



Mathematical and historical dynamics of modern economy : an application to the Korean economy

Deokmin Kim

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U.F.R DE SCIENCES ECONOMIQUES

THÈSE

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Deokmin KIM

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**Mathematical and Historical Dynamics of
Modern Economy: An Application to the
Korean Economy**

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¹source: KDI 2007: 173

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Résumé

L'une des principales caractéristiques de la crise économique, comme la Grande récession mondiale en 2008, est l'effondrement soudain de l'activité économique. Dans cette étude, nous n'avons pas essayé de décrire la crise comme le résultat de chocs externes (demande ou offre). Par conséquent, cette étude s'appuie fortement sur la discussion de l'économie non traditionnelle appelée théorie du cycle économique endogène. On pense qu'il doit être traité comme un processus non périodique et irrégulier.

Dans cette thèse, j'ai essayé de reproduire les aspects persistants et irréguliers des cycles économiques comme l'effondrement soudain du niveau général d'activité dans une économie, à savoir la crise. Pour cette recherche, il est essentiel d'étudier la dynamique non linéaire en mathématiques et nous permet d'interpréter des phénomènes aussi irréguliers et imprévisibles à la suite de processus déterministes, et non de simples erreurs ou chances statistiques. La dynamique non linéaire est une méthode analytique qui évalue les comportements fondamentaux de l'utilisation d'un système d'équation différentielle ou discret non linéaire pour voir si le système atteint l'équilibre ou continue à se répéter en cycles. Plus précisément, *la dynamique* se réfère aux changements de variables au fil du temps. L'adjectif, *non linéaire*, se réfère à des résultats non proportionnels pour le changement d'initial condition. Par conséquent, un système dynamique non linéaire nous permet de s'attendre à ce que des modèles complexes de variables apparentées puissent émerger. Des modifications subtiles dans les conditions initiales peuvent entraîner des résultats considérablement

différents.

Nous présentons plusieurs modèles non linéaires appliqués à l'économie. Le modèle du cycle de croissance de Goodwin en économie est le cas qui applique le célèbre modèle prédateur-proie à une relation entre le taux de salaire et le taux d'emploi. Le modèle vérifie les mouvements cycliques des deux variables par un simple système non linéaire. Kaldor a proposé un modèle prototype pour étudier l'effet des non-linéarités en économie (Gabisch et Lorenz 1989: 122; Lorenz 1993: 43). Son modèle *IS* modifié nous donne une nouvelle perspective sur l'équilibre. En outre, les conditions d'équilibre dans le modèle de Kaldor sont encore largement utilisées dans l'économie post-keynésienne. Le modèle de Metzler (1942) était le modèle d'inventaire de production semblable au modèle prédateur-proie. En outre, le cadre microéconomique de ce modèle peut être comparé à celui du problème de la gestion des stocks, qui est une autre méthode utilisée pour implémenter une dynamique non linéaire dans cette étude. Le modèle Macro Stock Management (MSMM dans cette thèse) est un modèle macroéconomique qui combine le modèle d'inventaire de production de Metzler avec le modèle de gestion des stocks dans la dynamique du système sous l'influence des autorités centrales qui exécutent les politiques macro comme les politiques fiscales et monétaires.

La dynamique du système est une méthodologie ainsi qu'une méthode pour implémenter des mouvements dynamiques non linéaires. Les éléments de base de la dynamique du système consistent en system thinking, le mécanisme de rétroaction (feedback mechanism), les structures de stock et de flux, time delays, les non-linéarités et le processus de simulation assisté par ordinateur. System thinking dans la dynamique du système se réfère à la pensée de rétroaction (feedback thinking) contrastée contre la pensée axée sur l'événement (event-oriented thinking). C'est une façon de penser que le comportement d'un système provient de l'ensemble de la structure du système. La réponse au problème n'est pas simplement trouvée dans le processus de réponse à chaque événement, mais seulement en observant de près le processus de rétroaction du système.

Les structures de stock et de flux avec time delays sont au centre du mécanisme de rétroaction et de divers types de modèles de stock. La structure de recherche d'objectif nous permet d'observer le processus d'ajustement des écarts entre les niveaux réels et le niveau désiré. De plus, time delays peuvent générer le modèle oscillant des comportements car eigen-values deviennent des conjugués complexes en raison des changements de time delays. La simulation assistée par ordinateur est fondamentale pour que la dynamique du système représente différents types de comportements. En raison de la complexité des modèles, la simulation est le seul moyen pratique de tester ces modèles. Les modules informatiques pour la simulation tels que VEMSIM nous permettent de tester les modèles complexes.

