès, Sørensen, and Rodriguez-Palenzuela (2011) which are characterized by a large dispersion. The posterior modes for ξ^{bE} and ξ^{bI} at 0.75 and 0.9 imply high stickiness for loan rates and weak monetary pass-through. The posterior mode for ξ^{bP} is at 0.94. A large ξ^{bP} implies delayed responses in deposits volumes and rates following changes in the policy rate. An important feature of the Great Recession in France is the fact that the fall in loans has been delayed compared to the sharp increase in spreads and the fall in consumption and investment. In this model, high levels of interest rate stickiness allow to generate a delay between the responses in loan volumes and the responses in spreads, consumption and investment, following a decrease in the policy rate.

Table 2.4 displays the estimation results for the different shock processes. Few shocks

Param.	Description	Prior			Posterior		
		Dist.	Mean	SD	Mode	5%	95%
ρ_{ζ_c}	Autocorr. consumption preference	beta	0.5	0.5	0.318	0.0988	0.532
ρ_a	Autocorr. technology	beta	0.5	0.5	0.0533	0.0111	0.134
ρ_{ζ_h}	Autocorr. housing preference	beta	0.5	0.5	0.5	0.157	0.804
ρ_y	Autocorr. price markup	beta	0.5	0.5	0.504	0.461	0.948
ρ_l	Autocorr. wage markup	beta	0.5	0.5	0.501	0.255	0.957
ρ_{ik}	Autocorr. MEI	beta	0.5	0.5	0.829	0.234	0.511
ρ_{σ^I}	Autocorr. household risk	beta	0.5	0.5	0.498	0.205	0.847
ρ_{σ^E}	Autocorr. entrepreneur risk	beta	0.5	0.5	0.989	0.966	0.996
ρ_{Φ}	Autocorr. common risk	beta	0.5	0.5	0.936	0.929	0.98
ρ_g	Autocorr. government spendings	beta	0.5	0.5	0.993	0.981	0.998
ρ_{δ^e}	Autocorr. dividends	beta	0.5	0.5	0.585	0.425	0.753
σ_{ζ_c}	SD consumption preference	inv2	0.0023	0.0033	0.00737	0.00495	0.00937
σ_a	SD technology	inv2	0.0023	0.0033	0.0164	0.01	0.0222
σ_{ζ_h}	SD housing preference	inv2	0.0023	0.0033	0.00223	0.000396	0.00598
σ_y	SD price markup	inv2	0.0023	0.0033	0.00745	0.000562	0.0112
σ_l	SD wage markup	inv2	0.0023	0.0033	0.00669	0.000419	0.0174
σ_{ik}	SD MEI	inv2	0.0023	0.0033	0.00733	0.00567	0.00907
σ_{σ^I}	SD household risk	inv2	0.0023	0.0033	0.00747	0.00535	0.00953
σ_{σ^E}	SD entrepreneur risk	inv2	0.0023	0.0033	0.00196	0.000437	0.00376
σ_{Φ}	SD common risk	inv2	0.0023	0.0033	0.0696	0.0422	0.0964
σ_m	SD monetary policy	inv2	0.0023	0.0033	0.000786	0.000639	0.000936
σ_g	SD government spendings	inv2	0.0023	0.0033	0.00457	0.00384	0.00519
σ_{δ^E}	SD dividend	inv2	0.0023	0.0033	0.0757	0.00384	0.00519

Table 2.4: Estimated Parameters (Shock Processes)

are highly persistent. The autocorrelation parameter for the collateral shock is high at 0.93, this is also the case for the government consumption shock and the risk shock σ^E . Many of the other autocorrelation parameters stay around their prior mean. Autoregressive coefficients for consumption preference and technology processes have posterior modes below their prior means allowing for these shocks to capture the highest frequency moves in inflation and consumption series. The estimated standard deviation for the collateral shock at 0.07 is high compared to standard deviations for the other shocks. Table 2.2 displays steady-state ratios for the estimated model. The discrepancies between the ratios implied by the model and by the data are small except for the shares of household and firm loans which are more sensitive to changes in the monitoring cost parameters and steady-state default rates. The next section uses the estimated model to study the sources of the business cycle in France over the past 15 years.

V. Results

This section presents results obtained from the estimated model, I focus on the role of financial shocks to explain economic fluctuations in France. The following results come from using the model at the mode.

A. Effects of the Collateral Shock

Here I present the impulse responses of the main variables following a negative collateral shock which corresponds to a fall in the housing and capital amounts that borrowers can pledge to collateralize their loans.

Because a collateral shock implies a reduction in the pledgeability of collateral and less skin in the game for borrowers, banks react by lowering their loan exposures and increase their lending rates. Figures 2.3 displays responses of key macroeconomic and financial variables to a collateral shock. With reduced loans, entrepreneurs are forced to reduce their capital purchase and the demand for investment goods falls. The price of capital plummets along with entrepreneurs' net worth. As entrepreneurs become suddenly more leveraged, their probability of default increases what triggers financial accelerator effects: banks react to higher risk by cutting down loans what increases borrower default further. With the marginal productivity of labor falling, intermediate firms reduce their demand for work, pushing down wages as well as the marginal cost of production and inflation.

On the households' side, reduced access to loans implies that impatient households have to cut down on final good expenditures. To smooth consumption and limit a drop in utility, impatient households sell their housing to patient households. The subsequent fall in housing price triggers financial accelerator effects similar to the mechanism described for entrepreneurs. As both the quantity and the value of their collateral decrease, impatient households become riskier and banks cut down loans even further. For the two types of borrowers, the initial increase in leverage implied by the collateral shock is progressively amplified by financial accelerator effects and followed by a long and progressive decline in loan volumes. As for impatient households, patient households are negatively impacted by the fall in labor demand and reduced wages. Because patient households have a higher discount factor and anticipate the future increase in housing price, they accept to hold more housing goods. The central bank decreases the policy rate to mitigate the fall in output and inflation. As loan rates adjust only very progressively

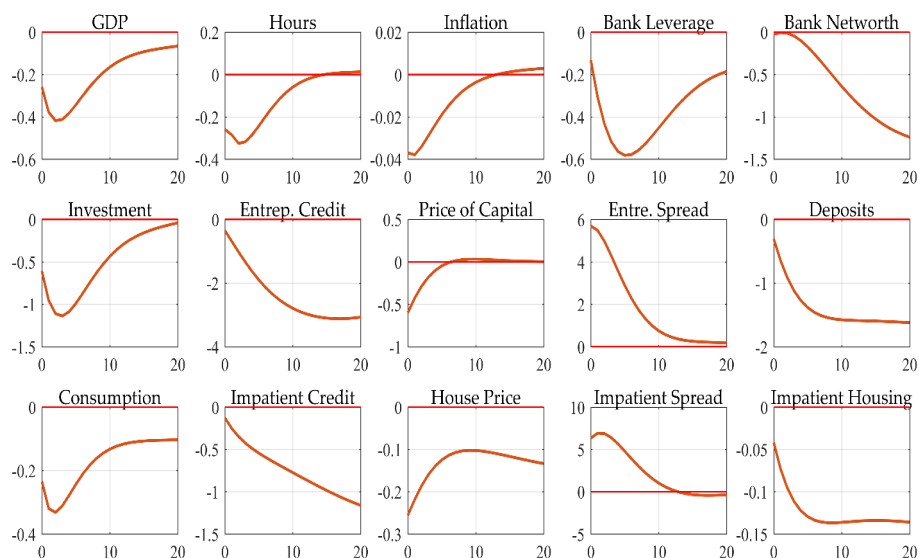


Figure 2.3: Responses to a Collateral Shock in the Estimated Model.

Note: Impulse responses to a one-standard-deviation shock. Spreads are in absolute basis point deviation from their steady state. All other variables are expressed in relative percentage deviation from their steady state. The horizontal axis is time, one period is a quarter.

to changes in the policy rate, the monetary policy pass-through is weak and delayed. Despite the increase in lending spreads, banks' profits are negatively impacted by the collateral shock as loan volumes fall and borrower default rates increase. With bank equity falling at a much slower pace than loan volumes, bank leverage falls below the regulatory bank capital requirements. To avoid penalty costs, wholesale branches reduce the wholesale spread what dampens the increase in lending rates.

With procyclical consumption, investment, loan volumes and bank leverage and countercyclical spreads, the reactions triggered by the collateral shock appear consistent with the symptoms of the last recessions observed in France.

B. Main Driving Forces

Table 2.5 reports the variance decomposition for the variables of the model at business cycle frequency. As in Bécard and Gauthier (2018), the collateral shock appears to be the leading driving force for GDP, consumption, investment and spread fluctuations. Supply shocks and the equity shock have also substantial implications for the two types of credit.

Monetary policy innovations play only little role for output fluctuations, this is also true for the risk shocks whose effects are restricted to households' credit. An appealing feature of the collateral shock is its ability to generate large comovements in investment and consumption what explains its strong implications for consumption fluctuations. This is not true for most financial shocks put forward in the literature.¹³

Shock	Collateral $\Phi_t^{I,E}$	M.E.I. $\zeta_{I,t}$	Supply $\varepsilon_t^a, \lambda_t^f$	Specific Risk σ_t^E, σ_t^I	Preference $\zeta_{c,t}, \zeta_{h,t}$	M.P. ε^m	Gov. ε_t^g	Equity δ_t^E
GDP	66	10	1	1	12	4	5	1
Consumption	35	0	0	4	35	2	24	0
Investment	61	27	2	2	0	5	0	3
Inflation	7	2	88	0	2	1	1	0
Household Credit	21	10	38	20	0	0	7	3
Firm Credit	37	3	19	3	1	2	1	34
Bank Leverage	40	2	34	5	0	4	4	10
Firm Spread	41	42	4	1	2	3	4	2
Household Spread	42	20	6	17	2	2	6	6

Notes: The variance decomposition is computed for the parameters evaluated at their posterior mode. Shares are in percent. Numbers in each row need not add up to 100 due to rounding.

Table 2.5: Variance Decomposition at Business Cycle Frequency

C. Historical Shock Decomposition

Figure 2.4 plots the historical shock decomposition for the main observables over the estimation period. The collateral shock accounts for the increase in loan volumes before the financial crisis in 2007, and the strong fall in bank spreads and the simultaneous increase in investment and consumption. The spike in spreads observed during the Great Recession is also attributed to negative collateral shocks while the impact on bank loans is accounted by supply shocks such as markup and technology shocks. On the other hand, collateral shocks account for the prolonged fall in loan volumes and the high spreads in the aftermath of the Eurozone crisis. Importantly, both equity and preference shocks are key to match the dynamics of firm credit and consumption.

Other shocks have little implication for investment and consumption dynamics. Demand shocks other than the preference shock explain the bulk of the fall in household loans in the aftermath of the second recession. Since the collateral shock generates a

¹³See for instance the results from Smets and Wouters (2003) for an estimated model of the euro area and Jermann and Quadrini (2012) or Christiano, Motto, and Rostagno (2014) models estimated using US data.

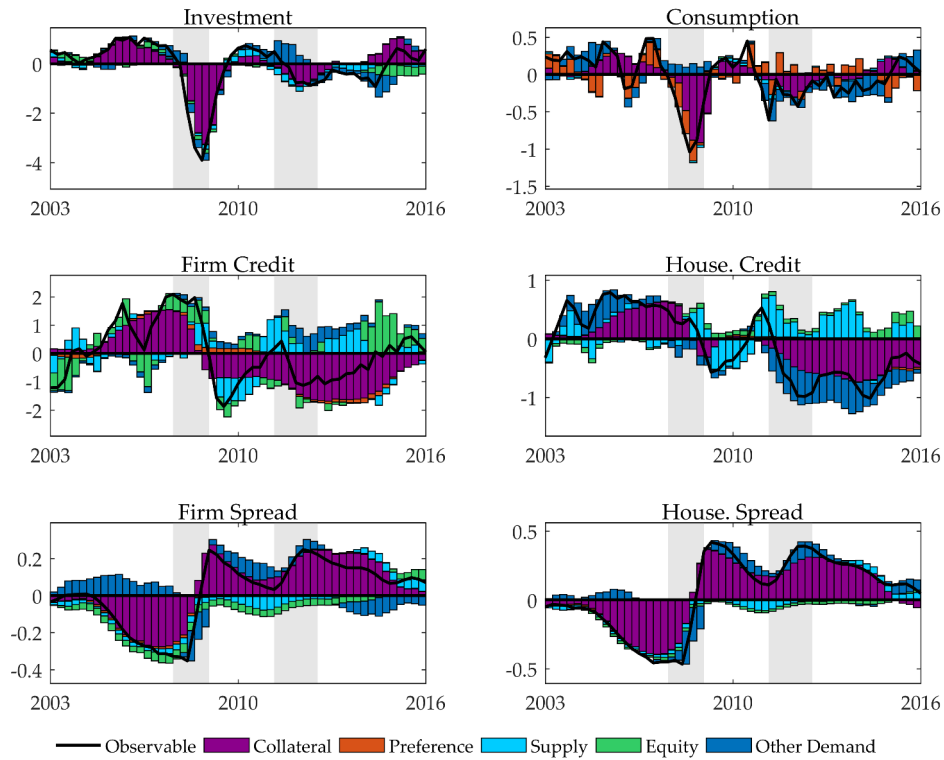


Figure 2.4: Historical Shock Decomposition.

Note: This graph shows the historical shock decomposition for the observables. Series other than spreads are expressed in growth rates smoothed over two quarters, spreads are expressed in basis points. Grey areas correspond to CEPR recession dates.

narrative coherent with the last recessions and explains a large share of business cycle fluctuations, I use this shock to study the implications of the zero lower bound in times of financial distress.

VI. Bank Competition at the Zero Lower Bound

This section discusses the implications of the zero lower bound depending on the degree of bank competition, characterized in the model both by markups and stickiness in interest rates.

A. Collateral Shocks and the Zero Lower Bound

When adverse shocks are sufficiently strong the economy enters a period of ZLB characterized by the absence of possible recourse to conventional monetary policy.¹⁴ This results in non-linearities which are captured using the algorithm developed by Holden and Paetz (2012).

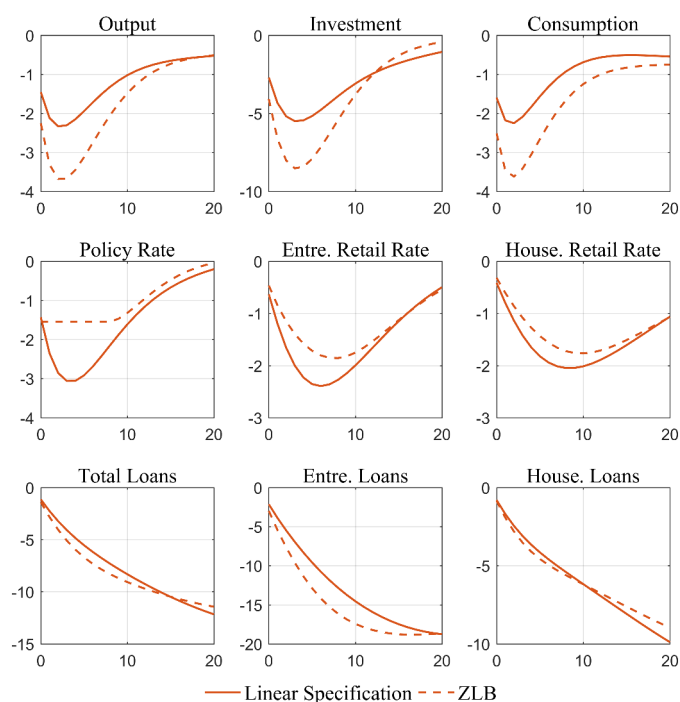


Figure 2.5: Responses to a Collateral Shock with ZLB.

Note: Impulse responses to a collateral shock. Rates are in annualized absolute deviation from their steady state. All other variables are expressed in relative percentage deviation from their steady state. The horizontal axis is time, one period is a quarter.

Figure 2.5 displays the impulse responses for a subset of variables following a negative collateral shock. The magnitude of the shocks in this section are chosen to mimic the magnitude of the collateral shock estimated during the Great Recession.¹⁵ The dashed

¹⁴Here I do not take into account the possibility of unconventional monetary policies which are helpful to relieve the economy in periods of ZLB. On this subject see for instance Gertler and Karadi (2011), Haberis (2017) or Cahn, Matheron, and Sahuc (2017).

¹⁵Interest rates displayed in this figure and the followings correspond to R_t^{bE} and R_t^{bI} which do not embed risk premia, to focus on the adjustment of loan rates to shifts in the policy rate.

line corresponds to the model with a ZLB, the continuous line corresponds to the baseline linear specification. In case of large collateral shock, the policy rate cannot decrease as much as would imply the estimated Taylor rule. In the baseline specification, the large decrease in the policy rate following a collateral shock mitigates the fall in consumption and investment by pushing down lending rates what limits the fall in credit for both types of borrowers. In the presence of a ZLB, the adverse effects from the collateral shock are amplified and the fall in GDP, investment and consumption are roughly twice as strong as in the linear specification. In contrast, the two specifications have closer implications for bank rates and loans, especially for household borrowers. Because loan rates in the estimated model are sticky, the monetary policy pass-through is weak. Changes in the policy rate take a long time to materialize with weak stabilizing impact. At its peak, the difference between the policy rates in the two different settings involves relatively little discrepancy in the responses of total loan volumes with a maximum difference of 2 percent. Because monetary policy is less effective when the banking sector is monopolistic, the adverse impact of the ZLB turns out to be relatively small for loans but with substantial implications for investment and consumption. The next subsection investigates the implications of the ZLB depending on the degree of bank competition.

B. Impact of Bank Competition

This subsection investigates the implications of bank competition when the ZLB is binding. In this case, the degree of bank competition is characterized by a combination of credit demand elasticities and interest rate stickiness that define both the level and dynamics of bank markups. When increasing the elasticity of credit demand and lowering interest rate stickiness, two opposite effects modify the impact of the collateral shock on loan volumes. Because a high elasticity of credit demand increases the sensitivity of loans to shifts in lending rates, everything else equal, a rise in bank rates triggers a deeper fall in loan volumes with significant repercussions on consumption and investment. On the other hand, a diminution of lending rate stickiness implies a better monetary policy pass-through and accordingly dampens the impact of financial shocks on loan volumes.

Figures 2.6 and 2.7 illustrate how these two effects articulate differently depending on possible recourse to conventional monetary policy. Figure 2.6 displays impulse responses for the main variables following a collateral shock in the linear model. Here two different

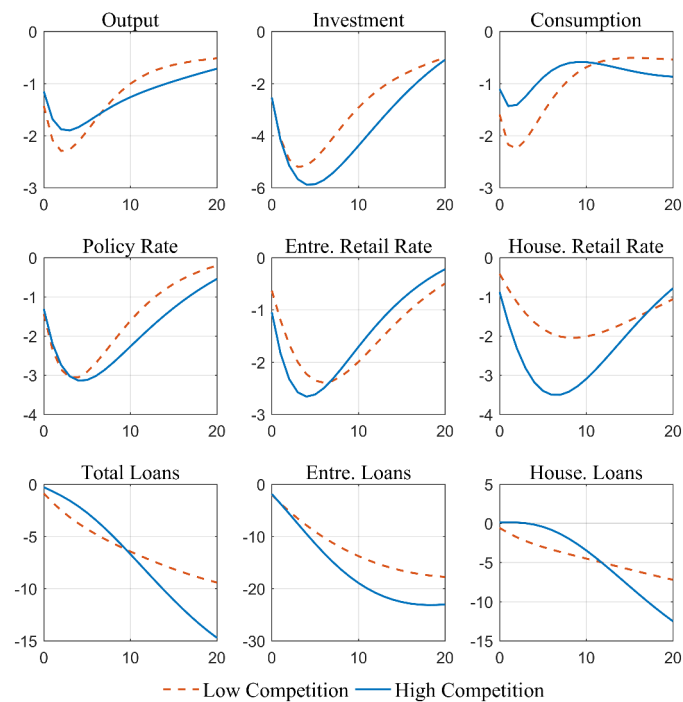


Figure 2.6: Responses to a Collateral Shock in a Counterfactual Economy - Linear.

Note: Impulse responses to a collateral shock. Rates are in annualized absolute deviation from their steady state. All other variables are expressed in relative percentage deviation from their steady state. The blue continuous line corresponds to the estimated model at the mode. The dash orange line corresponds to the same model with reduced bank interest rate stickiness and bank markups.

economies are considered, the first economy, the blue dash line corresponds to the model estimated using French data and characterized by both high-interest rate stickiness and high bank markups. The orange line corresponds to the same economy except that a more competitive banking system is considered: the Calvo parameters for interest rates ξ^{bE} and ξ^{bI} are reduced by fifteen percent each and markups for lending rates are reduced by thirty percent each. Following a collateral shock, consumption and investment fall slightly more on impact in the less competitive setting and loans are also more impacted regardless of the borrower's type. Because loan rates do not adjust immediately to the drop in the policy rate, loan spreads move up and loan volumes fall strongly. In contrast, interest rates adjust faster in the competitive economy and the fall in loans is less pronounced in the first quarter following the shock. With lending rates adjusting more progressively in the non-competitive setting, the effects of monetary policy are delayed.

While the effects of a change in interest rate stickiness and credit demand elasticity appear to even out in the two different models, the introduction of a binding ZLB alters the relative strength of the two effects described above by limiting recourse to conventional monetary policy. Figure 2.7 displays aggregate responses following a collateral shock for

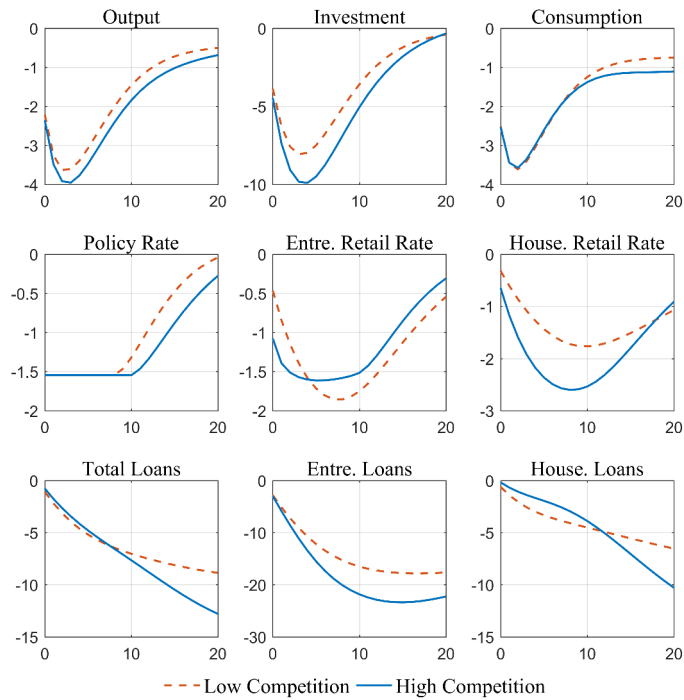


Figure 2.7: Responses to a Collateral Shock in a Counterfactual Economy - ZLB.

Note: Impulse responses to a collateral shock. Rates are in annualized absolute deviation from their steady state. All other variables are expressed in relative percentage deviation from their steady state. The horizontal axis is time, one period is a quarter. The blue continuous line corresponds to the estimated model at the mode. The dash orange line corresponds to the same model with reduced bank lending rate stickiness and markups.

the two previously defined economies except that the model now includes the possibility of a binding ZLB.

While in the absence of a minimum policy rate a collateral shock generates similar impacts on output, consumption, and investment for different degrees of bank competition, here the impact of the collateral shock is dampened in the economy characterized by a low degree of bank competition. The dynamics exhibited in case of ZLB are qualitatively similar to the previous case, except that bank lending rates cannot fall as much as in the linear case with the policy rate being stuck to zero: when resort to monetary policy is

limited by a binding ZLB, interest rate stickiness is less of an amplifying factor for financial shocks as monetary policy pass-through is weak anyway. In contrast, lower credit elasticities in the competitive economy still imply higher aggregate volatility conditional to a collateral shock. As a consequence, the competitive economy experiences a larger fall in firm loans with strong repercussions for labor demand, investment, and output. When the ZLB is binding, the collateral shock generates a deeper crisis for the economy where the banking sector is competitive. Hence, for some combinations of the parameters characterizing the dynamics and levels of markups, the impact of a binding ZLB turns out to be more disruptive for an economy with a high degree of bank competition, even when the linear model implies similar responses for the two settings.

C. Macroprudential Policy at the Zero Lower Bound

This section studies the implications of a countercyclical capital buffer in times of binding ZLB. The countercyclical buffer (CCyB) belongs to the toolbox of macroprudential policy to be activated at the discretion of national authorities. In line with Capital Requirements Directives IV and Capital Requirements Regulation, the buffer can be activated whenever the macroprudential authority considers there is a risk of procyclicality, raising concerns about systemic risk, credit bubbles, or loose risk monitoring.

The CCyB is a time-varying capital requirement which can be imposed on banks in addition to minimum capital requirements and whose release may reduce the cost of extending an additional unit of credit and thereby dampen the credit cycle by alleviating the pressure on banks to deleverage in bad times. While the presence of a monopolistic banking sector limits the efficiency of monetary policy, I find that implementing a countercyclical regulation directly on bank leverage can help to bypass a weak monetary policy pass-through.

Modeling a Countercyclical Capital Buffer

Remember that in the model, the target capital-to-asset ratio ν determines the spread between the policy rate R_t and wholesale rate R_t^b through its effect on the capital adjustment

cost function of the bank:

$$R_t^b - R_t = -\theta^B \left(\frac{n_t^B}{B_t} - \nu_t \right) \frac{n_t^{B^2}}{B_t^2}.$$

In the benchmark case, bank capital requirements are a constant pinned down by the steady-state level of the bank leverage. Once a CCyB is included, bank capital requirements are allowed to vary in a systematic fashion.

The adoption of a quasi-structural form of bank capital adjustment costs is standard in the literature (e.g. Cúrdia and Woodford (2010), Gerali, Neri, Sessa, and Signoretti (2010), Jermann and Quadrini (2012), Pariès, Sørensen, and Rodriguez-Palenzuela (2011), Suh (2014), and Woodford (2012) and Angelini, Neri, and Panetta (2014) even use it normatively). Nevertheless, the absence of an explicit microfoundation for the adjustment cost function implies that its use for normative purposes must be taken with caution. For this reason, I limit its role to describe the effects of a particular CCyB rule but I do not use the model to rank alternative CCyB rules.¹⁶ Therefore, I turn to a simple and arguably policy-relevant specification for a systematic CCyB rule as defined by Basel (2010) where the credit-to-GDP gap is used as an indicator for the activation and deactivation of the CCyB.¹⁷ This boils down to imposing the following rule for the evolution of the regula-

¹⁶Lopez (2015) carries out an explicit optimal policy exercise in a setting that offers a microfoundation to convex bank capital adjustment costs.

¹⁷An operational CCyB is defined in Basel (2010) as follows: let $Credit_t$ be a broad measure of credit to the private non-financial sector and GDP_t the gross domestic product, both being measured in nominal terms at a quarterly frequency; one then constructs the credit-to-GDP gap measure,

$$Gap_t = \frac{Credit_t}{GDP_t} \cdot 100 - HPfilter \left(\frac{Credit_t}{GDP_t} \cdot 100; \lambda = 400,000 \right),$$

where the long-term trend of the credit-to-GDP ratio is computed using a one-sided Hodrick-Prescott filter with a high smoothing parameter set to 400,000 (Basel Committee, 2010). The formula for the CCyB is subsequently capped to a maximal add-on of 2.5 percentage points of additional risk-weighted regulatory capital when the gap is larger than $H = 10$, and reacts only when the observed gap is larger than a minimal deviation $L = 2$, but is otherwise linearly related to the credit to GDP gap:

$$CCyB_t = \begin{cases} 0 & \text{if } Gap_t < L \\ 2.5 \cdot \frac{Gap_t - L}{H - L} & \text{if } L < Gap_t < H \\ 2.5 & \text{if } Gap_t > H. \end{cases}$$

tory capital target ν_t :

$$\nu_t = \nu + \Phi_\nu \left(\frac{b_t^I + b_t^E}{y_t} - \frac{b^I + b^E}{y} \right), \quad (2.19)$$

with $b^I + b^E$ and y being respectively total credit and output at the steady state. By construction, this CCyB is not exactly identical to the instrument envisaged in Basel (2010). First, the implemented CCyB does not exhibit lower and upper bounds. Nevertheless, to get magnitudes consistent with the actual CCyB, Φ_ν is set to 0.25, that is to say a deviation of the credit-to-GDP gap of 10 percent from its long-term trend is associated with a 2.5 percent point of additional capital over loans requirement. Second, the rule is symmetric so that the CCyB can be negative. However, this version of the CCyB is close to the prudential rules set by the regulator.

Implications of the CCyB at the Zero Lower Bound

Figure 2.8 presents the impulse responses of selected variables to a collateral shock. The orange dash line corresponds to impulse responses for the estimated model where the ZLB can be binding, the dash blue line corresponds to the same model including a CCyB rule, the orange line corresponds to the linear estimated model.

The presence of a CCyB rule reduces the adverse effects of a collateral shock when the ZLB is binding: when the CCyB is activated, the fall in the credit gap translates into additional costs for the wholesale branch which decreases lending rate to boost loans and limit costly deviations from the targeted bank leverage. Because in the model the effects of monetary policy are conveyed through the impact of the policy rate on the wholesale rate and further transmitted to loan and deposit rates, the presence of a CCyB that affects directly the wholesale rate, acts as a substitute for monetary policy in periods where no recourse to the conventional monetary policy is possible. This allows for the decrease of lending rates even when the policy rate is stuck to zero. With the wholesale spread falling, the recessive impact of the collateral shock on loans is dampened with weaker fall in consumption and investment. Because it acts directly on the balance sheet of the wholesale branches, the effects of CCyB on loan volumes can substitute to monetary policy in times of binding ZLB.

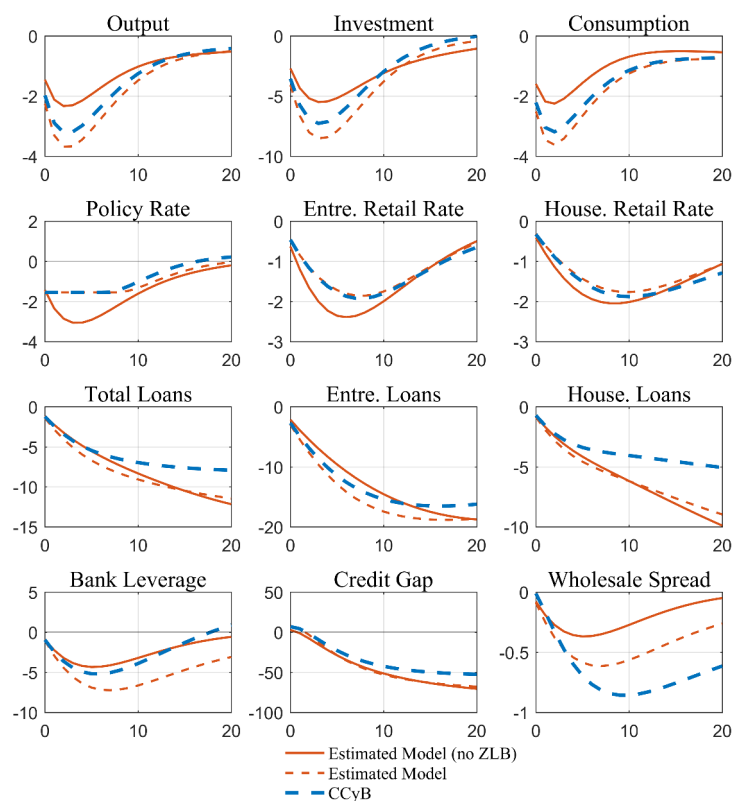


Figure 2.8: Responses to a Collateral Shock with a CCyB.

Note: Impulse responses to a collateral shock. Rates are in absolute deviation from their steady state and annualized. All other variables are expressed in relative percentage deviation from their steady state. The horizontal axis is time, one period is a quarter. The orange dashed line corresponds to the estimated model at the mode with a binding ZLB, the blue line corresponds to the same model including an additional CCyB rule, the orange continuous line corresponds to the linear case.

VII. Conclusion

In this paper, I present a general equilibrium model including a monopolistically competitive banking sector. The model is estimated for France over the period 2003 to 2017 using macro and financial series. I find that financial shocks explain much of the fluctuations in GDP, investment, consumption, as well as changes in spreads and loan volumes for firms and households. The model is calibrated for different levels of bank competition characterized here by stickiness and markups in lending rates. I investigate the effects of financial shocks for different degrees of banking competition. I find that competition in the banking sector usually implies that economic activity is more resilient to adverse

Chapter 2. Bank Competition and the Financial Crisis, the French Example

shocks as the monetary policy pass-through is better. In contrast, in situations where the zero lower bound is binding, concentration in the banking sector, implies that loans and deposits are less volatile what mitigates the recessive effects from financial shocks. The paper also illustrates the stabilizing impact of a CCyB rule to alleviate financial stress when the policy rate is stuck to zero.

Chapter 3

Financial Shocks and the Debt Structure

I. Introduction

Understanding how financial and economic activity interact is key to determine what causes recessions. Over the past 20 years, various methods have been proposed to identify financial disturbances often relying on models including spreads and asset prices to proxy credit conditions. While such strategies have led to a better understanding of how credit disruptions shape the business cycle, identification of financial shocks still is a hazardous task. Several reasons explain this difficulty to establish causal links between the financial sector and the rest of the economy. First, financial variables are strongly procyclical and forward-looking, making it arduous to separate financial shocks from the economic cycle with standard recursive identification schemes.¹ Second, because financial distress can turn out in credit rationing rather than in price changes, using statistical indicators of financial stress to proxy credit conditions faced by firms can be misleading. Third, theoretical models, such as DSGE, used to guide identification strategies do not always qualitatively distinguish shocks to credit conditions from other macroeconomic shocks, rendering identification very sensitive to the model structure.

In this paper, I try to address these issues by developing a method to identify financial shocks that is based on qualitative criteria and does not rely on financial stress indicators. To do so, I identify financial shocks based on firm funding decisions: because some firms can fund production using intermediated and direct credit, their funding decisions can

¹See for instance Mumtaz, Pinter, and Theodoridis (2018) for a critical review of financial shock identification using SVAR models.

be used as a direct measure of the credit condition they face.

A specificity of firms funding from markets and banks is that they can adjust both the level and composition of their debt. This can be used to identify the type of shocks driving economic fluctuations. As an illustration, consider a shock increasing firm debt demand but leaving their credit conditions unchanged. Everything else equal, this shock implies an increase in both loan and bond volumes. On the other hand, an exogenous shock to credit conditions leaving debt demand unchanged implies a new debt arbitrage and *opposite* movements in the two types of debt. To investigate how the level and compositional effects articulate in response to macroeconomic shocks in a general equilibrium environment, I augment the workhorse NK model with the mechanism of debt choice from De Fiore and Uhlig (2011). The model implies that only financial shocks generate opposite movements in loan and bond volumes on impact. On the other hand, supply, monetary, and other demand shocks generate co-movement in the two types of debt. The reason is that in response to a financial shock, firms adjust their funding choice to the new credit conditions and substitute the most efficient type of debt for the other. In contrast, adverse non-financial shocks imply that both types of debt become less desirable for firms what triggers a simultaneous fall in bond and loans. The signs of the impulse responses obtained from the model are robust for a wide set of calibrations.

In the second part of the paper, I implement the qualitative distinctions implied by the modified NK framework to inform a sign-restriction VAR model. The latter is estimated with US corporate firm balance-sheet data and standard macroeconomic series. The model is used to identify financial shocks and assess their business cycle implications. Because the identification scheme relies on firm funding decisions in place of the more usual spreads and asset prices extensively used to instrument financial perturbations, the method allows circumventing the problem of co-movements between macroeconomic and potentially fast-moving financial variables, as pointed out in Kashyap, Stein, and Wilcox (1993), Meeks (2012), and Caldara, Fuentes-Albero, Gilchrist, and Zakrajsek (2016). A byproduct of this method is that financial shocks need *not* to be identified as demand shocks. This restriction is commonly imposed to identify financial shocks in sign-restriction VAR and DSGE models but at odds with the recent evidence brought up by Gilchrist, Schoenle, Sim, and Zakrajšek (2017) who show that financial disturbances can induce constrained firms to raise prices following adverse financial shocks and Angeletos,

Collard, and Dellas (2018a) who find that shocks most likely driving output fluctuations are orthogonal to the ones responsible for price dynamics.

In the final part of the paper, I estimate the modified NK model so as to minimize the distance between impulse responses implied by this model and the VAR model. I find that the modified NK model can reproduce the quantitative features implied by the data for all types of shocks. The estimated model is used to recover a structural measure of the financial shocks observed over the past 30 years. The financial shocks obtained match other indices of financial stress and are highly predictive for bond spreads.

Over the past 20 years, various papers have studied financial shocks using bond spreads and asset prices to proxy credit conditions. Justiniano, Primiceri, and Tambalotti (2011), Christiano, Motto, and Rostagno (2014) and Ajello (2016) use general equilibrium models including financial frictions to show that financial shocks are the best candidates to simultaneously explain fluctuations in financial and non-financial sectors. Empirical studies such as Gilchrist and Zakrajšek (2012a,b) construct measures of bond spread purged of components other than the excess bond premium to identify exogenous changes in credit supply. In the meantime, economists have pointed to the identification challenge arising from jointly studying economic activity and financial markets. This is exemplified by Stock and Watson (2012) who underline the difficulty to separately identify financial and uncertainty shocks as reflected by the high correlation of shocks identified with the Gilchrist and Zakrajšek (2012b) spread and with the policy uncertainty index from Baker, Bloom, and Davis (2016). Meeks (2012) highlights similar issues when using spreads to identify financial shocks. He shows that much of the fluctuations observed in US bond spreads are better qualified as endogenous responses to shifts in default risk rather than as the result of exogenous changes in credit conditions.

In reaction, sign-restriction methods as developed by Faust (1998), Uhlig (2005) and Rubio-Ramirez, Waggoner, and Zha (2010), have become increasingly popular to identify financial shocks. Using a sign-restriction Bayesian VAR, Fornari and Stracca (2012) identify financial shocks as demand shocks increasing the share price of financial firms relative to the share price of non-financial firms. Furlanetto, Ravazzolo, and Sarferaz (2017) identify financial shocks as demand shocks simultaneously increasing the ratio of investment over output and the share price of firms. Cesa-Bianchi and Sokol (2017) combine an external instrument approach with sign-restriction methods and identify adverse

financial shocks as the only type of demand shock leading to a rise in lending rates. Cal-dara, Fuentes-Albero, Gilchrist, and Zakrajsek (2016) use a penalty function approach to construct an uncorrelated series of uncertainty and financial shocks.

The identification strategy I propose is also tightly related to a literature initiated by Kashyap, Stein, and Wilcox (1993) who use the evolution of commercial papers relative to corporate loans to evaluate the strength of the monetary policy credit channel. Since the 2007 financial crisis and the renewed interest for financial disruptions, their approach has been extended to capture exogenous contractions in the supply of credit. Based on firm-level data, Becker and Ivashina (2014) use the share of firms substituting bonds for loans as a proxy for credit conditions to identify adverse credit supply shocks. They show that the ratio of intermediated debt to direct debt is negatively affected by depressed aggregate lending, poor bank performances, and tight monetary policy. Altavilla, Darracq Pariès, and Nicoletti (2015) instrument credit conditions using bank lending surveys and find that adverse credit supply shocks imply strong contractions in corporate borrowing along with an increase in bond issuance as firms substitute direct debt for bank loans. Adrian, Colla, and Song Shin (2013) provide evidence that corporate firms have massively substituted bonds for loans during the 2007 financial crisis. They also find that changes in US corporate debt composition account for most of the simultaneous increase in bond spread.

To model non-trivial firm arbitrage between direct and indirect debt in a general equilibrium model, I include risky firms that fund working capital using external debt in the NK framework. I follow De Fiore and Uhlig (2011, 2015) in assuming the existence of banks more efficient than markets at resolving asymmetric information problems but also more costly. As in Holmstrom and Tirole (1997) and Berlin and Mester (1992), the model assumes that bank-funded firms can transmit private information to their lender and renegotiate their debt contract conditional on their idiosyncratic productivity. The mechanism of debt choice is also closely related to the debt arbitrage mechanism from Repullo and Suarez (2000). In their model, banks with high monitoring intensity are the only possible source of funds for firms with low net worth. Crouzet (2018) includes firm debt arbitrage in a general equilibrium model where banks provide flexible contracts to producing firms. As in De Fiore and Uhlig (2015), he finds that the impact of financial shocks is dampened when firms can fund production with direct debt. Including the debt

choice mechanism from De Fiore and Uhlig (2011) into the NK framework preserves the tractable structure of the original model and allows to study the main shocks considered in the business cycle literature within a general equilibrium framework.

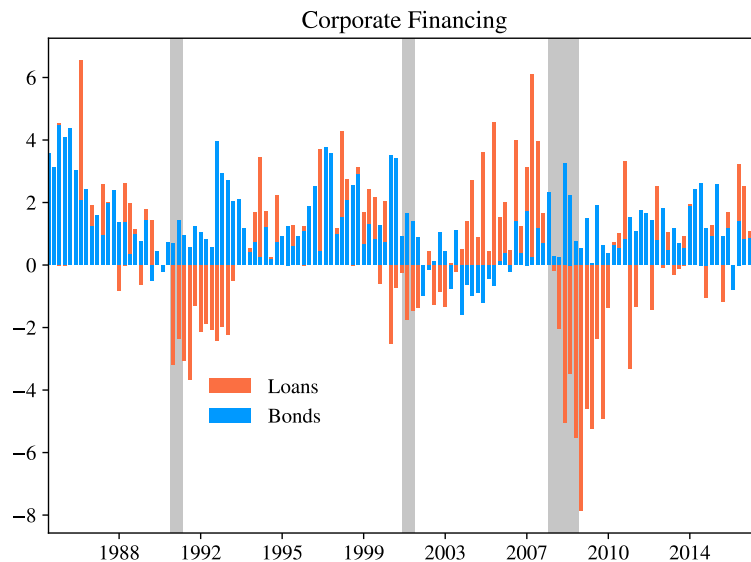


Figure 3.1: Bond and Loan Growth Rates.

Note: Bond and loan annual growth rates for non-financial corporate firms. Orange bars correspond to bank loans and blue bars correspond to bonds. The grey bands correspond to NBER recession dates.

Figure 3.1 illustrates the key characteristics of the evolution of intermediated and direct debt in the US since the mid-'80s. A few facts are worth noticing. First, bank loans are strongly procyclical, rising during episodes of expansion and falling during recessions. Second, while the two types of debt exhibit positive growth rate during expansions, all three recessions in the sample are characterized by opposite movements in bond and loan growth rates. Third, the joint evolution of loans and bonds is different prior to each recession: the growth rates for the two types of debt fall progressively before reaching zero at the outset of the early '90s recession, the 2001 recession is preceded by a sudden contraction in loans accompanied by a surge in bonds, and the Great Recession is preceded by a progressive but strong loan growth with a stable bond volume until the end of 2008.

The rest of the paper is organized as follows. Section II presents the modified NK model, section III details the model calibration and discusses its properties. Section IV estimates a sign-restriction VAR model and discusses the features of the financial shocks.

Section V estimates the modified NK model and provides out-of-sample exercises. Section VI concludes.

II. A New Keynesian Model with Debt Arbitrage

In this section, I present a general equilibrium model used to investigate the dynamics of firm debt choice. The model is based on De Fiore and Uhlig (2011) where producing entrepreneurs with idiosyncratic productivity can hedge some of their processing risk by engaging in costly contracts with banks, thereby giving rise to arbitrage between intermediated and direct debt. This section provides an overview of the model, a complete derivation and the full set of equations can be found in section VIII of the appendix.

The model is populated by three types of agents: households who consume, work and save, firms that use capital and labor to produce final goods and financial intermediaries that channel funds from households to the productive sector.

A. Households

The model assumes a large number of identical and competitive households. Each household contains every type of labor, h_{it} with $i \in [0, 1]$. A representative household maximizes its utility function defined as:

$$E_0 \sum_{t=0}^{\infty} \beta^t \zeta_{c,t} \left\{ \log(c_t - bc_{t-1}) - \psi_L \int_0^1 \frac{h_{it}^{1+\sigma_L}}{1+\sigma_L} di \right\},$$

where c_t is household consumption, $\zeta_{c,t} > 0$ is a preference shock, $\sigma^L > 1$ is the inverse of the Frisch elasticity of labor supply, b is the degree of habits and ψ_L is a weighting parameter for labor desutility. Each household is subject to the following budget constraint:

$$P_t c_t + P_t d_t + Q_t^k k_t \leq \int_0^1 W_{it} h_{it} di + R_t P_{t-1} d_{t-1} + [Q_t^k (1 - \delta) + u_t r_t^k - a(u_t)] k_{t-1} + \Omega_t. \quad (3.1)$$

Households spend on both consumption of the final goods priced at P_t , and on capital purchases k_t , bought from capital installers at price Q_t^k and sold back to them at the end of the period. Households get their revenues from selling differentiated labors h_{it} supplied by individuals at a real wage rate W_{it} set by monopoly unions. Previous period real deposits d_{t-1} are remunerated at a nominal rate R_t . Each period, households decide the

utilization rate of capital u_t and supply effective capital $u_t k_t$ to entrepreneurs at a competitive rental rate r_t^k . The function $a(\cdot)$ designates capital utilization costs. Finally, Ω_t corresponds to transfers from entrepreneurs.

Labor Market.—A representative competitive labor contractor aggregates the differentiated labor h_{it} into homogeneous labor services l_t , using the following technology:

$$l_t = \left[\int_0^1 h_{it}^{\frac{1}{\lambda_w}} di \right]^{\lambda_w}, \quad 1 \leq \lambda_w. \quad (3.2)$$

The labor contractor sells labor services to entrepreneurs at a real wage rate w_t . A monopoly union represents workers of each type i and set the corresponding wage subject to Calvo frictions: each period a fraction $1 - \xi_w$ of unions can set wages to their optimal level while the rest of the wages evolve according to an indexation rule defined as: $W_{it} = (\pi)^{\iota_w} (\pi_{t-1})^{1-\iota_w} W_{it-1}$, where π_t is the inflation rate, π is the steady-state level of inflation and ι_w is a parameter.

Capital Installers.—Capital installers buy investment goods I_t^k from the final good producer and turn it into installed capital which is sold to households in a competitive market at a price Q_t^k . Capital installers maximize their discounted sum of profits using household stochastic discount rate $\beta^t \zeta_{c,t} \Lambda_{z,t}$:

$$E_0 \sum_{t=0}^{\infty} \beta^t \zeta_{c,t} \Lambda_{z,t} \{ Q_t^k k_t - P_t I_t^k \},$$

using the following technology:

$$k_t = (1 - \delta)k_{t-1} + \left[1 - S \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) \right] I_t^k,$$

where $0 < \delta < 1$ is the depreciation rate of capital, $S(\cdot)$ is an increasing adjustment cost function defined below, and $\zeta_{I,t}$ is a shock to the marginal efficiency of investment in producing capital.

B. Firms

Firms produce final goods using capital and labor inputs. I follow Gali (2010) in assuming a three-sector structure for firms. Entrepreneurs produce homogeneous goods transformed by monopolistically competitive retailers into intermediate goods. The final good producers then combine intermediate goods bought from retailers to produce homogeneous final goods sold to households in competitive markets.

Entrepreneurs

Entrepreneurs are heterogeneous agents modeled as in De Fiore and Uhlig (2011). They contract with financial intermediaries to fund working capital used to produce homogeneous goods sold to intermediate producers. Because there exist different types of financial intermediaries, entrepreneurs can select the form of debt they prefer according to their own characteristics.

Production.—There is a continuum $e \in [0, 1]$ of risk neutral entrepreneurs operating in competitive markets. An entrepreneur e produces goods Y_{et}^E using capital and labor according to the following Cobb-Douglas technology:

$$Y_{et}^E = \varepsilon_{et}^E A_t (u_t k_{et-1})^\alpha l_{et}^{1-\alpha}, \quad (3.3)$$

where l_{et} and k_{et} denote respectively labor and capital inputs used for production. Variable A_t corresponds to the Solow residual and ε_{et}^E is a sequence of independent idiosyncratic shock realizations. To produce, entrepreneurs must fund labor and capital inputs with available funds x_{et} , according to the following debt constraint:

$$x_{et} \geq r_t^k k_{et} + w_t l_{et}, \quad (3.4)$$

where x_{et} corresponds to the sum of their net worth n_{et} and external debt d_{et} :

$$x_{et} = n_{et} + d_{et}. \quad (3.5)$$

Entrepreneur e starts the period t with net worth n_{et} , which corresponds to past period profits minus dividends transferred to the households. To obtain external funds d_{et} from

a financial intermediary, an entrepreneur must pledge her net worth according to the following leverage constraint:

$$x_{et} = \xi n_{et}, \quad (3.6)$$

where ξ is a parameter defining entrepreneurs' leverage.² After production, Y_{et}^E is sold to retailers at a competitive price P_t^E . The problem of an entrepreneur given available funds x_{et} is to choose the combination of capital and labor inputs maximizing her real profits defined as:

$$\frac{P_t^E Y_{et}^E}{P_t} - r_t^k k_{et} - w_t l_{et}, \quad (3.7)$$

subject to the debt constraint defined in equation (3.4). The solution to the optimization problem of an entrepreneur implies the following first order conditions:

$$\alpha x_{et} = r_t^k k_{et}, \quad (3.8)$$

$$(1 - \alpha)x_{et} = w_t l_{et}. \quad (3.9)$$

Defining s_t as the aggregate component of the marginal cost of production expressed in terms of the final goods yields:

$$s_t = \frac{1}{A_t u_t^\alpha} \left(\frac{P_t}{P_t^E} \right) \left(\frac{r_t^k}{\alpha} \right)^\alpha \left(\frac{w_t}{1 - \alpha} \right)^{1 - \alpha}. \quad (3.10)$$

For further use, it is also convenient to define $q_t = \frac{1}{s_t}$, where q_t can be interpreted as the aggregate entrepreneurial markup over input costs.³

Idiosyncrasy.—Before production takes place, each entrepreneur is hit by a series of successive idiosyncratic productivity shocks which determine whether an entrepreneur produces or not and her preferred type of financial intermediary. Three successive idiosyncratic shocks are considered here. First, a shock $\varepsilon_{1,et}$ is publicly observed and creates heterogeneity in the productivity of entrepreneurs. This shock realizes along with aggregate

²Similar to De Fiore and Uhlig (2011) and in contrast with the standard debt contracts from the canonical model of Bernanke, Gertler, and Gilchrist (1999), one need to assume fixed leverage for entrepreneurs to obtain an interior solution to the borrowing decision problem. The reason is that entrepreneurs have different credit worthinesses. In the practical case where the distribution of ε_{et}^E is bounded, optimal leverage implies a corner solution with all available funds going to the best entrepreneur.

³Here s_t must not be confounded with the marginal cost of the intermediate good producer, $pc_t = \frac{P_t^E}{P_t}$, which is taken as given by entrepreneurs.

shocks and before entrepreneurs have contracted with financial intermediaries. Second, a shock $\varepsilon_{2,et}$ occurs after financial contracts are set and is observed only by bank-funded entrepreneurs and their banks. This shock creates a rationale for choosing intermediated finance over direct finance. The third shock $\varepsilon_{3,et}$ is privately observed by entrepreneurs and realizes just before production takes place. This final shock justifies the existence of risky debt contracts between entrepreneurs and financial intermediaries. Both privately observed shocks $\varepsilon_{2,et}$ and $\varepsilon_{3,et}$ can be monitored at a cost by financial intermediaries.

Entrepreneurs have the option to contract with banks to decrease their residual processing risk. To do so they must pay a share τ^b of their net worth that is used to resolve part of their productivity uncertainty. A bank-funded entrepreneur e pays a cost $\tau^b n_{et}$ to observe the realization of $\varepsilon_{2,et}$ and to share it with her bank. Before production takes place and based on the realization of $\varepsilon_{2,et}$, bank-funded entrepreneurs have the possibility to renegotiate their contract, in which case they simply recover their pledged net worth and abstain from production. Denoting ω_{et}^f the realization of the uncertain productivity factor for entrepreneur e conditional on contracting with a financial intermediary of type f which can be b for bank or c for market,

$$\omega_{et}^f = \begin{cases} \varepsilon_{2,et}\varepsilon_{3,et} & , \text{ if bond financing} \\ \varepsilon_{3,et} & , \text{ if loan financing.} \end{cases}$$

After the first idiosyncratic shock $\varepsilon_{1,et}$ is observed, each entrepreneur decides whether she wants to produce and if so selects her optimal source of funds. An entrepreneur can choose either to contract with banks in which case production is conditioned on the realization of $\varepsilon_{2,et}$, or to fund from markets in which case she produces regardless of her residual uncertainty factor ω_{et}^f . Entrepreneurs abstaining from production keep their net worth until the end of the period. Producing entrepreneurs rent capital k_{et} and hire labor h_{et} from households. Factors repayment is done at the end of the period and backed by the value of pledged collateral and funds obtained from financial intermediaries. The net worth of an entrepreneur after having contracted with a financial intermediary is:

$$n_{et}^f = \begin{cases} n_{et} & , \text{ if bond financing} \\ (1 - \tau^b)n_{et} & , \text{ if loan financing.} \end{cases}$$

In the final stage of period t , the shock $\varepsilon_{3,et}$ realizes and is privately observed. Entrepreneurs announce the outcome of their production, sell it to retailers, repay production factors to households and reimburse their financial intermediary. The realization of ω_{et}^f is kept private unless the financial intermediary decides to monitor defaulting entrepreneurs in which case a fraction μ^f of seized assets is lost in the monitoring process.

In application, I assume that all three types of idiosyncratic shocks are normally and independently distributed across entrepreneurs such that $\varepsilon_{1,et} \sim \mathcal{N}(0, \sigma_1^2)$, $\varepsilon_{2,et} \sim \mathcal{N}(0, \sigma_2^2 + \nu_t)$ and $\varepsilon_{3,et} \sim \mathcal{N}(0, \sigma_3^2 - \nu_t)$, where ν_t is a shock shifting the relative share of idiosyncratic productivity that bank-funded entrepreneurs can observe and transmit to their bank. Variable σ_t^f is the standard deviation of the residual uncertainty productivity factor $\omega_{e,t}^f$ conditional on the entrepreneur funding decision:

$$\sigma_t^f = \begin{cases} \sqrt{\sigma_2^2 + \sigma_3^2} & , \text{ if bond financing} \\ \sqrt{\sigma_3^2 - \nu_t} & , \text{ if loan financing.} \end{cases}$$

Notice that this specification implies that the standard deviation of entrepreneur productivity prior to their funding decision - what also corresponds to the standard deviation of productivity conditional on funding with bonds, is left unchanged after a shock ν_t .

Financial Contracts.—The model assumes the existence of a continuum of risk-neutral financial intermediaries of each type, bank b or market c , able to fully diversify risk among entrepreneurs. After the realization of the first two idiosyncratic shocks, an entrepreneur e and a financial intermediary agree on a standard debt contract conditional on the expected productivity of the contracting entrepreneur ε_{et}^f , where:

$$\varepsilon_{et}^f = \begin{cases} \varepsilon_{1,et} & , \text{ if bond financing} \\ \varepsilon_{1,et}\varepsilon_{2,et} & , \text{ if loan financing.} \end{cases}$$

Denoting $\varphi(\omega_{et}^f; \sigma_t^f)$ and $\Phi(\omega_{et}^f; \sigma_t^f)$ the distribution and cumulative density functions of ω_{et}^f implied by the distributional assumptions for the idiosyncratic shock distributions and given an optimal threshold $\bar{\omega}$, the expected share of final output accruing to a contracting entrepreneur is:

$$v(\bar{\omega}; \sigma) = \int_{\bar{\omega}}^{\infty} (\omega - \bar{\omega})\varphi(\omega; \sigma)d\omega,$$

and the expected share of final output accruing to the lender is:

$$g(\bar{\omega}; \sigma) = \int_0^{\bar{\omega}} (1 - \mu)\omega\varphi(\omega; \sigma)d\omega + \bar{\omega}[1 - \Phi(\bar{\omega}; \sigma)].$$

The optimal contract chosen by an entrepreneur sets a threshold $\bar{\omega}_{et}^f$ under which monitoring occurs and maximizing the expected fixed repayment $\varepsilon_{et}^f \bar{\omega}_{et}^f q_t x_{et}$ paid to the financial intermediary subject to the constraint defined by equation 3.4 and,

$$\varepsilon_{et}^f q_t g(\bar{\omega}_{et}^f, \sigma_t^f) x_{et} \geq (x_{et} - n_{et}^f) R_t, \quad (3.11)$$

$$v(\bar{\omega}_{et}^f, \sigma_t^f) + g(\bar{\omega}_{et}^f, \sigma_t^f) \leq 1 - G_{\omega}^f(\bar{\omega}_{et}^f, \sigma_t^f), \quad (3.12)$$

$$\varepsilon_{et}^f q_t v(\bar{\omega}_{et}^f, \sigma_t^f) x_{et} \geq n_{et}^f, \quad (3.13)$$

where $G_{\omega}^f(\bar{\omega}_t^f, \sigma_t^f) = \mu^f \int_0^{\bar{\omega}_t^f} \omega\varphi(\omega, \sigma_t^f) d\omega$ is the share of output lost to monitoring. Equation 3.11 implies that financial intermediary expected returns must exceed repayment for households, equation 3.12 ensures the feasibility of the debt contract, and equation 3.13 guarantees the entrepreneur's willingness to borrow from a financial intermediary. Notice that because the problem of the entrepreneur is linear in net worth, the optimal solution implies that each entrepreneur invests all or none of her net worth.

Under optimal contracts and assuming free entry for financial intermediaries such that equation 3.11 is always binding, the optimal threshold $\bar{\omega}_{et}^f$ is given as the minimal solution to:

$$g(\bar{\omega}_{et}^f, \sigma_t^f) = \left(\frac{\xi - 1}{\xi} \right) \frac{R_t}{\varepsilon_{et}^f q_t}. \quad (3.14)$$

This equation can be used to implicitly define thresholds $\bar{\omega}_{et}^f$ as functions of aggregate variables q_t, R_t, ν_t and idiosyncratic expected productivity $\varepsilon_{et}^f q_t$ such that:

$$\bar{\omega}_{et}^f = \begin{cases} \bar{\omega}^c(\varepsilon_{1,et}, q_t, R_t) & , \text{ if bond financing} \\ \bar{\omega}^b(\varepsilon_{1,et} \varepsilon_{2,et}, q_t, R_t, \nu_t) & , \text{ if loan financing,} \end{cases}$$

where it can be seen from equation 3.14 that $\bar{\omega}_{et}^f$ is increasing in R_t and decreasing in q_t, ν_t and ε_{et} .

Funding Choices.—Following De Fiore and Uhlig (2011) it is possible to prove the existence and uniqueness of thresholds in the realization of idiosyncratic productivity shocks characterizing entrepreneur funding decisions.

Consider an entrepreneur e having contracted with a bank in period t . After having observed the realization of the second idiosyncratic shock $\varepsilon_{2,et}$, this entrepreneur decides to proceed with its loan only if her expected share of profit is higher than the opportunity cost of producing, what corresponds to her net worth. Defining $V^d(\varepsilon_{1,et}, \varepsilon_{2,et}, q_t, R_t, \nu_t)n_{et}^b$ the expected output share accruing to entrepreneur e , this yields:

$$V^d(\varepsilon_1, \varepsilon_2, q, R, \nu) = \varepsilon_1 \varepsilon_2 q v(\bar{\omega}^b(\varepsilon_1 \varepsilon_2, q, R, \nu)). \quad (3.15)$$

Conditional on the realization of $\varepsilon_{1,et}$ and aggregate factors, entrepreneur e proceeds with bank finance only if the realization of $\varepsilon_{2,et}$ is higher than a threshold $\bar{\varepsilon}_d(\varepsilon_{1,et}, q_t, R_t, \nu_t)$ satisfying:

$$1 = V^d(\varepsilon_{1,et}, \bar{\varepsilon}_{2,et}, q_t, R_t, \nu_t). \quad (3.16)$$

The funding decision of an entrepreneur having observed $\varepsilon_{1,et}$ can be deduced similarly by comparing her expected payoffs conditional on her funding choice. The expected payoff for an entrepreneur proceeding with bank finance conditional on the realization of $\varepsilon_{1,et}$ is $V^b(\varepsilon_{1,et}, q_t, R_t, \nu_t)n_{et}^b$ where:

$$V^b(\varepsilon_1, q, R, \nu) = (1 - \tau^b) \left(\int_{\bar{\varepsilon}_d} V^d(\varepsilon_1, \varepsilon_2, q, R, \nu) \Phi(d\varepsilon_2) + \Phi(\bar{\varepsilon}_d(\varepsilon_1, q, R, \nu)) \right). \quad (3.17)$$

Similarly, the expected payoff for an entrepreneur proceeding with bond finance conditional on $\varepsilon_{1,et}$ is $V^c(\varepsilon_{1,et}, q_t, R_t)n_{et}^c$ where:

$$V^c(\varepsilon_1, q, R) = \varepsilon_1 q v(\bar{\omega}^c(\varepsilon_1, q, R))\xi. \quad (3.18)$$

Finally, the expected payoff for an entrepreneur abstaining from production is n_{et} . Conditional on $\varepsilon_{1,et}$ each entrepreneur selects the funding option delivering the maximum expected payoff $V(\varepsilon_{1,et}, q_t, R_t)n_{et}$ defined as:

$$V(\varepsilon_1, q, R, \nu) = \max\{1, V^b(\varepsilon_1, q, R, \nu), V^c(\varepsilon_1, q, R)\}. \quad (3.19)$$

Under the conditions that $\frac{\partial V^b(\cdot)}{\partial \varepsilon_1} \geq 0$ and $\frac{\partial V^c(\cdot)}{\partial \varepsilon_1} > \frac{\partial V^b(\cdot)}{\partial \varepsilon_1}$, it can be shown that there exists a unique threshold $\bar{\varepsilon}^b$ for ε_1 implicitly defined by the condition $V^b(\bar{\varepsilon}_{b,t}, q_t, R_t, \nu_t) = 1$ and under which entrepreneurs do not rise external finance. Because this cutoff point depends only on aggregate variables such that $\bar{\varepsilon}_{b,t} = \bar{\varepsilon}_b(q_t, R_t, \nu_t)$, it is identical across all entrepreneurs. Similarly, there exists a unique threshold $\bar{\varepsilon}^c$ for ε_1 above which entrepreneurs prefer to fund from markets and implicitly defined by the condition $V^b(\bar{\varepsilon}_{c,t}, q_t, R_t, \nu_t) = V^c(\bar{\varepsilon}_{c,t}, q_t, R_t)$ such that: $\bar{\varepsilon}_{c,t} = \bar{\varepsilon}_c(q_t, R_t, \nu_t)$. Conditional on q_t, R_t , and ν_t entrepreneurs split into three distinct sets mapping the realization of the first idiosyncratic productivity shock $\varepsilon_{1,et}$ to their optimal funding choice.

Defining s_t^a, s_t^b, s_t^c and s_t^{bp} respectively the shares of entrepreneurs that abstain from production, contract with banks, proceed with bonds and proceed with bank loans, I obtain:

$$s_t^a = \Phi(\bar{\varepsilon}^b(q_t, R_t, \nu_t)), \quad (3.20)$$

$$s_t^b = \Phi(\bar{\varepsilon}^c(q_t, R_t, \nu_t)) - \Phi(\bar{\varepsilon}^b(q_t, R_t, \nu_t)), \quad (3.21)$$

$$s_t^c = 1 - \Phi(\bar{\varepsilon}^c(q_t, R_t, \nu_t)), \quad (3.22)$$

$$s_t^{bp} = \int_{\bar{\varepsilon}^b(q_t, R_t, \nu_t)}^{\bar{\varepsilon}^c(q_t, R_t, \nu_t)} \int_{\bar{\varepsilon}^d(\varepsilon_1, q_t, R_t, \nu_t)} \Phi(d\varepsilon_2) \Phi(d\varepsilon_1). \quad (3.23)$$

Financial Variables.—Using the productivity thresholds $\bar{\varepsilon}_t^b$ and $\bar{\varepsilon}_t^c$, it is possible to express entrepreneur average risk premia and default rates conditional on entrepreneur funding decisions. Denoting respectively ψ_t^{mb} and ψ_t^{mc} the default rates for bank-funded and market-funded firms yields:

$$\psi_t^{mb} = \int_{\bar{\varepsilon}_b(q, R, \nu)}^{\bar{\varepsilon}_c(q, R, \nu)} \int_{\bar{\varepsilon}_d(\varepsilon_1, q, R, \nu)} \Phi(\bar{\omega}^b(\varepsilon_1 \varepsilon_2, q, R, \nu)) \Phi(d\varepsilon_2) \Phi(d\varepsilon_1), \quad (3.24)$$

$$\psi_t^{mc} = \int_{\bar{\varepsilon}_c(q, R, \nu)} \Phi(\bar{\omega}^c(\varepsilon_1, q, R, \nu)) \Phi(d\varepsilon_1). \quad (3.25)$$

With expected fixed repayment for the financial intermediary being $\varepsilon_{et}^f \bar{\omega}_{et}^f q_t$ per unit of fund x_t , the credit spread for an entrepreneur e writes:

$$\Lambda_{e,t}^f = \frac{\xi}{\xi - 1} \frac{q_t \varepsilon_{e,t}^f \bar{\omega}_{e,t}^f}{R_t} - 1. \quad (3.26)$$

Denoting ψ_t^{rb} and ψ_t^{rc} the aggregate realizations of entrepreneur credit spreads for bank-funded and market-funded firms:

$$\psi_t^{rb} = \int_{\bar{\varepsilon}_b(q,R,\nu)}^{\bar{\varepsilon}_c(q,R,\nu)} \int_{\bar{\varepsilon}_d(\varepsilon_1,q,R,\nu)} \left\{ \frac{\xi}{\xi-1} \frac{\varepsilon_1 \varepsilon_2 \bar{\omega}_{e,t}^b q_t}{R_t} - 1 \right\} \Phi(d\varepsilon_2) \Phi(d\varepsilon_1), \quad (3.27)$$

$$\psi_t^{rc} = \int_{\bar{\varepsilon}_c(q,R,\nu)} \left\{ \frac{\xi}{\xi-1} \frac{\varepsilon_1 \bar{\omega}_{e,t}^c q_t}{R_t} - 1 \right\} \Phi(d\varepsilon_1). \quad (3.28)$$

Finally, it is possible to express Λ_t^b the average spread for bank-financed firms and Λ_t^c the average spread for bond-financed firms express as:

$$\Lambda_t^b = \frac{\psi_t^{rb}(q, R, \nu)}{s_t^{bp}}, \quad (3.29)$$

$$\Lambda_t^c = \frac{\psi_t^{rc}(q, R, \nu)}{s_t^c}. \quad (3.30)$$

Aggregation.—Integrating across entrepreneurs for the first order conditions 3.8 and 3.9 yields aggregate capital and labor demands:

$$h_t = (1 - \alpha) \frac{x_t}{w_t}, \quad (3.31)$$

$$k_t = \alpha \frac{x_t}{r_t^k}. \quad (3.32)$$

Using equations 3.3 and 3.10 yields entrepreneur final aggregate production:

$$\begin{aligned} Y_t^E &= \int_0^1 Y_{et}^E de, \\ &= \frac{\psi_t^y \xi n_t}{s_t}, \end{aligned}$$

where n_t corresponds to the aggregate entrepreneur net worth and variable ψ_t^y aggregates the realizations of the different idiosyncratic productivity shocks of period t into a single productivity factor similarly. The aggregate profits of entrepreneurs Π_t^E are defined as:

$$\Pi_t^E = \psi_t^V n_t, \quad (3.33)$$

where ψ_t^V is defined in section VIII of the appendix and aggregates the overall profits across all entrepreneurs. Each period, a share $1 - \gamma$ of entrepreneur past period profits is transferred to households as dividends o_t . The rest of the profits are accumulated as net worth with the following law of motion:

$$n_t = \gamma \psi_{t-1}^V n_{t-1}, \quad (3.34)$$

accordingly, the dividends redistributed to households evolve as:

$$o_t = (1 - \gamma) \psi_{t-1}^V n_{t-1}. \quad (3.35)$$

Retailers

Retailers are monopolistically competitive firms indexed by $j \in [0, 1]$. They produce differentiated final goods Y_{jt} using the following linear homogeneous technology:

$$Y_{jt} = Y_{jt}^E,$$

where Y_{jt}^E is the quantity of the intermediate goods used by retailers j as an input and purchased to entrepreneurs in competitive markets at price P_t^E . Assuming Calvo staggered price contracts, $1 - \xi_p$ denotes the probability for a retailer to be able to readjust her price each period. Retailers unable to reoptimize their prices follow an indexation rule defined as: $P_{jt} = (\pi)^{\iota_p} (\pi_{t-1})^{1-\iota_p} P_{jt-1}$, where ι_p is a parameter.

Final Good Producers

A representative final good producer combines intermediate goods Y_{jt} into homogeneous final goods Y_t using the following technology:

$$Y_t = \int_0^1 \left[Y_{jt}^{\frac{1}{\lambda^p}} \right]^{\lambda^p}, \lambda^p > 1,$$

where λ^p is the markup set over the intermediate good price P_t^E . The first order conditions for profit maximization by final goods producers imply the following demand schedule:

$$P_{jt} = P_t \left(\frac{Y_{jt}}{Y_t} \right)^{\frac{\lambda^p}{\lambda^p - 1}}, \quad j \in [0, 1],$$

where P_{jt} is the price of good Y_{jt} and where P_t is the price of the final good which satisfies the following relation:

$$P_t = \left[\int_0^1 P_{jt}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}. \quad (3.36)$$

C. Monetary Authority

The monetary authority sets the nominal interest rate according to a standard Taylor rule expressed in linearized form as:

$$R_t - R = \rho_p (R_{t-1} - R) + (1 - \rho_p) \left[\alpha_\pi (E\pi_{t+1} - \pi) + \frac{\alpha_{\Delta y}}{4} g_{y,t} \right] + \frac{1}{400} \epsilon_t^p, \quad (3.37)$$

where ϵ_t^p is a monetary policy shock expressed in annual percentage points, and ρ_p is a smoothing parameter of the policy rule. Also, $R_t - R$ is the deviation of the net quarterly interest rate, R_t , from its steady-state value R , and α_π and $\alpha_{\Delta y}$ are Taylor rule coefficients for the rate of expected quarterly inflation $E\pi_{t+1} - \pi$ and for the quarterly GDP growth $g_{y,t}$.

D. Aggregates and Cost Functions

The aggregate resource constraint of the economy writes:

$$Y_t = c_t + I_t^k + a(u_t)k_t + y_t^a, \quad (3.38)$$

where y_t^a corresponds to the resources consumed in monitoring and in bank-specific information acquisition costs:

$$y_t^a = [\tau^b s_t^b + \psi_t^m \xi q_t] n_t. \quad (3.39)$$

Here ψ_t^m is the entrepreneur aggregate rate of default defined in section VIII of the appendix. Aggregate funds raised by entrepreneurs are obtained by integrating individual

funds over the continuum of entrepreneurs, what yields:

$$x_t = \left[(1 - \tau^b) s_t^{bp} + s_t^c \right] \xi n_t. \quad (3.40)$$

Similarly the aggregate external debt raised by entrepreneurs d_t is given by:

$$d_t = \left[(1 - \tau^b) s_t^{bp} + s_t^c \right] (\xi - 1) n_t. \quad (3.41)$$

The utilization cost function and investment adjustment cost function are taken from Christiano, Motto, and Rostagno (2014). The utilization function is a convex and increasing function defined as:

$$a(u) = r^k \left[\exp(\sigma_a(u - 1)) - 1 \right] \frac{1}{\sigma_a}. \quad (3.42)$$

This formulation implies a unitary value for the steady-state capital utilization which is independent of the value of the curvature parameter σ_a , where $\sigma_a > 0$. The variable r^k corresponds to the steady-state level of capital rental rate. The investment adjustment cost function writes:

$$S(\eta_t) = \frac{1}{2} \left[\exp \left(\sqrt{S''/2}(\eta_t - \eta) \right) + \exp \left(-\sqrt{S''/2}(\eta_t - \eta) \right) - 2 \right],$$

where $\eta_t = \zeta_{I,t} I_t^k / I_{t-1}^k$. Note that this implies $S(\eta) = S'(\eta) = 0$ and $S''(\eta) = S''$ which is a parameter.

E. Shock Processes

The model includes four different shock processes, $A_t, \zeta_t^c, \zeta_t^i$, and ν_t corresponding respectively to technology, preference and marginal efficiency of investment shocks. The shock ν_t is a financial shock affecting the efficiency of banks to limit firm asymmetric information problem and whose properties are discussed later. All shocks follow standard autoregressive processes of degree one. Hence a generic exogenous variable x_t writes as:

$$\log \left(\frac{x_t}{x} \right) = \rho_x \log \left(\frac{x_{t-1}}{x} \right) + \epsilon_t^x \text{ and } \epsilon_t^x \sim N(0, \sigma_x).$$

In addition, exogenous shifts in monetary policy are captured by innovations ϵ_t^p which are assumed iid and normally distributed. The model is linearized and simulated locally around its steady state. The next section discusses the calibration of the model.

III. Calibration and Model Properties

This section presents the calibration and static properties of the model and discusses the impulse responses for the different aggregate shocks.

A. Model Calibration

Using a calibrated version of the model, I investigate the evolution of firm debt structure in response to different types of aggregate shocks. There are 25 parameters in total. Most of the parameters are standard in the DSGE literature and are calibrated based on conservative values. Parameter α is set at 0.37 to target a labor share around 60 percent as observed for US non-financial corporate firms in Karabarbounis and Neiman (2014). The depreciation rate δ is set at 0.025 to obtain an annual depreciation rate of capital stock around 10 percent. Household discount factor β is set to 0.99 to pin down a policy rate of 4 percent, corresponding to the average annualized federal funds rate since the '80s. Following Christiano, Eichenbaum, and Evans (2005), I set price and wage markups, λ^p and λ^w respectively to 1.2 and 1.1. The subsidy rate on the purchase of intermediate goods is set to 0.17 to equate the price of the intermediate goods to the price of the final goods.⁴ The inverse of the Frisch elasticity σ^L and the labor disutility ψ^L are set respectively to 1 and 0.68 to normalize steady-state hours to unity. Parameters for the Taylor rule coefficients, price and wage stickiness, cost curvature and habit consumption are calibrated so as to lie within posterior densities obtained estimating medium-scale New-Keynesian models for the US over the past thirty years.⁵ Calibration for these parameters is summarized in table 3.1.

Parameters for the financial sector and idiosyncratic productivity distributions are less usual and are calibrated to jointly match the characteristics of intermediated and direct

⁴Because profit maximization for the final good producer under flexible prices yields: $P_t = \lambda^p(1-\tau^y)P_t^E$, this implies $\tau^y = 1 - \frac{1}{\lambda^p}$.

⁵See for instance Smets and Wouters (2007), Justiniano, Primiceri, and Tambalotti (2011), Christiano, Motto, and Rostagno (2014) and Bécard and Gauthier (2018).

Param.	Description	Value
α	Capital share	0.37
β	Discount factor	0.99
δ	Depreciation rate	0.025
λ^p	Price markup	1.2
λ^w	Wage markup	1.1
ψ^L	Labor disutility	0.68
σ^L	Frish elasticity	1
τ^y	Retailers subsidy	0.17
$a_{\Delta y}$	Taylor rule output coefficient	0.3
a_{π}	Taylor rule inflation coefficient	2
ρ_p	Taylor rule smoothing	0.7
ξ_p	Calvo price stickiness	0.6
ξ_w	Calvo wage stickiness	0.6
l_p	Price indexation on inflation target	0.3
l_w	Wage indexation on inflation target	0.3
σ_a	Utilization cost curvature	2
S''	Invest. adjustment cost curvature	2.5
b	Consumption habit	0.3

Table 3.1: Calibrated Parameters

debt for US non-financial corporate firms. Table 3.3 displays the targeted financial variables and their model counterparts. The calibration for financial parameters is summarized in table 3.2. These parameters are set to match the loan-to-bond and the debt-to-equity ratios computed using data from the Flow of Funds Accounts for non-financial US corporate firms over the period 1985 to 2018. Their average values amount respectively to 0.42 and 0.43 with the ratio of loans over bonds increasing to 0.66 when removing the 2007 crisis period from the sample. The risk premium for loans is calculated using the

Param.	Description	Value
τ^b	Bank intermediation costs	0.0116
ξ	Steady-state leverage	1.98
$1 - \gamma$	Dividend rate	0.11
μ^b	Bank monitoring cost	0.131
μ^c	Market monitoring cost	0.111
σ_1	Idiosyncratic shock dispersion	0.136
σ_2	Idiosyncratic shock dispersion	0.113
σ_3	Idiosyncratic shock dispersion	0.357

Table 3.2: Calibrated Parameters (Financial)

Survey on Term Business Lending from the Federal Reserve Board as the spread between

the interest rate for commercial and industrial loans over 1 million dollars and the federal funds rate. I find a 1.9 percent annual mean spread over the 1986 to 2017 period. Following De Fiore and Uhlig (2011) I take the average Moody’s 12-months default rate for speculative-grade non-financial corporations rated over the period 1999 to 2007 as a proxy for the model bond default rate. The default rate for corporate loans comes from Emery and Cantor (2005) who show that the average default rate for loans has been approximately 20 percent lower than the average default rate for bonds.⁶ Except for the ratio of loan-to-bond which is slightly higher than its observed counterpart the model is able to accurately replicate all the above financial facts.

Variable	Description	Model	Data
l/b	Loan-to-bond ratio	0.689	0.42
d/n	Debt-to-equity Ratio	0.437	0.43
Δ^c	Risk premium for bonds	1.36	1.43
Δ^b	Risk premium for loans	1.92	1.88
F^c	Delinquency rate for bonds	5.77	5.37
F^b	Delinquency rate for loans	4.06	4.3

Table 3.3: Financial Facts - Model vs Data

Note: Default rates and risk premia are expressed in annualized percentage points.

B. Firm Funding Decisions

Before presenting the dynamic implications of the model, I illustrate the relationship between entrepreneurs’ expected productivity and their funding decisions in the static model. The upper panel in figure 3.2 displays expected profits for an entrepreneur conditional on her funding decisions and on the realization of the idiosyncratic shock ε_1 . The lower panel displays the density of the idiosyncratic shock ε_1 . The grey, orange, and blue areas correspond respectively to the shares of entrepreneurs abstaining from production, contracting with banks and funding from markets. Entrepreneurs with intermediate expected productivity contract with banks while those with high expected productivity prefer to fund from markets. The reason is that entrepreneurs with low expected pro-

⁶Their study covers the period 1995 to 2003. Their results are confirmed by more recent evidence presented in Lonski (2018).

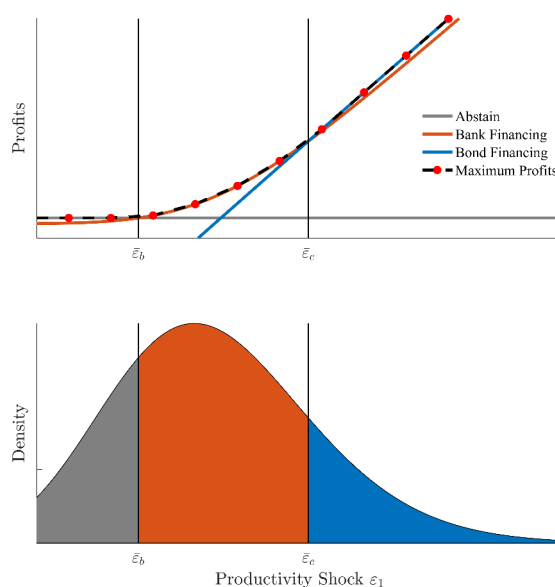


Figure 3.2: Firm Funding Decisions.

Note: The first panel corresponds to the expected profits of entrepreneurs depending on their funding choices and conditional on the realization of the first idiosyncratic shock ε_1 which density is displayed in the second panel.

ductivity have a higher probability of default and prefer to hedge their net worth from processing risks by not producing or by entering into renegotiable contracts with banks. On the other hand, entrepreneurs with high productivity and low risk of default are better off funding from markets and avoiding intermediation costs. This mapping between entrepreneurs' expected productivity and their funding decision implied by the model is coherent with the evidence presented in Denis and Mihov (2003). Based on firm-level data for US corporations, they show that the credit quality of the issuer is the primary determinant of firm debt structure with most productive firms funding from markets and firms with lower credit quality funding from banks.⁷ Also, because maximum expected profits are a monotonic function of net worth, the model rules out the possibility that entrepreneurs obtain funds simultaneously from markets and banks. This implicit assumption of debt specialization is backed by the evidence presented in Colla, Ippolito, and Li (2013) who show that 85 percent of US-listed firms have recourse only to one type of debt.

⁷Adrian, Colla, and Song Shin (2013) also stress the importance of credit quality as a determinant of firms' debt structure.

C. Model Dynamics and the Debt Structure

This subsection presents the dynamic implications of various macroeconomic shocks. An important result is that only the responses of direct and intermediated debt allow to qualitatively distinguish financial shocks from other macroeconomic shocks.

The Financial Shock

I start with the presentation of the bank efficiency shock ν_t . Figure 3.3 displays impulse responses for the main variables. The bank efficiency shock reduces the asymmetric information problem of banks by lowering the share of unknown idiosyncratic productivity for bank-funded entrepreneurs. Because financial contracts in the model imply that financial intermediaries only take on downside risk, a lower dispersion of idiosyncratic productivity for bank-funded entrepreneurs increases the expected share of output accruing to banks. Due to competition among financial intermediaries resulting in zero profits, bank-funded entrepreneurs can pledge a lower fraction of their profits to banks, what increases their expected payoff. In contrast, the expected payoff for abstaining and market-funded entrepreneurs is unchanged. As a result, entrepreneurs that were indifferent between not producing and contracting with a bank or indifferent between contracting with a bank and borrowing from markets now favor bank finance.

With the share of market-funded entrepreneurs decreasing and the share of entrepreneurs funding with bank loan rising - the extreme case being if none of the entrepreneurs switching to bank finance decide to proceed with their loan, the financial shock generates opposite movements in the shares of bank and bond-funded entrepreneurs. Because net worth is a predetermined variable, the initial change in the total level of debt of an entrepreneur can only be accounted for by changes in their debt composition. Overall, the total level of debt increases as the proportion of abstaining entrepreneurs switching to bank finance and proceeding with their loan outweigh the share of entrepreneurs switching from market finance to bank finance and *not* proceeding with their loan. As funds available to entrepreneurs move up, demand for labor and capital inputs increases along with wages and the capital rental rate. The marginal cost of production goes up. Output, investment, consumption and hours increase along with the capital price, inflation, and the policy rate. Upward shifts in the policy rate and in the marginal cost of production dampen the debt increase as it pushes up funding and

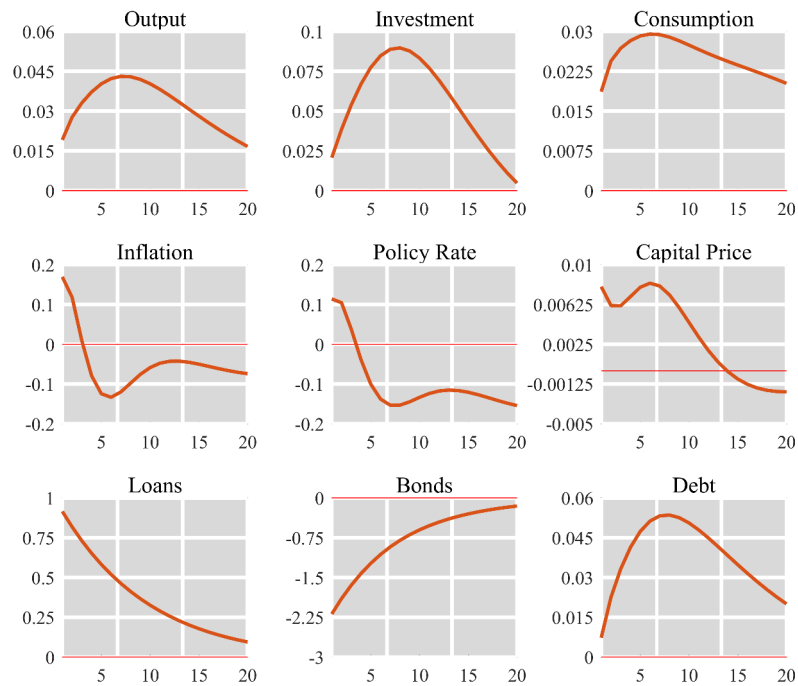


Figure 3.3: Responses to a Bank Efficiency Shock.

Note: All series are expressed in deviation from steady-state in percentage points. Inflation and the policy rate responses are expressed in basis points.

production costs. On the other hand, because entrepreneurs' aggregate profits react positively to the fall in aggregate uncertainty triggered by the financial shock, aggregate net worth accumulates, feeding up next period borrowing through the leverage constraint. Following the reduction in the risk of bank-funded entrepreneurs, the risk borne by bond holders also declines as only the least productive of market-funded entrepreneurs switch to bank funding. This leads to a fall in risk premia for the two types of debt. Overall the financial shock pushes firms to substitute loans for bonds and triggers a rise in output and in debt.⁸

⁸Here I focus on a bank efficiency shock ν_t but other financial shocks embedded in the model have similar qualitative implications. This is the case for instance for an exogenous shock to the financial intermediation costs τ^b or to the dividend rate δ . As for a bank efficiency shock, these shocks imply a simultaneous increase in output and loans and a fall in bonds.

Macroeconomic Shocks

Without detailing impulse responses for other shocks, it is important to notice that non-financial shocks transmit differently to entrepreneur funding decisions in comparison to financial shocks. Figure 3.4 presents impulse responses following technology, preference, investment, and monetary shocks. First, notice that the introduction of debt arbitrage in the NK framework does not modify its qualitative implications. The signs of the impulse responses for non-financial shocks correspond to those described in Peersman and Straub (2006). A common feature of these different shocks is that they all generate co-movement in output, loans, and bonds. Two effects are at play. Because all these shocks imply a fall in entrepreneurs' marginal cost of production, their profitability increases. This pushes up net worth and increases entrepreneur demand for the two types of debt. Loans and bonds increase altogether. On the other hand, the decline in the marginal cost of production reduces entrepreneurs processing risk and modifies their funding decisions. Some entrepreneurs abstaining from production are better off producing after the shock is realized. Hence, the shares of entrepreneurs abstaining from production or not proceeding with bank loan decrease. On the other hand, some entrepreneurs that were contracting with a bank prior to the shock now prefer to avoid intermediation costs and switch to market finance. Overall the share of abstaining entrepreneurs decreases and both the share of market-funded entrepreneurs and the share of entrepreneurs proceeding with bank loans increase. Following non-financial shocks, both bond and loan volumes co-move with output.

Section IX of the appendix presents impulse responses from the model calibrated with different combinations of parameters. The signs of the responses for output, loans and bonds to financial and other aggregate shocks are robust to various parameter specifications. Comparing impulse responses for the different types of shock, it exists no robust qualitative differences between demand and financial shocks other than the response of bonds. The reason is that even with standard parameter values, investment can actually increase in response to a positive preference shock. In that case, investment and preference shocks have the same qualitative characteristics. In the next section, I use the qualitative features implied by the NK model to inform a sign-restriction VAR and identify financial shocks based on loan and bond fluctuations.

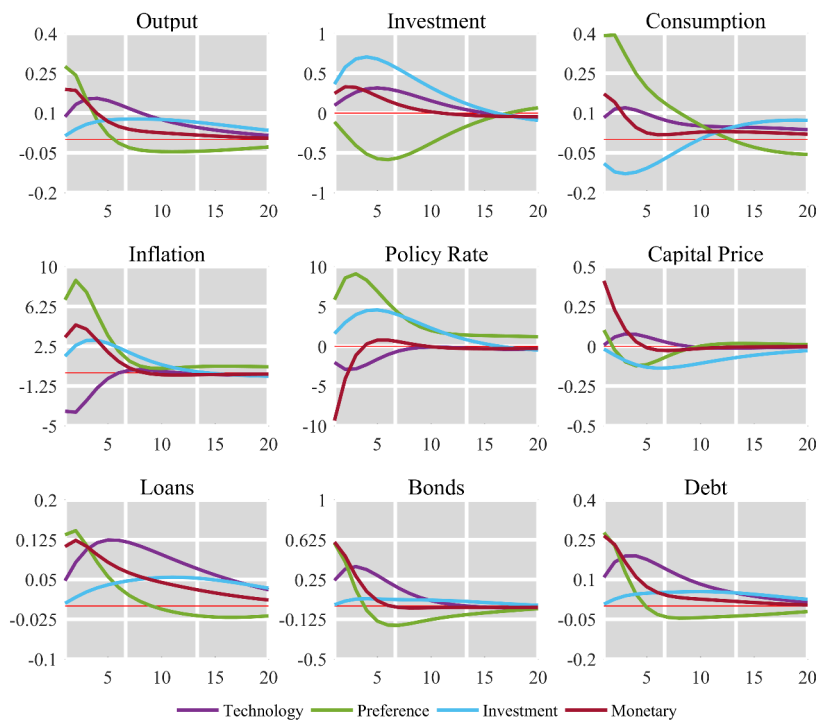


Figure 3.4: Responses to Non-Financial Shocks.

Note: All series are expressed in deviation from steady-state in percentage points. Inflation and the policy rate responses are expressed in basis points.

IV. Empirical Analysis

This section presents results from a sign-restriction VAR model used to characterize financial shocks and evaluate their business cycle implications.

A. The Sign-Restriction VAR

I implement the qualitative features of the different shocks implied by the modified NK model in a sign-restriction Bayesian VAR estimated with quarterly US data for the period 1985 to 2018. The data set includes the gross domestic product, the ratio of investment-over-GDP, the GDP implicit price deflator and the annualized effective federal funds rate. I take outstanding loan and bond volumes for corporate non-financial firms to track the evolution of firm debt composition. Loan series includes loans from depository institutions and mortgage loans. Bond series includes both bonds and commercial papers.

All series are seasonally adjusted and expressed in log-levels except for the federal funds rate. The series are displayed in section VII of the appendix. The model is estimated using a lag order of two what minimizes the Bayesian information criterion and the Hannan-Quinn information criterion.⁹ The estimation of the model involves two separate steps. The first step is to estimate a reduced form Bayesian VAR model. I then use the algorithm presented in Rubio-Ramirez, Waggoner, and Zha (2010) to generate candidate impulse responses and retain models satisfying the sign-restrictions imposed until a sufficient number of draws are obtained. Section VII of the appendix contains a more detailed presentation of the econometric methods used to estimate the Bayesian VAR model and retain the models that satisfy the imposed sign-restrictions.

	<i>Supply</i>	<i>Demand</i>	<i>Investment</i>	<i>Monetary</i>	<i>Financial</i>
GDP	+	+	+	+	+
Prices	-	+	+	+	?
Interest rate	?	+	+	-	?
Investment / Output	?	-	+	?	?
Loans	+	+	+	+	+
Bonds	+	+	+	+	-

Table 3.4: Sign-Restrictions

Note: Sign-restrictions imposed for the BVAR estimation. The restrictions are imposed on impact only. The presence of a question mark indicates the absence of restriction.

I consider five types of structural shocks identified based on the signs of the impulse responses on impact for the different variables. A sixth shock is left unrestricted to add a degree of freedom to the estimation. The restrictions imposed and the series used are chosen so as to classify shocks into five broad categories - supply, demand, investment, monetary and financial. These capture most of the shocks found in the business cycle literature as well as the shocks present in the modified NK model.¹⁰ The sign-restrictions

⁹The model is also estimated with a lag order of four. While impulse responses for the different shocks appear robust to this modification, the share of output and inflation variance explained by demand shocks increases slightly relative to supply shocks.

¹⁰The sign-restrictions imposed also lies in the intervals of robust impulse responses derived by Canova and Paustian (2011) based on a variety of DSGE models. This is true except for the response of interest rate to a supply shock which is left unrestricted. This is to take into account the fact that the sign of the interest rate response to a supply shock hinges on the degree of price stickiness as shown by Peersman and Straub (2009).

imposed are summarized in table 3.4. Supply shocks are identified as implying opposite movements in output and prices. Demand and investment shocks generate co-movement in output and prices and respectively negative and positive impacts on the investment-to-output ratio. Monetary shocks generate opposite responses in the policy rate and output and prices. Finally, in conformity with the predictions of the NK model, I assume that all these shocks generate co-movements in output, loans, and bonds. The sign-restrictions imposed for financial shocks are less usual. They are identified as the only type of shock that can simultaneously generate co-movements in output and loans and opposite movements in output and bonds. As I do not impose any restrictions on the responses of inflation, interest rate and the investment-to-output ratio responses conditional to a financial shock, these can be used as a simple test for the overidentifying predictions of the VAR model.

B. Empirical Results

This section presents the results from the VAR model, I focus on the characteristics of financial shocks and how they relate to financial shocks identified using different econometric methods.

What Financial Shocks Do

Figure 3.5 displays the median impulse responses following a one standard deviation financial shock. The grayed-area corresponds to the 16th and 84th quantiles. The response of output following a financial shock is short-lived with a duration shorter than 10 quarters before returning to zero. While left unrestricted, the impact of the investment-to-output ratio is positive and twice as strong as for output with a similarly short duration. In comparison, the impact on loans takes more than 15 quarters to fade out and is nearly 5 times stronger than for output. The maximum impact is reached after 10 quarters with a value close to 2 percent. The fall in bonds is twice weaker than the increase in loans and peaks more rapidly after only 5 quarters. The federal funds rate which is left unrestricted in the estimation exhibits a large positive hump-shaped response which dies out after 10 quarters. I also find the response of inflation to be weak and positive following a financial shock. The responses of the policy rate and inflation are consistent with a large body of empirical and theoretical evidence. Schularick and Taylor (2009) present international ev-

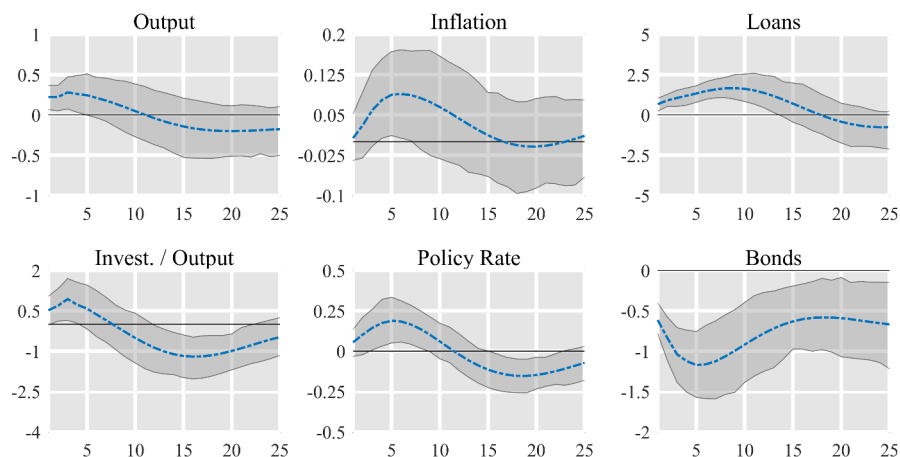


Figure 3.5: Responses to a Financial Shock.

Note: Median impulse responses to a one standard deviation financial shock. The grey area corresponds to the 16th and 84th quantiles. All series are expressed in percentage points. Inflation and the policy rate are annualized.

idence of aggressive monetary policy in response to financial shocks during the postwar era. Using a set of estimated DSGE models, Cesa-Bianchi and Sokol (2017) find that the policy rate systematically decreases in response to adverse financial shocks. Gertler and Karadi (2011) also show that expansionary financial shocks which relax firms' borrowing constraints can lead to inflationary pressures.

While financial shocks are identified restricting only responses for output, loans and bonds, the responses for the investment-to-output ratio, the policy rate and inflation match the dynamics implied by financial shocks in most DSGE model.¹¹ The median impulse responses for the other shocks are displayed in section XI of the appendix.

Aggregate Shocks and the Business Cycle

Figure 3.6 displays the median historical shock decomposition for output smoothed over 2 quarters. Even though financial shocks play the leading role over the whole estimation period, all three recessions contained in the sample are associated with different types of perturbations.

According to the model estimates, the outset of the 90's recession is dominated by a

¹¹See for instance Gertler and Kiyotaki (2010), Christiano, Motto, and Rostagno (2014) and Boissay, Col-lard, and Smets (2016).

combination of demand and supply shocks increasing from 1990 onward. Walsh (1993) and Blanchard (1993) stress the strong role of adverse demand shocks in the early 90's recession.¹² In contrast, the model attributes the fluctuations of output in 1993 and 1998 to financial shocks. Interestingly the two periods coincide with the Japanese bank crisis and the LTCM Russian crisis. These two events are described respectively by Peek and Rosengren (2000) and Chava and Purnanandam (2011) as examples of credit supply shocks affecting non-financial firms via their negative impact on US bank equity. The recession of the early 2000s is also associated with financial as well as monetary and demand factors.¹³ Perhaps more surprising, the model attributes only a limited role to finan-

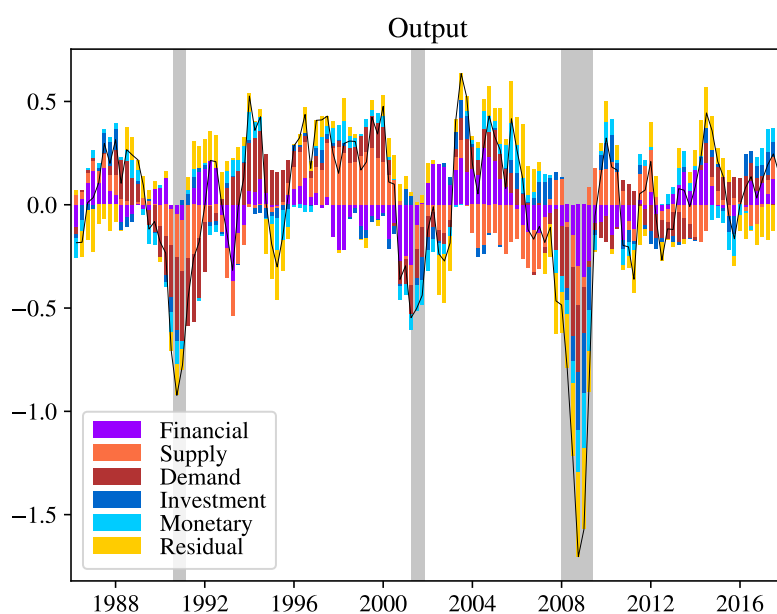


Figure 3.6: Historical Shock Decomposition for GDP.

Note: The GDP is expressed in quarterly growth and smoothed over 2 quarters.

¹²The role of oil shocks and the Iraq war in the 90's recession is more controverted. Kilian and Vigfusson (2017) find a significant impact of oil shocks on US activity when using net oil price - the difference of oil price with its peak value over the 12 previous months, instead of a standard linear model. Hamilton (2009) studies the impact of oil shocks on the auto industry between 1990Q1 and 2007Q4. He finds a significant impact of oil shocks during the 90's recession.

¹³With a different econometric approach, Caldara, Fuentes-Albero, Gilchrist, and Zakrajsek (2016) find that the fall of industrial production of the early 2000s is entirely attributed to financial exogenous perturbations.

cial shocks during the Great Recession. The initial fall in output is attributed mainly to supply-side disturbances with an important role for demand and monetary factors at the core of the recession. This view of the crisis is consistent with the results from Stock and Watson (2012). They estimate a dynamic factor model and find that the Great Recession is best explained by heterogeneous shocks where oil shocks account for the initial slowdown, financial and demand shocks explain the bulk of the recession and a subsequent drag is added by an effectively tight conventional monetary policy arising from the zero lower bound. Here, financial shocks start weighing down on activity by the end of 2008. Ivashina and Scharfstein (2010) explain this feature of the crisis. They show that the beginning of the financial crisis was in fact accompanied by an increase in commercial and industrial loans as corporate borrowers drew on their existing credit lines in reaction to the expected financial stress. In contrast, all types of loan fell radically by the end of 2008, with lending volumes dropping by 79 percent relative to their peak level of mid-2007.

Overall, implications of financial shocks for both recessions and expansions over the data sample are close to the historical shock decomposition obtained by Caldara, Fuentes-Albero, Gilchrist, and Zakrajsek (2016) who focus on disentangling financial and uncertainty disturbances. While the econometric method I use is closer to Furlanetto, Ravazzolo, and Sarferaz (2017) who identify financial shocks using stock prices, they find that much of variance in output growth over the past thirty years is due to supply shocks. A possible explanation is that, as they identify financial disturbances as demand shocks, only supply shocks can compensate for periods of weak disinflation as observed in the Great Recession. In contrast, the current specification allows inflation to respond freely to financial shocks.

Figure 3.7 displays the median variance decomposition for the observables at different horizons. Financial and supply shocks are the most important driving forces for output fluctuations at short and long term horizons. Their impact range respectively from a fifth to half of the total output variance and close to half of the loan variance at all frequencies. Nearly all of bonds variance is explained by financial shocks. This can be viewed as evidence that the bond market acts as a substitute for loans when intermediated lending is gripped.¹⁴ Other shocks have limited implications for output. Monetary and investment shocks explain respectively 20 percent of the policy rate and the investment-to-GDP

¹⁴In line with the spare tire analogy from Greenspan (1999).

ratio variance but have little implications for output fluctuations. In line with what is documented in the literature, fluctuations in inflation appear disconnected from financial shocks at every frequencies. Papers using sign-restriction methods to identify financial

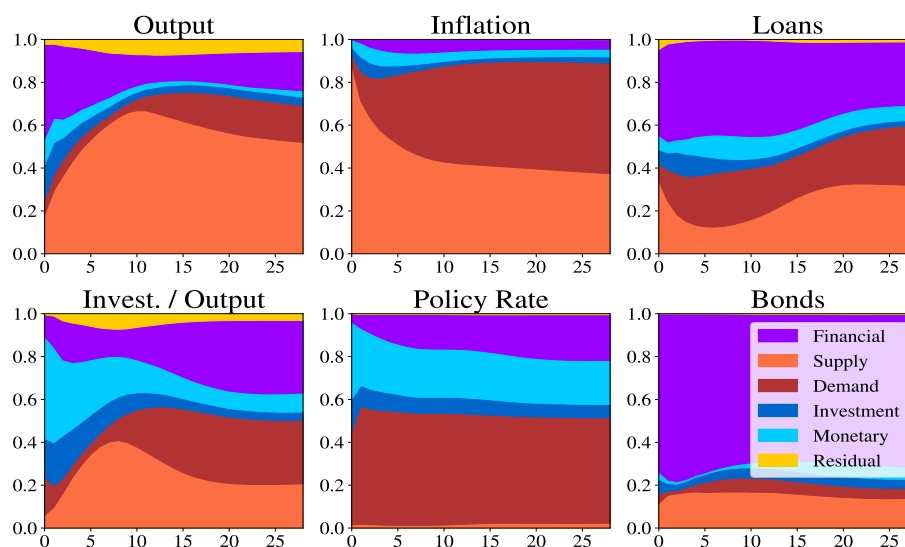


Figure 3.7: Variance Decomposition.

Note: Median variance decomposition at different horizons.

shocks as Meeks (2012), Fornari and Stracca (2012) and Furlanetto, Ravazzolo, and Sarferaz (2017) find that between a tenth to a third of output fluctuations can be attributed to financial shocks. This is less than results usually obtained from DSGE models estimated with bond spreads such as Justiniano, Primiceri, and Tambalotti (2011), Christiano, Motto, and Rostagno (2014) and Ajello (2016) who find that financial shocks account for close to half of output business cycle fluctuations.

Finally, to verify that the characteristics obtained from the financial shocks do not hinge on the sign-restrictions imposed on price, interest rate and investment responses, I re-estimate the VAR model while keeping only the restrictions for GDP, loans and bonds. Section X of the appendix displays IRFs for a financial shock and historical shock decomposition for the different observables. The results obtained are identical to the results obtained from the fully specified model.

The upshot of these empirical results is that, first, the model implications are coherent with results from a large set of empirical and theoretical studies based on more constrained econometric approaches, second, that financial shocks are a central component

of the business cycle, but not a unique one, and third that the joint behavior of bonds, loans and output is enough to identify financial shocks.

V. Putting the Model to the Test

In this final section, I use an estimated version of the modified NK model to investigate how financial shocks identified using firms' debt composition relate to measures of financial stress such as the corporate bond spread.

A. Impulse Response Matching

The estimation procedure consists in minimizing the distance between the median impulse responses from the structural VAR and from the modified NK model. Denoting θ the vector that contains all the estimated parameters listed in table 3.6 of the appendix, the estimator θ^* is obtained as the solution of:

$$\theta^* = \underset{\theta}{\operatorname{argmin}} \left[\hat{\Psi} - \bar{\Psi}(\theta) \right]' V^{-1} \left[\hat{\Psi} - \bar{\Psi}(\theta) \right].$$

Here, $\hat{\Psi}$ is a vector that contains the median impulse responses obtained from the VAR model, $\bar{\Psi}(\theta)$ contains the impulse responses from the NK model and V is a diagonal matrix with the variances of the empirical impulse responses stacked along its main diagonal. I consider an horizon of 25 periods for the five different structural shocks and the six different variables. This implies that $\bar{\Psi}(\theta)$ is a 750 column vector. Figure 3.8 displays impulse responses to a financial shock for the estimated NK model and the VAR model. The modified NK model is able to reproduce both qualitative and quantitative features of the VAR model for all shocks with parameter values in line to those obtained from medium-scale DSGE models estimated with US data.¹⁵ Impulse responses for the other shocks are provided in section XI of the appendix.

B. Financial Shocks and the Bond Spread

Going back to the question of whether corporate debt choice can help to identify financial shocks, I investigate the relevance of the identification strategy based on two criteria.

¹⁵See for instance Christiano, Trabandt, and Walentin (2010), Jermann and Quadrini (2012) and Del Negro, Giannoni, and Schorfheide (2015).

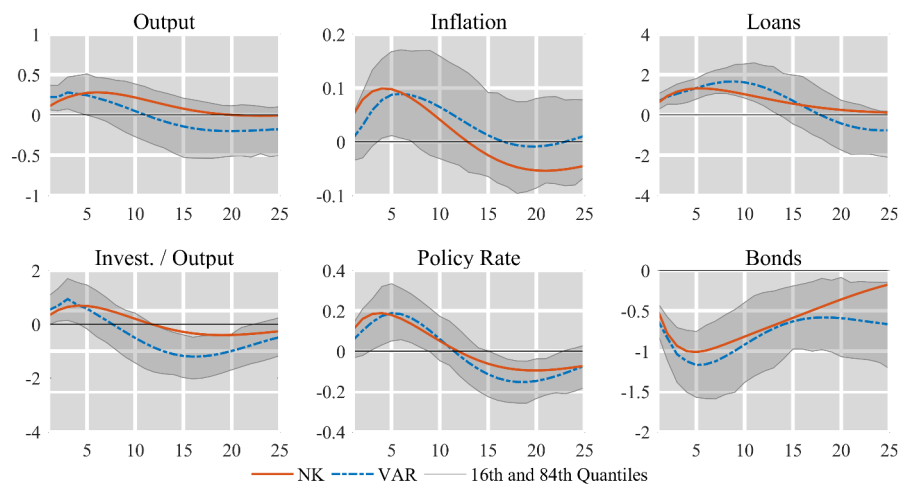


Figure 3.8: Impacts of a Financial Shock in the VAR and NK Models.

Note: Median impulse responses to a one standard deviation financial shock. The grey area corresponds to the 16th and 84th quantiles for the VAR model. All series are expressed in percentage points. Inflation and the policy rate are annualized.

First, does the identification method yields financial shocks that actually resemble measures of financial stress as experienced by non-financial firms? And second, does firm funding decisions help to predict disruptions in the financial system? To address these questions, I proceed as follows. I start by assuming that the estimated NK model is the true data generating process and use it to recover the structural shocks implied by the data set.¹⁶

Figure 3.9 plots the financial shock process ν_t obtained from the modified NK model and Moody’s seasoned Baa corporate bond minus federal funds rate. The financial shock process resembles the bond spread. The two series are correlated at 0.67 over the whole sample.¹⁷ The proximity between the two series indicates that the modified NK model inherits the quantitative properties of the sign-restriction VAR and most importantly that the identification method is able to capture financial stress based on aggregate firm funding choices. Finally, I investigate whether financial shocks can help predict the bond spread. Table 3.5 displays result from Granger causality tests at different lag orders. The

¹⁶The data used are the same as for the sign-restriction VAR model. Series for output, loans, bonds, and inflation are stationarized using a first difference filter. Because there are only five types of shocks in the NK model, I assume distinct measurement errors for each of the different series as in Bianchi, Kung, and Morales (2019).

¹⁷I also find a high correlation close to 0.5 when comparing ν_t with the EBP.

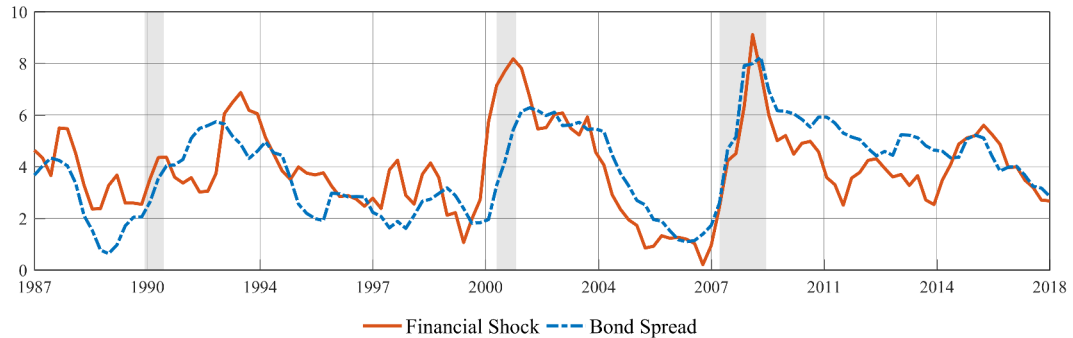


Figure 3.9: Financial Stress and the Bond Spread.

The orange line corresponds to the opposite of the smoothed ν_t process which is HP-filtered using a smoothing parameter λ of 1600. The blue line corresponds to the Moody's seasoned Baa corporate bond minus federal funds rate. Grey areas correspond to NBER recession dates.

hypothesis that financial shocks do not Granger cause the bond spread is strongly rejected for all specifications. This simple exercise brings further evidence that firm debt arbitrage is a better predictor of credit conditions than bond spreads. Most importantly, it shows that one cannot reject the fact that fluctuations in bond spreads are caused by fluctuations in firm debt arbitrage.

H_0 : Financial Shocks do not cause Bond Spreads				
Lags	1	2	3	4
P-values	0.000002	0.000044	0.000106	0.000258

Table 3.5: Granger Causality Tests

Note: Granger causality is inferred based on likelihood-ratio test. The financial shocks correspond to bank efficiency shocks ϵ_t^e obtained using a Kalman filter.

VI. Conclusion

I include a mechanism of debt arbitrage into a New Keynesian model to investigate the evolution of firms' debt structure in response to various macroeconomic shocks. The model implies that only financial shocks produce opposite movements in intermediated and direct debt. In contrast, other macroeconomic shocks generate opposite movements in the two types of debt. I use these results to inform a sign-restrictions VAR model

estimated with US data. The characteristics of the financial shocks obtained from the VAR model are consistent with results from various empirical studies based on more constrained identification strategies. In the final part, I estimate the modified NK model using impulse response matching methods. I find that the NK model is able to replicate the quantitative implications of the VAR model for *all* types of shocks. The estimated model is then used to recover structural shocks in the US over the thirty past years. The financial shocks resemble measures of financial stress and have predictive power for firm credit conditions.

Technical Appendix to Financial Shocks and the Debt Structure

VII. VAR Analysis

A. Bayesian VAR Method

This section gives an overview of the methods used to compute the form VAR model, a complete description of the Bayesian VAR methodology can be found in Kilian and Lütkepohl (2017). Consider the following reduced form VAR of order p :

$$y_t = c + \sum_{i=1}^p B_i y_{t-i} + u_t, \quad (3.43)$$

where y_t is a $N \times 1$ vector containing the N endogenous variables, c a $N \times 1$ vector of constant, B_i for $i = 1, \dots, p$ are $N \times N$ parameter matrices. The vector u_t is a $N \times 1$ prediction errors with $u_t \sim N(0, \Sigma)$ and Σ a variance-covariance matrix.

Defining $Y = [y_1 \dots y_T]'$, $B = [c \ B1 \dots \ Bp]'$, $U = [u_1 \dots u_T]'$ and:

$$X = \begin{bmatrix} 1 & y'_0 & y'_1 & \dots & y'_{-p} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & y'_{T-1} & y'_1 & \dots & y'_{T-p} \end{bmatrix},$$

the VAR model rewrites as $Y = XB + U$. Vectorising this equation yields:

$$y = (I_N \otimes X)\beta + u, \quad (3.44)$$

where $y = \text{vec}(Y)$, $\beta = \text{vec}(B)$ and $u = \text{vec}(U)$, where $\text{vec}()$ denotes column wise vectorisation operator. The error term u follows a normal distribution with a zero mean and a

variance-covariance matrix $\Sigma \otimes I_T$. The likelihood function in B and Σ can be expressed as:

$$L(B, \Sigma) \propto |\Sigma|^{-\frac{T}{2}} \exp \left[-\frac{1}{2} (\beta - \hat{\beta})' (\Sigma^{-1} \otimes X'X) (\beta - \hat{\beta}) \right] \exp \left[-\frac{1}{2} \text{tr} (\Sigma^{-1} S) \right], \quad (3.45)$$

where $S = \left[(Y - X\hat{B})' (Y - X\hat{B}) \right]$ and $\hat{\beta} = \text{vec}(\hat{B})$ and $\hat{B} = (X'X)^{-1}X'Y$.

Using a diffuse prior for B and Σ proportional to $|\Sigma|^{-\frac{(n+1)}{2}}$, Kadiyala and Karlsson (1997) show that the joint posterior density for B and Σ writes as:

$$p(B, \Sigma | Y, X) \propto |\Sigma|^{-\frac{T+n+1}{2}} \exp \left[-\frac{1}{2} (\beta - \hat{\beta})' (\Sigma^{-1} \otimes X'X) (\beta - \hat{\beta}) \right] \exp \left[-\frac{1}{2} \text{tr} (\Sigma^{-1} S) \right]. \quad (3.46)$$

Using Gibbs sampling it is possible to draw β conditional on Σ from:

$$\beta | \Sigma, Y, X \sim N(\hat{\beta}, \Sigma \otimes (X'X)^{-1}), \quad (3.47)$$

and to draw Σ from:

$$\Sigma | Y, X \sim IW(S, z), \quad (3.48)$$

where $z = (T - N) \times (p - 1)$.

B. Sign-Restriction VAR Algorithm

This subsection sketches the method used to generate a subset of structural VAR models satisfying the imposed sign restrictions and drawn from the previous distribution of models. While various identification schemes are available, imposing sign-restrictions allows to identify structural shocks based on a minimalist and qualitative set of hypotheses.¹⁸

The algorithm used in this paper is developed by Rubio-Ramirez, Waggoner, and Zha (2010), the principle is as follows. It is possible to express the vector of prediction error u_t as a combination of structural innovations ε_t with $u_t = D\varepsilon_t$ and $\varepsilon_t \sim N(0, I_N)$ where I_N is an identity matrix and D a non-singular parameter matrix with $DD' = \Sigma$. To construct the matrix D , one first draw candidates β and Σ from the posterior distributions 3.47 and 3.48. The next step is to obtain a random orthogonal matrix Q drawn from $N(0, I_N)$. To do so, one first draw a matrix W from $N(0, I_N)$ and transform it into an orthogonal Q matrix using the QR factorization. The matrix D is then computed as the product matrix of P and Q , where P corresponds to the lower-triangular Cholesky decomposition of Σ .

Using the matrices of coefficients β and D , it is now possible to compute the impulse responses implied for the different structural shocks ε_t . If the draws for β , Σ and the rotation matrix W imply impulse responses satisfying the imposed sign restrictions they are kept. The same process is repeated until a sufficient number of draws is obtained. The set of structural models gathered allows characterizing the distributions of models derived from the reduced form VAR and satisfying the imposed sign restrictions.

¹⁸Advantages of sign-restriction methods are detailed in Uhlig (2005), see Fry and Pagan (2011) for a more critical treatment.

C. Estimation Data

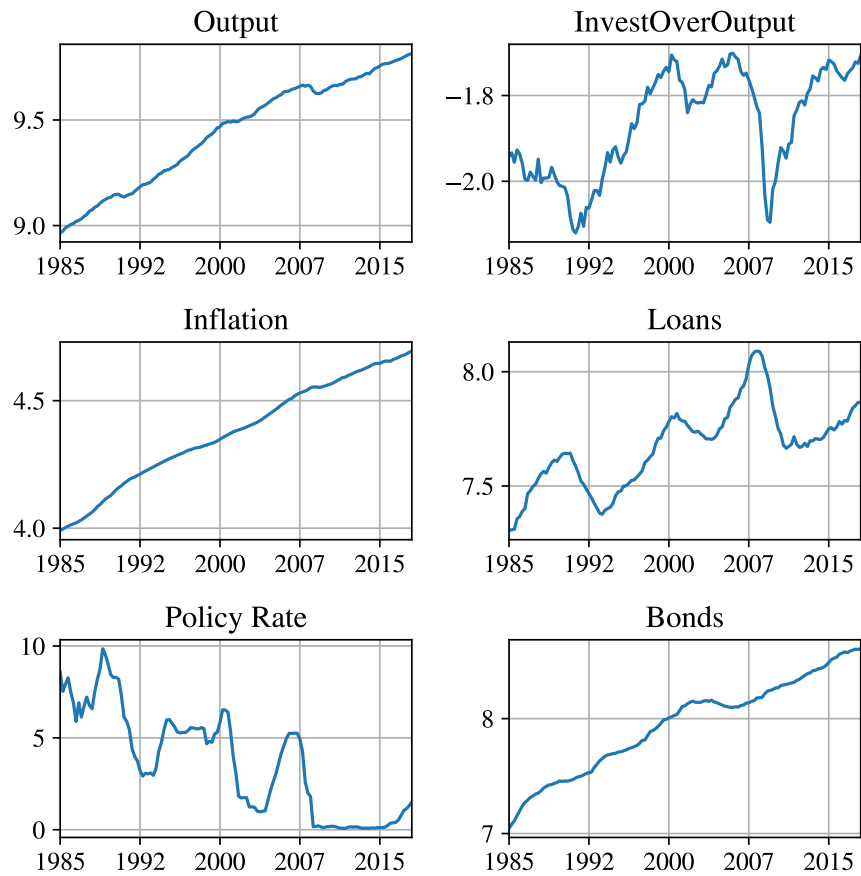


Figure 3.10: Data for the SR-VAR

Note: All series are expressed in log-level except the policy rate which is expressed in annual percentage points. GDP, investment, as well loan and bond volumes are expressed in real terms. Inflation corresponds to the GDP deflator.

VIII. New Keynesian Framework

A. Households

A representative household maximizes its utility defined as:

$$E_0 \sum_{t=0}^{\infty} (\beta)^t \zeta_{c,t} \left\{ \log(c_t - bc_{t-1}) - \psi_L \int_0^1 \frac{h_{it}^{1+\sigma_L}}{1+\sigma_L} di \right\},$$

The budget constraint writes:

$$P_t c_t + P_t d_t + Q_t^k k_t \leq \int_0^1 W_{it} h_{it} di + R_t P_{t-1} d_{t-1} + [Q_t^k (1 - \delta) + u_t r_t^k - a(u_t)] k_{t-1} + \Omega_t. \quad (3.49)$$

Households' problem writes:

$$\begin{aligned} \mathcal{L} = E_0 \sum_{t=0}^{\infty} (\beta)^t \zeta_{c,t} \left\{ \log(c_t - bc_{t-1}) - \psi_L \int_0^1 \frac{h_{it}^{1+\sigma_L}}{1+\sigma_L} di \right. \\ \left. + \Lambda_{z,t} [d_{t-1} + [Q_t^k (1 - \delta) + u_t r_t^k - a(u_t)] k_{t-1} + \Omega_t - P_t c_t - P_t d_t - Q_t^k k_t] \right\}. \end{aligned}$$

The first-order condition with respect to consumption c_t is:

$$\zeta_{c,t} \Lambda_{z,t} P_t = \frac{\zeta_{c,t}}{c_t - bc_{t-1}} - b\beta E_t \frac{\zeta_{c,t+1}}{c_{t+1} - bc_t}. \quad (3.50)$$

The first-order condition with respect to risk-free deposits d_t is:

$$\zeta_{c,t} \Lambda_{z,t} P_t = \beta P_t E_t \zeta_{c,t+1} \Lambda_{z,t+1} \frac{R_{t+1}}{\pi_{t+1}}. \quad (3.51)$$

In addition households decide the utilization rate of capital u_t and supply effective capital $u_t k_t$ to the entrepreneurs. The first-order condition with respect to capital k_t is:

$$\zeta_{c,t} \Lambda_{z,t} = \beta E_t \zeta_{c,t+1} \Lambda_{z,t+1} R_{t+1}^k, \quad (3.52)$$

with,

$$R_{t+1}^k = \frac{Q_{t+1}^k (1 - \delta) + [u_{t+1} r_{t+1}^k - a(u_{t+1})] P_{t+1}}{Q_t^k}, \quad (3.53)$$

where $a(\cdot)$ is an increasing and convex function implying an increasingly costly capital utilization. Optimal utilization for capital implies that $r_t^k = a'(u_t)$.

B. Capital Installer

The capital installer maximizes its sum of profits using households' discount rate:

$$E_0 \sum_{t=0}^{\infty} (\beta)^t \zeta_{c,t} \Lambda_{z,t} \{Q_t^k k_t - P_t I_t^k\},$$

and subject to the following technology:

$$k_t = (1 - \delta)k_{t-1} + \left[1 - S\left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k}\right)\right] I_t^k.$$

The first order condition for profit maximization writes:

$$\begin{aligned} \zeta_{c,t} \Lambda_{z,t} Q_t^k \left[1 - S\left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k}\right) - \zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} S'\left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k}\right)\right] - \zeta_{c,t} \Lambda_{z,t} P_t \\ + \beta \zeta_{c,t+1} \Lambda_{z,t+1} Q_{t+1}^k \zeta_{I,t+1} \left(\frac{I_{t+1}^k}{I_t^k}\right)^2 S'\left(\zeta_{I,t+1} \frac{I_{t+1}^k}{I_t^k}\right) = 0. \end{aligned} \quad (3.54)$$

C. Firms

I follow Gali (2010) in assuming a three-sector structure for good producers. Firms in the final goods sector produce differentiated goods using entrepreneurs production sold in competitive markets. The former are subject to nominal rigidity introduced via staggered price contracts a la Calvo.

Entrepreneurs

Entrepreneurs produce intermediate goods using capital and labor obtained from the households. There exists a continuum $e \in [0, 1]$ of entrepreneurs operating in competitive markets. Entrepreneur e enter the period with network n_{et} and use it as collateral for debt. Debt is used to funds working capital and is a fixed proportion of the network invested,

$$x_{et} = \xi n_{et}, \quad (3.55)$$

where ξ is a parameter corresponding to entrepreneurs leverage. Entrepreneur e sells production Y_{et}^E at price P_t^E to retailers using the following Cobb-Douglas technology:

$$Y_{et}^E = \varepsilon_{et} A_t (u_t k_{et})^\alpha h_{et}^{1-\alpha}, \quad (3.56)$$

where h_{et} , k_{et} are labor and capital input used for production. Variable A_t is the Solow residual and ε_{et} is a sequence of idiosyncratic shock realizations. Entrepreneurs are constrained on their labor inputs k_{et} and capital inputs h_{et} relative to their debt capacity x_{et} according to:

$$x_{et} \geq r_t^k k_{et} + w_t h_{et}. \quad (3.57)$$

An entrepreneur e maximizes her real profits:

$$\frac{P_t^E Y_{et}^E}{P_t} - r_t^k k_{et} - w_t h_{et}, \quad (3.58)$$

subject to the debt constraint (3.57). First order conditions for the optimization problem of the entrepreneur are:

$$\alpha x_{et} = r_t^k k_{et}, \quad (3.59)$$

$$(1 - \alpha) x_{et} = w_t h_{et}. \quad (3.60)$$

Production Y_{et}^E is sold at competitive price P_t^E . Defining s_t the aggregate component of the marginal cost of production expressed in terms of final goods yields:

$$s_t = \frac{1}{A_t u_t^\alpha} \left(\frac{P_t}{P_t^E} \right) \left(\frac{w_t}{1 - \alpha} \right)^{1-\alpha} \left(\frac{r_t^k}{\alpha} \right)^\alpha. \quad (3.61)$$

The sequential shock realization is summarized as:

Shock $\varepsilon_{1,et}$: Publicly-observed, realizes along aggregate shocks. Creates heterogeneity among firms in the risk of default.

Shock $\varepsilon_{2,et}$: Publicly-observed, only for bank-financed firms. Rationale for choosing bank finance.

Shock $\varepsilon_{3,et}$: Privately-observed, can be monitored at a cost by financial intermediaries. Rationale for the existence of risky debt optimal contract.

The expected output at the time of contracting with a financial intermediary writes as:

$$Y_{et}^E = \varepsilon_{et} h_{et}^{1-\alpha} (u_t k_{et})^\alpha, \quad (3.62)$$

using first-order conditions,

$$h_{et} = (1 - \alpha) \frac{x_{et}}{w_t}, \quad (3.63)$$

$$k_{et} = \alpha \frac{x_{et}}{r_t^k}, \quad (3.64)$$

it can be expressed in terms of final good:

$$\begin{aligned} Y_{et}^E &= \varepsilon_{et} \left(\frac{P_t^E}{P_t} \right) h_{et}^{1-\alpha} (u_t k_{et})^\alpha, \\ &= \varepsilon_{it} \left(\frac{P_t^E}{P_t} \right) A_t \left((1 - \alpha) \frac{x_{et}}{w_t} \right)^{1-\alpha} \left(\alpha \frac{u_t x_{et}}{r_t^k} \right)^\alpha, \\ &= \varepsilon_{et} \left(\frac{P_t^E}{P_t} \right) A_t x_{et} \left(\frac{1 - \alpha}{w_t} \right)^{1-\alpha} \left(u_t \frac{\alpha}{r_t^k} \right)^\alpha, \\ &= \frac{\varepsilon_{et}^E x_{et}}{s_t}. \end{aligned}$$

Defining $\psi_t^y = \int_0^1 \varepsilon_{et}^E de$, entrepreneur aggregate production yields:

$$\begin{aligned} Y_t^E &= \int_0^1 Y_{et}^E, \\ &= \frac{\psi_t^y \xi n_t^e}{s_t}. \end{aligned}$$

Where n_t is the aggregate network and ψ_t^y aggregates the realizations of the different idiosyncratic productivity shock.

D. Retailers

Retailers are assumed to be monopolistically competitive firms indexed by $j \in [0, 1]$ and producing differentiated final good Y_{jt} using the following technology :

$$Y_{jt} = Y_{jt}^E,$$

where Y_{jt}^E is the quantity of the intermediated good used by retailers j as an input and purchased to entrepreneurs j in a competitive market at price P_t^E . Assuming price-staggered contracts as in Calvo (1983), $1 - \theta_p$ denotes the probability for each retailer

to be able to adjust its price each period. Nominal flows of profits for retailers at period $t + s$ writes:

$$P_{jt+s}Y_{jt+s} - (1 - \tau^y)P_{t+s}^E Y_{jt+s}^E, \quad (3.65)$$

with τ^y a subsidy rate. Net present value of retailers real profits is defined as:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s}^z \left[\frac{P_{jt+s}}{P_{t+s}} Y_{jt+s} - (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} Y_{jt+s}^E \right],$$

where,

$$\lambda_{t+s}^z = \frac{\Lambda_t^z}{P_t}, \quad (3.66)$$

is the multiplier on firm profits in the household's budget constraint expressed in real terms. Taking into account the demand curve of final goods producer from equation 3.73, this yields:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s}^z \left[\left(\frac{P_{jt+s}}{P_{t+s}} \right)^{\frac{1}{1-\lambda^p}} Y_{t+s} - (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} \left(\frac{P_{jt+s}}{P_{t+s}} \right)^{\frac{\lambda^p}{1-\lambda^p}} Y_{t+s} \right].$$

With P_{jt+s} the price of a firm in period $t + s$ setting $P_{jt} = \tilde{P}_{jt}$ and that does not reoptimise between $t + 1, \dots, t + s$. Using the indexing rule of non-adjusters,

$$\begin{aligned} P_{jt+s} &= P_{jt+s-1} \tilde{\pi}_{t+s} \\ &= P_{jt} \tilde{\pi}_{t+1} \tilde{\pi}_{t+2} \dots \tilde{\pi}_{t+s}, \end{aligned}$$

and

$$\begin{aligned} P_{t+s} &= P_{t+s-1} \pi_{t+s} \\ &= P_t \pi_{t+1} \pi_{t+2} \dots \pi_{t+s}. \end{aligned}$$

Hence,

$$\frac{P_{jt+s}}{P_{t+s}} = \frac{P_{jt}}{P_t} X_t^s = p_{jt} X_t^s,$$

where

$$X_t^s = \begin{cases} \frac{\tilde{\pi}_{t+s} \tilde{\pi}_{t+s}}{\pi_{t+s} \pi_{t+s}}, & \text{if } s > 0 \\ 1 & \text{if } s = 0. \end{cases}$$

Rewriting the net present value of real profits implies,

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s}^z \left[\left(\frac{P_{jt+s}}{P_{t+s}} \right)^{\frac{1}{1-\lambda^p}} Y_{t+s} - (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} \left(\frac{P_{jt+s}}{P_{t+s}} \right)^{\frac{\lambda^p}{1-\lambda^p}} Y_{t+s} \right],$$

or alternatively:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s}^z Y_{t+s} \left[(X_t^s p_{jt})^{\frac{1}{1-\lambda^p}} - (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} (X_t^s p_{jt})^{\frac{\lambda^p}{1-\lambda^p}} \right].$$

The first-order condition for maximizing the net discounted sum of profits writes:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \Psi_{t+s} \tilde{p}_t^{\frac{\lambda^p}{1-\lambda^p}} \left[\tilde{p}_t X_t^s - \lambda^p (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} \right] = 0,$$

where Ψ_{t+s} is exogenous from the point of view of the firm:

$$\Psi_{t+s} = \lambda_{t+s}^z Y_{t+s} (X_t^s)^{-\sigma_p}.$$

Rearranging the previous condition I obtain the optimal price for a reoptimizing firm:

$$\tilde{p}_t = \lambda^p \frac{E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \Psi_{t+s} (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}}}{E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \Psi_{t+s} X_t^s} = \frac{K_{p,t}}{F_{p,t}}.$$

Defining $K_{p,t}$ and $F_{p,t}$:

$$K_{p,t} = (1 - \tau^y) \lambda^p E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \Psi_{t+s} \frac{P_{t+s}^E}{P_{t+s}},$$

$$F_{p,t} = E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \Psi_{t+s} X_t^s.$$

This gives:

$$\tilde{p}_t = \frac{K_{p,t}}{F_{p,t}}. \tag{3.67}$$

The aggregate price index writes:

$$\begin{aligned}
 P_t &= \left[\int_0^1 P_{jt}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}, \\
 &= \left[\int_{j \text{ adj}} P_{jt}^{\frac{1}{1-\lambda^p}} dj + \int_{j \text{ dont adj}} P_{jt}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}, \\
 &= \left[\int_{j \text{ adj}} \tilde{P}_{jt}^{\frac{1}{1-\lambda^p}} dj + \tilde{\pi}_t^{\frac{1}{1-\lambda^p}} \int_{j \text{ dont adj}} P_{jt-1}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}, \\
 &= \left[(1 - \xi_p) \tilde{P}_t^{\frac{1}{1-\lambda^p}} + \tilde{\pi}_t^{\frac{1}{1-\lambda^p}} \xi_p \int_j P_{jt-1}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}.
 \end{aligned} \tag{3.68}$$

Then inflation can be written as:

$$\begin{aligned}
 \pi_t &= \left[(1 - \xi_p) \tilde{p}^{\frac{1}{1-\lambda^p}} \pi_t^{\frac{1}{1-\lambda^p}} + \xi_p \tilde{\pi}_t^{\frac{1}{1-\lambda^p}} \right]^{1-\lambda^p}, \\
 &= \left[\frac{\xi_p}{1 - (1 - \xi_p) \tilde{p}^{\frac{1}{1-\lambda^p}}} \right]^{1-\lambda^p} \tilde{\pi}_t,
 \end{aligned} \tag{3.69}$$

and the aggregate price index:

$$\tilde{p}_t = \left[\frac{1 - \xi_p \left(\frac{\tilde{\pi}_t}{\pi_t} \right)^{\frac{1}{1-\lambda^p}}}{1 - \xi_p} \right]^{1-\lambda^p}. \tag{3.70}$$

Finally, I obtain the following forms for the first-order conditions:

$$E_t \left[\lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda^p}} F_{p,t+1} - F_{p,t} \right] = 0, \tag{3.71}$$

$$E_t \left[\lambda^p (1 - \tau^y) \frac{P_{t+s}^E}{P_{t+s}} \lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{\lambda^p}{1-\lambda^p}} K_{p,t+1} - K_{p,t} \right] = 0. \tag{3.72}$$

E. Final Goods Producers

A representative final good producer manufactures homogeneous final output using technology:

$$Y_t = \int_0^1 \left[Y_{jt}^{\frac{1}{\lambda^p}} \right]^{\lambda^p} dj, \lambda^p > 1.$$

The first order conditions for profit maximization by final good producers are:

$$P_{jt} = P_t \left(\frac{Y_{jt}}{Y_t} \right)^{\frac{\lambda^p}{\lambda^p - 1}}, \quad j \in [0, 1]. \quad (3.73)$$

The price of final goods satisfies the following:

$$P_t = \left[\int_0^1 P_{jt}^{\frac{1}{1-\lambda^p}} dj \right]^{1-\lambda^p}. \quad (3.74)$$

Labor Contractors

Perfectly competitive labor contractors combine specialized labor services from patient households h_{it} into homogeneous labor h_t sold to intermediate firms using the following technology:

$$h_t = \left[\int_0^1 (h_{it})^{\frac{1}{\lambda^w}} di \right]^{\lambda^w},$$

where $\sigma_w \geq 1$ is the elasticity of labor demand. Total payroll writes:

$$\int_0^1 W_{it} h_{it} di = W_t h_t.$$

The Lagrangean associated to maximizing h_t is:

$$\mathcal{L} = \left[\int_0^1 (h_{it})^{\frac{1}{\lambda^w}} di \right]^{\lambda^w} + \varepsilon \left(W_t h_t - \int_0^1 W_{it} h_{it} di \right).$$

The first-order condition with respect to differentiated labor $h_{i,t}$ is:

$$\left[\int_0^1 (h_{it})^{\frac{1}{\lambda^w}} di \right]^{\lambda^w - 1} h_{it}^{\frac{1-\lambda^w}{\lambda^w}} = \varepsilon W_{it}.$$

Rewriting this expression, I get:

$$\left(\frac{h_{it}}{h_t} \right)^{\frac{\lambda^w - 1}{\lambda^w}} = \varepsilon W_{it}.$$

Multiplying the first-order condition by h_{it} , integrating over all labor services, and solving for the multiplier ε yields:

$$\varepsilon = \frac{1}{W_t}.$$

After substituting, this gives the demand function for generic labor input i :

$$h_{it} = \left(\frac{W_{it}}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} h_t.$$

Plugging the demand function into the Dixit-Stiglitz aggregator allows to write the wage index of households as:

$$W_t = \left[\int_0^1 (W_{it})^{\frac{1}{1-\lambda_w}} di \right]^{1-\lambda_w}.$$

Monopoly Unions

Unions represent workers by type j and set their wage rate W_{jt} . They are subject to Calvo frictions in a similar fashion to intermediate firms. A fraction $1 - \xi_w$ of monopoly unions chooses their wage optimally. The remaining fraction follows an indexation rule:

$$W_{jt} = (\pi_t^*)^{\iota_w} (\pi_{t-1})^{1-\iota_w} W_{jt-1},$$

where $0 < \iota_w < 1$. A variable without the subscript t denotes its steady state value. The definition of the aggregate wage level is:

$$W_t = \left[(1 - \xi_w) (\tilde{W}_t)^{\frac{1}{1-\lambda_w}} + \xi_w (\tilde{\pi}_{w,t} W_{t-1})^{\frac{1}{1-\lambda_w}} \right]^{1-\lambda_w},$$

where \tilde{W}_t is the wage chosen by all wage-optimizing unions, and $\tilde{\pi}_{w,t}$ is an indexation term defined as:

$$\tilde{\pi}_{w,t} = (\pi_t^*)^{\iota_w} (\pi_{t-1})^{1-\iota_w}.$$

Dividing by W_t on both sides and rearranging yields:

$$\frac{\tilde{W}_t}{W_t} = \left[\frac{1 - \xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w}.$$

Monopoly unions discount the future the same way as households do. When setting their wage optimally they maximize the following objective function:

$$E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} \left[-\psi_L \int_0^1 \frac{(h_{jt+s})^{1+\sigma_L}}{1+\sigma_L} dj + \Lambda_{z,t+s} W_{i,t} \Pi_{t,t+s}^w h_{jt+s} \right],$$

subject to:

$$h_{jt+s} = \left(\frac{W_{jt} \Pi_{t,t+s}^w}{W_{t+s}} \right)^{\frac{\lambda_w}{1-\lambda_w}} h_{t+s},$$

where,

$$\Pi_{t,t+s}^w = \prod_{k=1}^s \tilde{\pi}_{w,t+k},$$

and,

$$W_{t+s} = \pi_{w,t+s} \dots \pi_{w,t+1} W_t.$$

The first-order condition with respect to the wage $\tilde{W}_t = W_{jt}$ is:

$$E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} h_{t+s} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\frac{\tilde{W}_t}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left[\Lambda_{z,t+s} \frac{1}{1-\lambda_w} \Pi_{t,t+s}^w - \psi_L \frac{\lambda_w}{1-\lambda_w} \frac{(h_{jt+s})^{\sigma_L}}{\tilde{W}_t} \right] = 0.$$

After rearranging the first-order condition this gives:

$$\tilde{W}_t = \frac{\psi_L E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} \lambda_w \left[\left(\frac{\tilde{W}_t \Pi_{t,t+s}^w}{W_{t+s}} \right)^{\frac{\lambda_w}{1-\lambda_w}} h_{t+s} \right]^{1+\sigma_L}}{E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} h_{t+s} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\frac{\tilde{W}_t}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \Lambda_{z,t+s} \Pi_{t,t+s}^w}.$$

Divide by $W_t = W_{t+s}/(\pi_{w,t+s} \dots \pi_{w,t})$ on both sides, multiply by $\left(\frac{\tilde{W}_t}{W_t} \right)^{\frac{\lambda_w}{\lambda_w-1}(1-\sigma_L)}$ on both sides, and rearranging,

$$\begin{aligned} \left(\frac{\tilde{W}_t}{W_t} \right)^{1+\frac{\lambda_w}{\lambda_w-1}\sigma_L} \frac{W_t}{P_t} \frac{1}{\psi_L} &= \frac{E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{\lambda_w}{1-\lambda_w}(1+\sigma_L)} (h_{t+s})^{1+\sigma_L}}{E_t \sum_{s=0}^{\infty} \xi_w^s (\beta)^s \zeta_{c,t+s} \frac{h_{t+s}}{\lambda_w} \left(\frac{\Pi_{t,t+s}^w}{\pi_{w,t+s} \dots \pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{\pi_{w,t+s} \dots \pi_{w,t}}{\pi_{t+s} \dots \pi_t} \right) \Lambda_{z,t+s} P_{t+s}} \\ &= \frac{K_{w,t}}{F_{w,t}}. \end{aligned}$$

Expressing the infinite sums, $K_{w,t}$ and $F_{w,t}$ in recursive form as:

$$K_{w,t} = \zeta_{c,t}(h_t)^{1+\sigma_L} + \xi_w \beta E_t \left(\frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}(1+\sigma_L)} K_{w,t+1},$$

and,

$$F_{w,t} = \zeta_{c,t} \frac{h_t}{\lambda_w} P_t \Lambda_{z,t} + \xi_w \beta E_t (\tilde{\pi}_{w,t+1})^{\frac{1}{1-\lambda_w}} \left(\frac{1}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \frac{1}{\pi_{t+1}} F_{w,t+1}.$$

Therefore, the optimal wage writes:

$$\frac{\tilde{W}_t}{W_t} = \left[\frac{\psi_L}{W_t/P_t} \frac{K_{w,t}}{F_{w,t}} \right]^{\frac{1-\lambda_w}{1-\lambda_w(1+\sigma_L)}}.$$

Using the expression found for \tilde{W}_t^p/W_t^p , this rewrites as:

$$\frac{1}{\psi_L} \left[\frac{1 - \xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w(1+\sigma_L)} \frac{W_t}{P_t} F_{w,t} - K_{w,t} = 0.$$

The final conditions write:

$$K_{w,t} = \zeta_{c,t}(h_t)^{1+\sigma_L} + \xi_w \beta E_t \left(\frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}(1+\sigma_L)} K_{w,t+1}, \quad (3.75)$$

$$F_{w,t} = \zeta_{c,t} \frac{h_t}{\lambda_w} \lambda_{z,t} + \xi_w \beta E_t (\tilde{\pi}_{w,t+1})^{\frac{1}{1-\lambda_w}} \left(\frac{1}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \frac{1}{\pi_{t+1}} F_{w,t+1}, \quad (3.76)$$

and

$$\frac{1}{\psi_L} \left[\frac{1 - \xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w(1+\sigma_L)} \tilde{w}_t F_{w,t} - K_{w,t} = 0. \quad (3.77)$$

Summary of Equilibrium Conditions

For convenience let us define $q_t^k = \frac{Q_t^k}{P_t}$, $p_t^c = \frac{P_t^E}{P_t}$ and, $\lambda_t^z = \Lambda_t^z P_t$.

Prices

First-order condition 1 price:

$$E_t \left[\zeta_{c,t} \lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda^p}} F_{p,t+1} - F_{p,t} \right] = 0 \quad (3.1)$$

First-order condition 2 price:

$$E_t \left[(1 - \tau^Y) \lambda_p p_t^c \zeta_{c,t} \lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{\lambda_p}{1-\lambda^p}} K_{p,t+1} - K_{p,t} \right] = 0 \quad (3.2)$$

Aggregate price index:

$$\tilde{p}_t = \left[\frac{1 - \xi_p \left(\frac{\tilde{\pi}_t}{\pi_t} \right)^{\frac{1}{1-\lambda^p}}}{1 - \xi_p} \right]^{1-\lambda^p} \quad (3.3)$$

Wages

First-order condition 1 wage:

$$K_{w,t} = \zeta_{c,t} (h_t)^{1+\sigma_L} + \xi_w \beta E_t \left(\frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w} (1+\sigma_L)} K_{w,t+1} \quad (3.4)$$

First-order condition 2 wage:

$$F_{w,t} = \zeta_{c,t} \frac{h_t}{\lambda_w} \lambda_{z,t} + \xi_w \beta E_t \left(\frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{1}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \frac{1}{\pi_{t+1}} F_{w,t+1} \quad (3.5)$$

Optimal wage:

$$\frac{1}{\psi_L} \left[\frac{1 - \xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w(1+\sigma_L)} \tilde{w}_t F_{w,t} - K_{w,t} = 0 \quad (3.6)$$

Households

Households' resource constraint:

$$c_t + d_t + Q_t^k k_t = \tilde{w}_t h_t + \frac{R_t}{\pi_t} d_{t-1} + [Q_t^k (1 - \delta) + u_t r_t^k - a(u_t)] k_{t-1} + \Omega_t \quad (3.7)$$

First-order condition consumption:

$$\zeta_{c,t} \lambda_{z,t} = \frac{\zeta_{c,t}}{c_t - bc_{t-1}} - b\beta E_t \frac{\zeta_{c,t+1}}{c_{t+1} - bc_t} \quad (3.8)$$

First-order condition investment:

$$\begin{aligned} & \zeta_{c,t} \lambda_{z,t} Q_t^k \left[1 - S \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) - \zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} S' \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) \right] - \zeta_{c,t} \lambda_{z,t} \\ & + \beta \zeta_{c,t+1} \lambda_{z,t+1} Q_{t+1}^k \zeta_{I,t+1} \left(\frac{I_{t+1}^k}{I_t^k} \right)^2 S' \left(\zeta_{I,t+1} \frac{I_{t+1}^k}{I_t^k} \right) = 0 \end{aligned} \quad (3.9)$$

First-order condition deposit:

$$\zeta_{c,t} \lambda_{z,t} = \beta E_t \zeta_{c,t+1} \lambda_{z,t+1} \frac{R_{t+1}}{\pi_{t+1}} \quad (3.10)$$

First-order condition capital:

$$\zeta_{c,t} \lambda_{z,t} = \beta E_t \zeta_{c,t+1} \lambda_{z,t+1} R_{t+1}^k \quad (3.11)$$

Capital accumulation:

$$k_t = (1 - \delta) k_{t-1} + \left[1 - S \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) \right] I_t^k \quad (3.12)$$

Capital returns:

$$R_{t+1}^k = \pi_{t+1} \frac{Q_{t+1}^k (1 - \delta) + u_{t+1} r_{t+1}^k - a(u_{t+1})}{Q_t^k} \quad (3.13)$$

Entrepreneurs

Output:

$$Y_t = \frac{\psi_t^y \xi n_t}{s_t} \quad (3.14)$$

First-order condition capital:

$$\alpha x_t = r_t^k k_t \quad (3.15)$$

First-order condition labor

$$(1 - \alpha)x_t = w_t h_t \quad (3.16)$$

Marginal cost:

$$s_t = \frac{1}{A_t u_t^\alpha p_t^c} \left(\frac{r_t^k}{\alpha} \right)^\alpha \left(\frac{w_t}{1 - \alpha} \right)^{1 - \alpha} \quad (3.17)$$

Entrepreneur dividends:

$$o_t = (1 - \gamma)\psi_{t-1}^V n_{t-1} \quad (3.18)$$

Entrepreneur capital:

$$z_t = \gamma\psi_{t-1}^V n_{t-1} \quad (3.19)$$

Aggregates

Aggregate resource constraint:

$$Y_t = c_t + I_t^k + a(u_t)k_t + y_t^a \quad (3.20)$$

Aggregate profits

$$\psi_t^V = \int V(\varepsilon_1, q, R, \nu) \Phi(d\varepsilon_1) \quad (3.21)$$

$$\psi_t^V = s^a + \int_{\bar{\varepsilon}_b(q, R, \nu)}^{\bar{\varepsilon}_c(q, R, \nu)} V^b(\varepsilon, q, R, \nu) \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q, R, \nu)} V^c(\varepsilon_1, q, R) \Phi(d\varepsilon_1) \quad (3.22)$$

Aggregate productivity:

$$\psi_t^y = (1 - \tau^b) \int_{\bar{\varepsilon}_b(q, R, \nu)}^{\bar{\varepsilon}_c(q, R, \nu)} \varepsilon_1 \int_{\bar{\varepsilon}_d(\varepsilon_1, q, R, \nu)} \varepsilon_2 \Phi(d\varepsilon_2) \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q, R, \nu)} \varepsilon_1 \Phi(d\varepsilon_1) \quad (3.23)$$

Aggregate default:

$$\psi_t^m = (1 - \tau^b)\mu^b\psi_t^{mb} + \mu^c\psi_t^{mc} \quad (3.24)$$

$$\psi_t^{mb} = \int_{\bar{\varepsilon}_b(q,R,\nu)}^{\bar{\varepsilon}_c(q,R,\nu)} \int_{\bar{\varepsilon}_d(\varepsilon_1,q,R,\nu)} \Phi(\bar{\omega}^b(\varepsilon_1\varepsilon_2, q, R, \nu))\Phi(d\varepsilon_2)\Phi(d\varepsilon_1) \quad (3.25)$$

$$\psi_t^{mc} = \int_{\bar{\varepsilon}_c(q,R,\nu)} \Phi(\bar{\omega}^c(\varepsilon_1, q, R, \nu))\Phi(d\varepsilon_1) \quad (3.26)$$

Monetary Policy

$$R_t - R = \rho_p(R_{t-1} - R) + (1 - \rho_p) \left(\alpha_\pi (\pi_{t+1} - \pi_t^*) + \frac{\alpha_{\Delta y}}{4} g_{y,t} \right) + \frac{1}{400} \varepsilon_t^p \quad (3.27)$$

Miscellaneous

$$S(x_t) = \frac{1}{2} \left\{ \exp \left[\sqrt{S''/2}(x_t - x) \right] + \exp \left[-\sqrt{S''/2}(x_t - x) \right] - 2 \right\} \quad (3.28)$$

F. Log-Linearised Equations

Prices

First-order condition 1 price:

$$E_t \left[\zeta_{c,t} \lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda_p}} F_{p,t+1} - F_{p,t} \right] = 0 \quad (3.1)$$

$$(1 - \beta_p \xi_p) (\hat{\lambda}_t^z + \hat{\zeta}_{c,t} + \hat{Y}_t) + \left[\left(\frac{1}{1 - \lambda_p} \right) (\hat{\pi}_{t+1} - \hat{\pi}_{t+1}) + \hat{F}_{p,t+1} \right] = \hat{F}_{p,t} \quad (3.2)$$

First-order condition 2 price:

$$E_t \left[(1 - \tau^Y) \lambda_p p_t^c \zeta_{c,t} \lambda_t^z Y_t + \beta \xi_p \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{\lambda_p}{1-\lambda_p}} K_{p,t+1} - K_{p,t} \right] = 0 \quad (3.3)$$

$$(1 - \beta_p \xi_p) \left[\hat{p}_t^c + \hat{\lambda}_t^z + \hat{\zeta}_{c,t} + \hat{Y}_t \right] + \beta_p \xi_p \left[\frac{\lambda_p}{1 - \lambda_p} (\hat{\pi}_{t+1} - \hat{\pi}_{t+1}) + \hat{K}_{p,t+1} \right] = \hat{K}_{p,t} \quad (3.4)$$

Aggregate price index:

$$\tilde{p}_t = \left[\frac{1 - \xi_p \left(\frac{\tilde{\pi}_t}{\pi_t} \right)^{\frac{1}{1-\lambda_p}}}{1 - \xi_p} \right]^{1-\lambda_p} \quad (3.5)$$

$$K_{p,t} - F_{p,t} = \frac{\xi_p}{1 - \xi_p} \left[\hat{\pi}_t - \hat{\tilde{\pi}}_t \right] \quad (3.6)$$

Wages

First-order condition 1 wage:

$$K_{w,t} = \zeta_{c,t} (h_t)^{1+\sigma_L} + \xi_w \beta E_t \left(\frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w} (1+\sigma_L)} K_{w,t+1} \quad (3.7)$$

$$\hat{K}_{w,t} = (\hat{\zeta}_{c,t} + (1 + \sigma_L) \hat{h}_t) (1 - \beta_p \xi_p) + \xi_p \beta_p \left[\left(\frac{\lambda_w}{1 - \lambda_w} (1 + \sigma_L) \right) (\hat{\pi}_{w,t+1} - \hat{\pi}_{w,t+1}) + \hat{K}_{w,t+1} \right] \quad (3.8)$$

First-order condition 2 wage:

$$F_{w,t} = \zeta_{c,t} \frac{h_t}{\lambda_w} \lambda_{z,t} + \xi_w \beta E_t (\tilde{\pi}_{w,t+1})^{\frac{1}{1-\lambda_w}} \left(\frac{1}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \frac{1}{\pi_{t+1}} F_{w,t+1} \quad (3.9)$$

$$\hat{F}_{w,t} = (1 - \beta \xi_w) (\hat{\zeta}_{c,t} + \hat{h}_t + \hat{\lambda}_t^z) + \xi_w \beta_p \left[\frac{1}{1 - \lambda_w} \hat{\tilde{\pi}}_{w,t+1} + \frac{\lambda_w}{1 - \lambda_w} \hat{\pi}_{w,t+1} - \hat{\pi}_{t+1} + \hat{F}_{w,t+1} \right] \quad (3.10)$$

Optimal wage:

$$\frac{1}{\psi_L} \left[\frac{1 - \xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{1-\lambda_w(1+\sigma_L)} \tilde{w}_t F_{w,t} - K_{w,t} = 0 \quad (3.11)$$

$$\hat{K}_{w,t} - \hat{F}_{w,t} = \hat{w}_t + \left(1 + \frac{\lambda_w}{1 - \lambda_w} \sigma_L \right) \left(\frac{\xi_w}{1 - \xi_w} \right) \left[\hat{\pi}_t - \hat{\tilde{\pi}}_t \right] \quad (3.12)$$

Households

Households' resource constraint (not required):

$$c_t + d_t + Q_t^k k_t = \tilde{w}_t h_t + \frac{R_t}{\pi_t} d_{t-1} + Q_t^k \frac{(1 + r_t^k - \delta)}{\pi_t} k_{t-1} + \Omega_t \quad (3.13)$$

First-order condition consumption:

$$\zeta_{c,t} \lambda_{z,t} = \frac{\zeta_{c,t}}{c_t - bc_{t-1}} - b\beta E_t \frac{\zeta_{c,t+1}}{c_{t+1} - bc_t} \quad (3.14)$$

$$\hat{\lambda}_t^z (1 - b)(1 - b\beta) = -(1 + b\beta^2) \hat{c}_t + b\hat{c}_{t-1} + b\beta \hat{c}_{t+1} + b\beta(1 - b) \hat{\zeta}_{c,t} - b\beta(1 - b) \hat{\zeta}_{c,t+1} \quad (3.15)$$

First-order condition investment:

$$\zeta_{c,t} \lambda_{z,t} Q_t^k \left[1 - S \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) - \zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} S' \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) \right] - \zeta_{c,t} \lambda_{z,t} \quad (3.16)$$

$$+ \beta \zeta_{c,t+1} \lambda_{z,t+1} Q_{t+1}^k \zeta_{I,t+1} \left(\frac{I_{t+1}^k}{I_t^k} \right)^2 S' \left(\zeta_{I,t+1} \frac{I_{t+1}^k}{I_t^k} \right) = 0$$

$$\hat{Q}_t^k = S'' \left[-\hat{I}_{t-1}^k + (1 + \beta) \hat{I}_t^k + \hat{\zeta}_t^I - \beta \hat{I}_{t+1}^k - \beta \hat{\zeta}_{t+1}^I \right] \quad (3.17)$$

First-order condition deposit:

$$\zeta_{c,t}\lambda_{z,t} = \beta E_t \zeta_{c,t+1} \lambda_{z,t+1} \frac{R_{t+1}}{\pi_{t+1}} \quad (3.18)$$

$$\hat{\zeta}_t + \hat{\lambda}_t^z = \hat{\zeta}_{t+1} + \hat{\lambda}_{t+1}^z + \hat{R}_{t+1} - \hat{\pi}_{t+1} \quad (3.19)$$

First-order condition capital:

$$\zeta_{c,t}\lambda_{z,t} = \beta E_t \zeta_{c,t+1} \lambda_{z,t+1} R_{t+1}^k \quad (3.20)$$

$$\hat{\zeta}_t + \hat{\lambda}_t^z = \hat{\zeta}_{t+1} + \hat{\lambda}_{t+1}^z + \hat{R}_{t+1}^k - \hat{\pi}_{t+1} \quad (3.21)$$

Capital accumulation:

$$k_t = (1 - \delta)k_{t-1} + \left[1 - S \left(\zeta_{I,t} \frac{I_t^k}{I_{t-1}^k} \right) \right] I_t^k \quad (3.22)$$

$$\hat{k}_t = (1 - \delta)\hat{k}_{t-1} + \delta \hat{I}_t^k \quad (3.23)$$

Capital returns:

$$\frac{R_{t+1}^k}{\pi_{t+1}} = \frac{Q_{t+1}^k(1 - \delta) + u_{t+1}r_{t+1}^k - a(u_{t+1})}{Q_t^k} \quad (3.24)$$

$$\hat{R}_{t+1}^k - \hat{\pi}_{t+1} = \frac{\hat{Q}_{t+1}^k(1 - \delta) + r^k \hat{r}_{t+1}^k}{R^k} - \hat{Q}_t^k \quad (3.25)$$

Entrepreneurs

Output:

$$Y_t = \frac{\psi_t^y \xi n_t}{s_t} \quad (3.26)$$

$$\hat{Y}_t = \hat{\psi}_t^y + \hat{n}_t - \hat{s}_t \quad (3.27)$$

First-order condition capital:

$$\alpha x_t = r_t^k k_t \quad (3.28)$$

$$\hat{x}_t = \hat{r}_t^k + \hat{k}_t \quad (3.29)$$

First-order condition labor:

$$(1 - \alpha)x_t = w_t h_t \quad (3.30)$$

$$\hat{x}_t = \hat{w}_t + \hat{h}_t \quad (3.31)$$

Marginal cost:

$$s_t = \frac{1}{A_t u_t^\alpha p_t^c} \left(\frac{r_t^k}{\alpha} \right)^\alpha \left(\frac{w_t}{1 - \alpha} \right)^{1 - \alpha} \quad (3.32)$$

$$\hat{s}_t = (1 - \alpha)\hat{w}_t + \alpha\hat{r}_t^k - \hat{A}_t - \alpha u_t - \hat{p}_t^c \quad (3.33)$$

Entrepreneur dividends:

$$o_t = (1 - \gamma)\psi_{t-1}^V n_{t-1} \quad (3.34)$$

$$\hat{o}_t = \hat{\psi}_{t-1}^V + \hat{n}_{t-1} \quad (3.35)$$

Entrepreneur capital:

$$z_t = \gamma\psi_{t-1}^V n_{t-1} \quad (3.36)$$

$$\hat{z}_t = \hat{\psi}_{t-1}^V + \hat{n}_{t-1} \quad (3.37)$$

Entrepreneur's funding:

$$x_t = \left[(1 - \tau^b)s_t^{bp} + s_t^c \right] \xi n_t \quad (3.38)$$

Aggregates

Resource constraint:

$$Y_t = c_t + I_t^k + a(u_t)k_t + y_t^a \quad (3.39)$$

$$\hat{Y}_t = \frac{c}{Y}\hat{c}_t + \frac{I^k}{Y}\hat{I}_t^k + a' \frac{k}{Y}\hat{u}_t + \frac{y^a}{Y}\hat{y}_t^a \quad (3.40)$$

Debt equilibrium:

$$d_t = \left[(1 - \tau^b)s_t^{bp} + s_t^c \right] (\xi - 1)n_t \quad (3.41)$$

Profits:

$$\psi_t^V = \int V(\varepsilon_1, q, R, \nu) \Phi(d\varepsilon_1) \quad (3.42)$$

$$\psi_t^V = s^a + \int_{\bar{\varepsilon}_b(q,R,\nu)}^{\bar{\varepsilon}_c(q,R,\nu)} V^b(\varepsilon, q, R, \nu) \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q,R,\nu)} V^c(\varepsilon_1(q, R, \nu)) \Phi(d\varepsilon_1) \quad (3.43)$$

Productivity:

$$\psi_t^y = (1 - \tau^b) \int_{\bar{\varepsilon}_b(q,R,\nu)}^{\bar{\varepsilon}_c(q,R,\nu)} \varepsilon_1 \int_{\bar{\varepsilon}_d(\varepsilon_1,q,R,\nu)} \varepsilon_2 \Phi(d\varepsilon_2) \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q,R,\nu)} \varepsilon_1 \Phi(d\varepsilon_1) \quad (3.44)$$

Monitoring costs:

$$\psi_t^m = (1 - \tau^b) \mu^b \psi_t^{mb} + \mu^c \psi_t^{mc} \quad (3.45)$$

$$\psi_t^{mb} = \int_{\bar{\varepsilon}_b(q,R,\nu)}^{\bar{\varepsilon}_c(q,R,\nu)} \int_{\bar{\varepsilon}_d(\varepsilon_1,q,R,\nu)} \Phi(\bar{\omega}^b(\varepsilon_1 \varepsilon_2, q, R, \nu)) \Phi(d\varepsilon_2) \Phi(d\varepsilon_1) \quad (3.46)$$

$$\psi_t^{mc} = \int_{\bar{\varepsilon}_c(q,R,\nu)} \Phi(\bar{\omega}^c(\varepsilon_1, q, R, \nu)) \Phi(d\varepsilon_1) \quad (3.47)$$

Monetary Policy

$$R_t - R = \rho_p (R_{t-1} - R) + (1 - \rho_p) \left(\alpha_\pi (\pi_{t+1} - \pi_t^*) + \frac{\alpha_{\Delta y}}{4} g_{y,t} \right) + \frac{1}{400} \varepsilon_t^p \quad (3.48)$$

Miscellaneous

$$S(x_t) = \frac{1}{2} \left\{ \exp \left[\sqrt{S''/2} (x_t - x) \right] + \exp \left[-\sqrt{S''/2} (x_t - x) \right] - 2 \right\} \quad (3.49)$$

IX. Robustness Tests

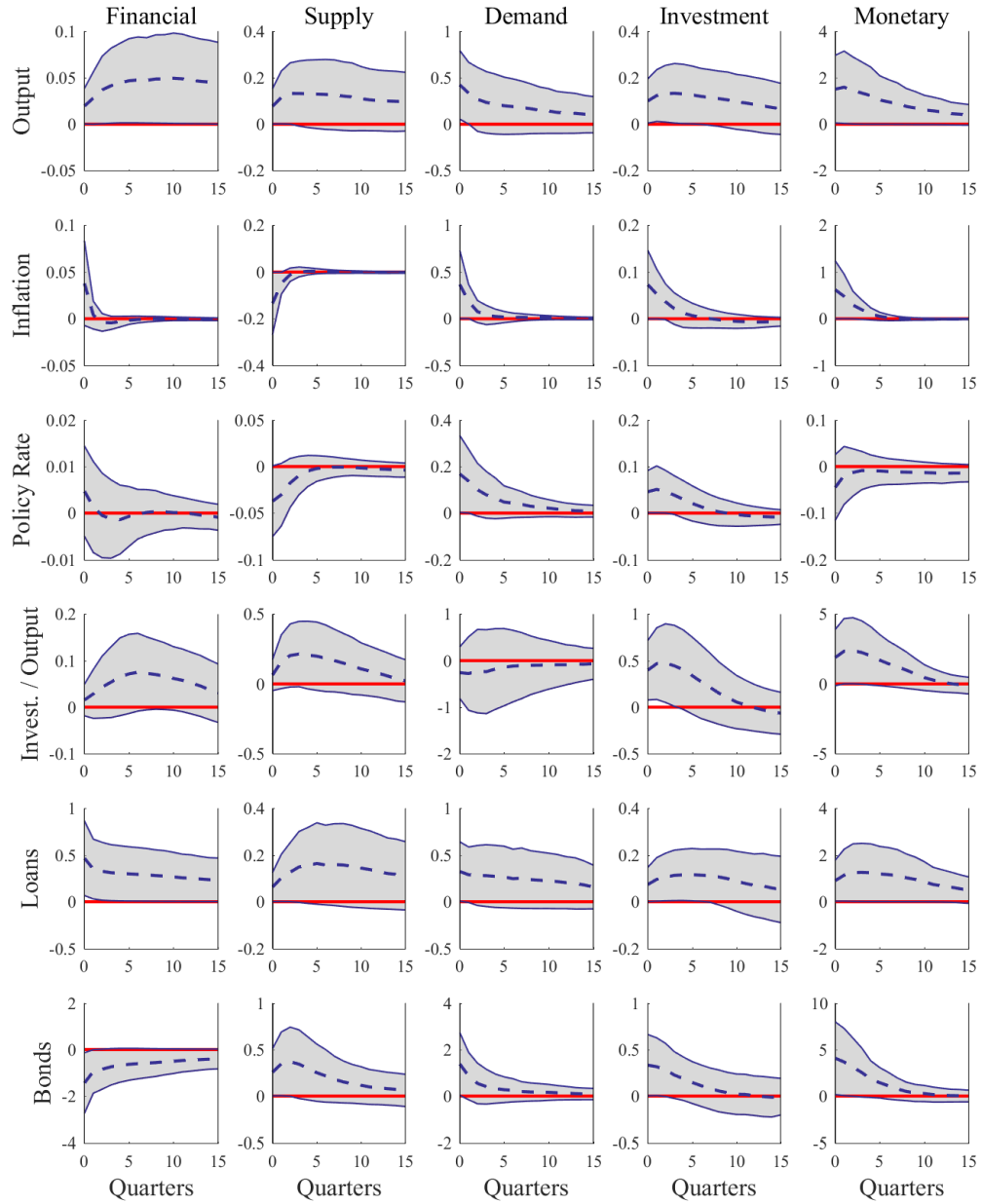


Figure 3.11: Robust Responses

Note: Impulse response functions for the different shocks. The grey area corresponds to the IRFs for the different calibrations. The 2.5 highest and lowest quantiles are trimmed out as they mostly corresponds to responses when the model approaches instability. The dashed lines correspond to the mean of the set of IRFs. Parameters are drawn from uniform distributions displayed in figure 3.12.

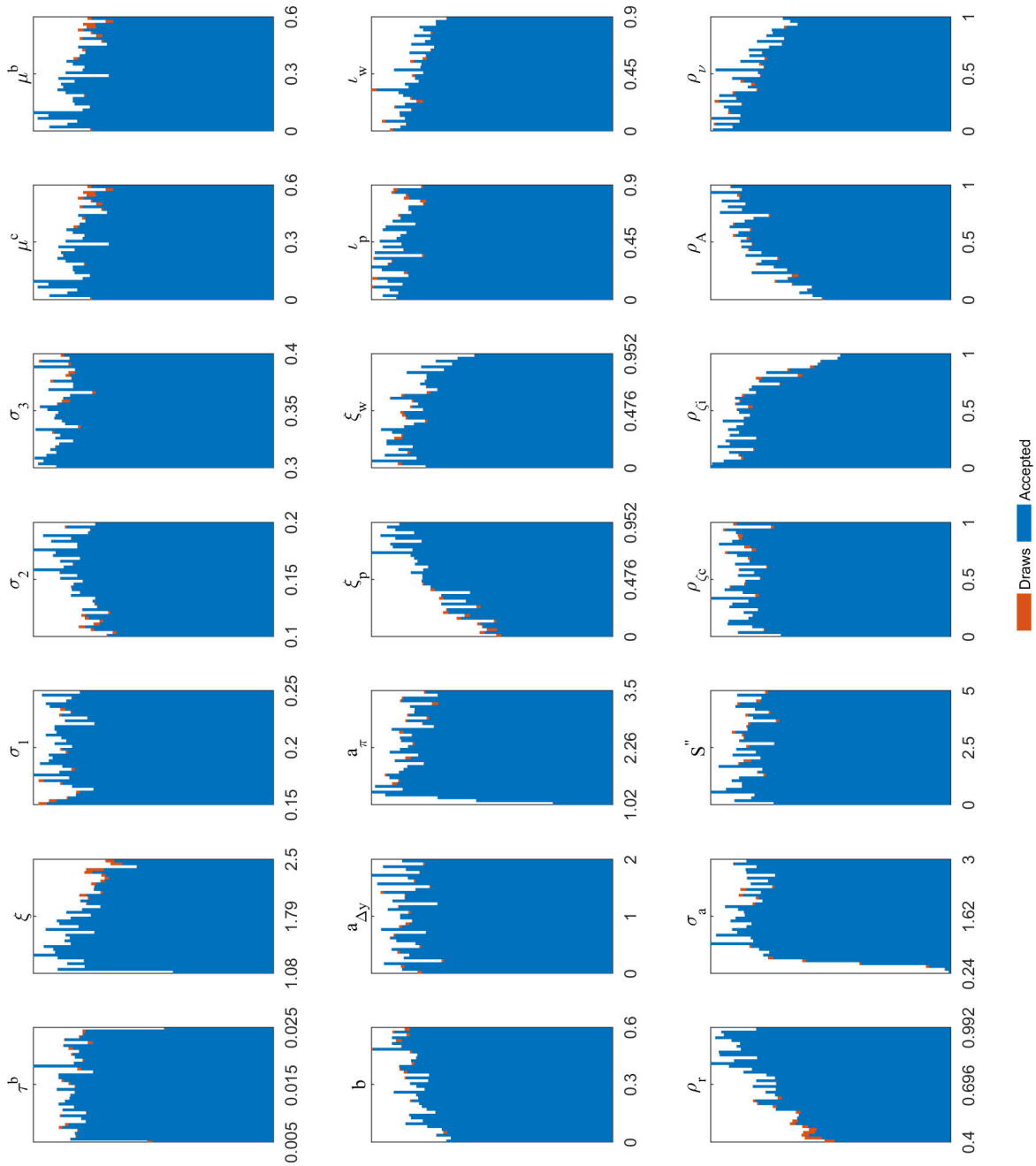


Figure 3.12: Parameter Acceptance.

Note: Parameters that imply opposite movements in bond and loans conditional to financial shocks and comovements for other shocks.

X. SR-VAR Estimation

This section presents the IRFs for financial shocks and historical shock decomposition for GDP obtained when estimating the VAR model with sign restrictions only for GDP, loan and bond responses. The characteristics of the financial shocks are very close to what is obtained from the more constrained model. The historical shock decomposition for GDP is also robust to this change, the share of output fluctuations related to financial shocks corresponds to the results from the more constrained model.

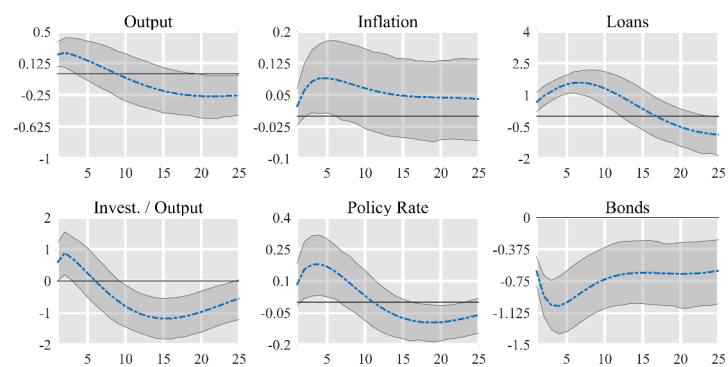
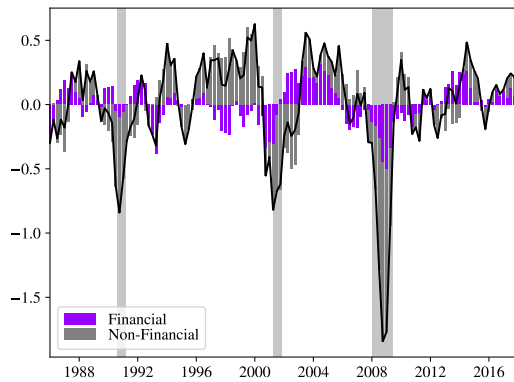


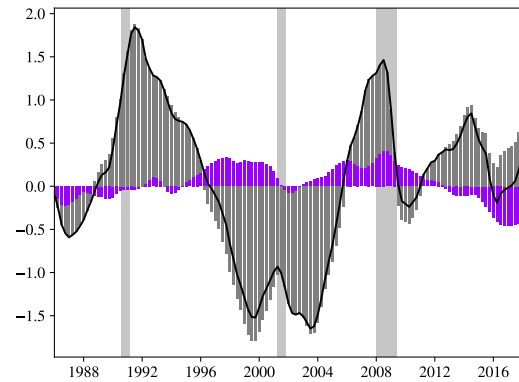
Figure 3.13: Response to a Financial Shock.

Note: Median impulse responses to a one standard deviation financial shock. The grey area corresponds to the 16th and 84th quantiles. All series are expressed in percentage points. Inflation and the policy rate are annualized.

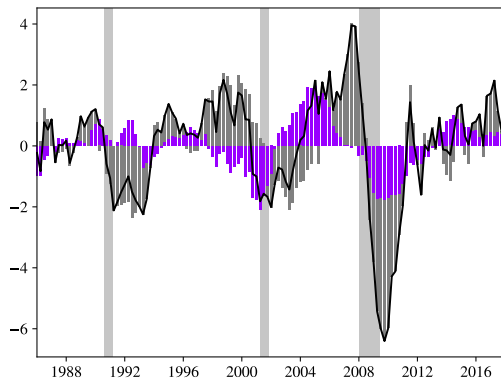
Chapter 3. Financial Shocks and the Debt Structure



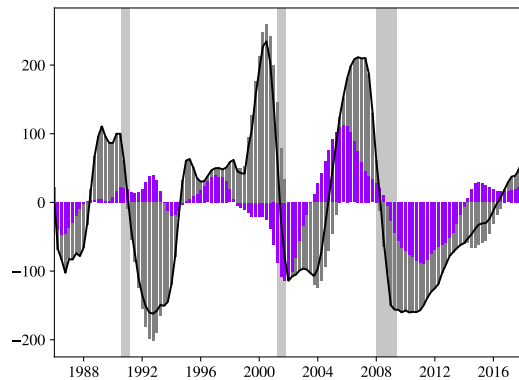
(a) Output



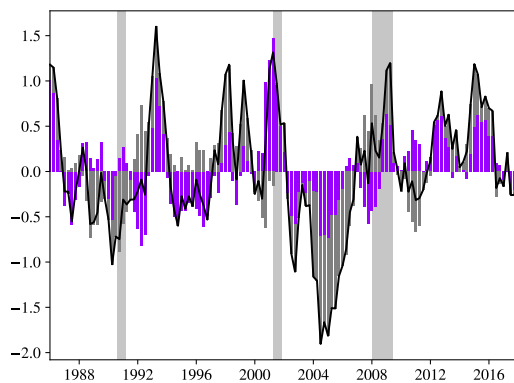
(d) Investment./Output



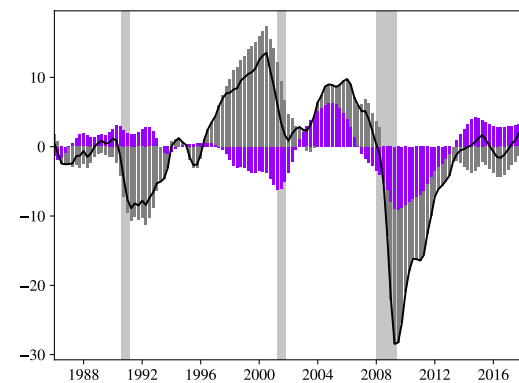
(b) Loans



(e) Policy Rate



(c) Bonds



(f) Inflation

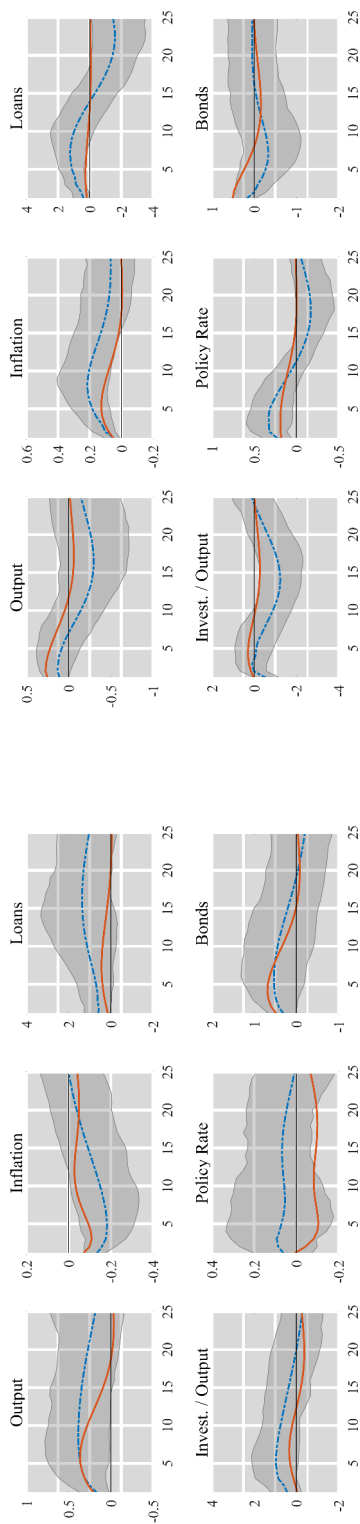
Historical variance decomposition for the model where only financial and non-financial shocks are identified. Output, loans and bonds are expressed in first difference, investment, the policy rate and inflation are expressed without the constant term.

Param.	Description	Mode
τ^b	Bank intermediation costs	0.011
ξ	Pledgeable fraction of networth	3.1
μ^b	Monitoring cost for loans	0.21
μ^c	Monitoring cost for bonds	0.32
σ_1	Idiosyncratic shock dispersion	0.19
σ_2	Idiosyncratic shock dispersion	0.097
σ_3	Idiosyncratic shock dispersion	0.24
$a_{\Delta y}$	Taylor rule output coefficient	1
a_{π}	Taylor rule inflation coefficient	1.6
ρ_p	Taylor rule smoothing	0.53
ξ_p	Calvo price stickiness	0.89
ξ_w	Calvo wage stickiness	0.35
l_p	Price indexation on inflation target	0.037
l_w	Wage indexation on inflation target	0.039
σ_a	Utilization cost curvature	1.1
S''	Invest. adjustment cost curvature	1.4
b^p	Consumption habit	0.079
ρ_{ζ_c}	Autocorr. preference	0.86
ρ_{ζ_i}	Autocorr. MEI	0.83
ρ_A	Autocorr. stationary technology	0.79
ρ_{σ_2}	Autocorr. financial	0.88
σ_{ζ_c}	SD preference	0.0046
σ_{ζ_i}	SD MEI	0.0094
σ_A	SD stationary technology	0.0068
σ_{ν}	SD financial	0.077
σ_{ε^p}	SD monetary policy	0.23

Table 3.6: Estimated Parameters

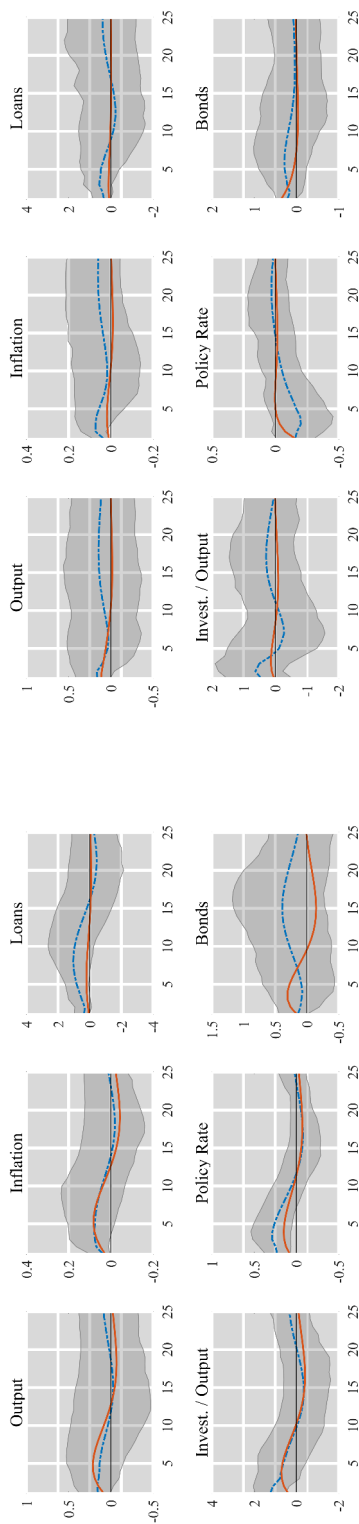
Note: This table contains parameters minimizing the distance between impulse responses from the modified NK model and from the median responses from the BVAR.

XI. Impulse Response Matching



(a) Response to a supply shock.

(b) Response to a demand shock.



(c) Response to an investment shock.

(d) Response to a monetary shock.

Note: Median impulse responses to a one standard deviation financial shock. The grey area corresponds to the 6th and 94th quantiles. All series are expressed in percentage points. Inflation and the policy rate are annualized. The dash blue lines correspond to the median responses from the VAR models, the orange lines correspond to responses from the NK model.

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Stress financier et le cycle des affaires

Résumé

Le fil directeur de cette thèse est l'étude du stress financier et en particulier de ses implications pour les fluctuations économiques. Comment expliquer l'impact des crises financières ? Quel est le rôle du système bancaire dans la propagation des chocs financiers ? Comment reconnaître et prévoir une crise financière ? Chacun des chapitres de cette thèse a pour but d'apporter des éléments de réponse nouveaux à ces grandes questions de la macroéconomie moderne. Dans le premier chapitre, réalisé en collaboration avec Yvan Bécard, nous estimons un modèle d'équilibre général dans lequel les banques ajustent leurs conditions de crédit selon leur capacité à liquider le collatéral de leurs emprunteurs. Nous montrons que les chocs de collatéral, c'est à dire des chocs affectant l'efficacité des banques à liquider le collatéral, permettent de comprendre le cycle des affaires américain et en particulier les variations de la consommation, des volumes de prêts et des taux d'emprunt. Les chocs de collatéral ont aussi la particularité de ressembler aux conditions de crédits bancaires observées ces trente dernières années pour les firmes et les ménages. Dans un second chapitre, je développe un modèle d'équilibre général où le système bancaire est organisé en compétition de monopole. J'utilise le modèle pour étudier le rôle de la compétition bancaire dans la propagation des crises financières. Je trouve qu'un faible degré de compétition du système bancaire peut limiter l'impact des chocs financiers lorsque l'efficacité de la politique monétaire est limitée par la borne à taux zéro. Dans le troisième chapitre, j'étudie l'évolution des choix de financement des firmes américaines en réponse à différents types de chocs économiques. Je trouve que seuls les chocs financiers impliquent des mouvements opposés pour les prêts bancaires et les prêts obligataires. J'utilise ce résultat couplé avec une méthode dite de restriction de signe pour identifier les chocs financiers dans un modèle VAR. Je trouve que les chocs ainsi identifiés expliquent une large partie du cycle des affaires et en particulier les deux dernières récessions. Finalement, cette stratégie d'identification me permet de calculer une mesure de stress financier capable de prédire l'évolution des spreads obligataires.

Mots-clés

Stress financier, banques, cycle des affaires, identification, estimation.

Financial Stress and the Business Cycle

Summary

In this thesis, I investigate the implications of financial stress for economic fluctuations along several dimensions. What is it that makes financial crisis so disruptive? What is the role of the banking system in their propagation? How to identify and forecast financial distress? Each chapter brings new elements to complement the literature on these broad questions. In the first chapter of this thesis, written together with Yvan Bécard, we estimate a general equilibrium model where banks can adjust their lending standards for households and firms depending on their ability to liquidate the collateral of their borrowers. We find that collateral shocks, shocks that modify the liquidity of banks' collateral, explain most of the US business cycle fluctuations for investment, consumption, loan volumes, and the credit spreads. In addition, the collateral shocks resemble measures of bank lending standard as observed over the past 30 years for households and firms. In the second chapter, I develop a model where the banking system is characterized by monopolistic competition and used to study the role of bank competition in the propagation of financial crises. I find that low competition in the banking system can dampen the impact of financial stress in situations where monetary policy is impeded by the ZLB. In the last chapter, I study the evolution of firm debt choices in response to different types of aggregate shocks. I find that only financial shocks imply opposite movements in bond and loan volumes. I use this result with sign-restriction methods to identify financial shocks in a VAR model. I find that financial shocks identified with bond and loan series explain a large share of the business cycle and especially the two last recessions. I also use the identification strategy to recover a measure of financial stress. This measure allows predicting the evolution of corporate bond spreads.

Key Words

Financial stress, banks, business cycles, shock identification, estimation.