Le cadre du problème de la gestion des stocks (Stock management problem) montre de manière intensive le point de vue de la dynamique du système. Le problème de la gestion des stocks se réfère aux efforts des gestionnaires ou des décideurs pour atteindre leur taux désiré (par exemple, le taux d'utilisation de la capacité et le taux cible d'inventaire). Une modification de la vitesse d'ajustement pour les le écarts entre le taux réel et le taux désiré est associée à la progression non seulement de la gestion privée mais publique. Il est également possible d'imaginer le processus de coordination des écarts dans le secteur financier, ainsi que le domaine de la gestion d'entreprise. Time delay dans le secteur financier se réfère à la réactivité du secteur aux besoins financiers de l'économie. Ces relations systémiques globales sont représentées et simulées par la dynamique du système.

Au cours de la dernière partie de cette étude, divers outils d'analyse des time series sont utilisés pour estimer les effets de l'investissement sur les taux de profit et les effets de l'inégalité salariale et de la dette des consommateurs sur la demande intérieure depuis la crise financière mondiale de 2008. Parce que le modèle Structural Vector Auto-Regressif (SVAR) impose des restrictions à long terme ou à court terme sur le système VAR, il utilise pour distinguer deux variables avec des caractéristiques similaires, telles que le taux de profit après impôts et le taux de profit après paiement des intérêts et des dividendes excluant taxes (le taux de profit après paiement). Aux restrictions à court terme de SVAR,

On suppose que le taux de profit après impôts prend plus de temps pour affecter l'investissement des entreprises que le taux de profit après paiement. Au lieu de cela, l'accumulation de capital réagit en même temps à une modification du taux de profit après paiement ou de la dette extérieure des entreprises dans l'économie sud-coréenne, car on suppose que l'imposition est déterminée par la politique de l'État, qui prend un peu plus de temps pour décider.

Beaucoup de données de time series ont caché des ruptures de potentiel. Perron (1989) fait valoir que les tests traditionnels de unit root tels que le test Augmenté Dickey-Fuller sont susceptibles de ne pas détecter la stationnarité ou la non-stationnarité des données si elles ont des ruptures structurelles. Zivot et Andrews (1992) proposent le test de unit root des données de time series avec une seule rupture dans time series. Le test Zivot-Andrews fournit le modèle qui estime un point de la rupture structurelle endogène dans les données. Lumsdaine et Papell (1997) proposent le modèle de test unit root avec deux ruptures structurelles endogènes. Le test Gregory-Hansen fournit des informations sur une rupture structurelle dans un test de co-intégration. Gregory et Hansen (1996) suggèrent trois modèles du changement structurel dans la relation de co-intégration: niveau, tendance et changement de régime. Si une équation de cointegration a un point d'arrêt dans le niveau, la tendance ou le changement de régime, un test supplémentaire pour la relation de co-intégration sera nécessaire. Le test Gregory-Hansen fournit les valeurs critiques de savoir si la relation de co-intégration est valable ou non malgré la rupture structurelle.

Le modèle Auto Regressive Distributed Lags (ARDL) est utilisé pour capturer les relations à long terme entre les variables. Le modèle ARDL fournit un cadre pour résoudre le problème du petit échantillon (small sample problem) qui découle de la rupture structurelle identifiée par le test Gregory-Hansen. La technique de co-intégration de ARDL est robuste et cohérente par rapport à d'autres techniques de co-intégration, même si les données ont le problème du petit échantillon. En outre, il peut être sélectionné pour cette étude, même si les tests unit root avec ou sans les ruptures structurelles ne sont pas cohérents, car $I(1)$, $I(0)$ et la combinaison des deux ordres sont autorisés dans la technique

ARDL.

Goodwin (1990) a présenté l'un des modèles de dynamique non linéaire représentatifs en économie. Le modèle en 1990 a une forme peu différente avec le modèle de cycle de croissance. Il consiste en trois équations différentielles comprenant une variable de contrôle qui assure la stabilité du système, contrairement aux deux équations différentielles du modèle du cycle de croissance. En introduisant les variables de contrôle dans le système, la dynamique chaotique se produit dans le système plutôt que simplement des cycles répétitifs du modèle du cycle de croissance, bien que les premières deux équations du modèle en 1990 soient très similaires à celles du modèle du cycle de croissance. En outre, il a un attracteur étrange (strange attractor), appelé l'attracteur de Rössler, qui est un attracteur qui apparaît seulement autour d'un point fixe par rapport à un attracteur de Lorenz, appelé attracteur de papillons (butterfly attractor). Cependant, le modèle économique de Goodwin utilisant l'attracteur de Rössler a une limite absolue. Le modèle a décrit les variables dans les niveaux-dimension où le modèle met en œuvre une situation irréaliste, par exemple, des niveaux de production négatifs. Ainsi, j'ai transformé le modèle de Goodwin en *la dimension de taux de changement*, c'est-à-dire le taux de changement de variables. Cette stratégie a rendu l'attracteur étrange réaliste dans la situation économique. De plus, j'ai appliqué cette approche au système de reproduction marxiste.

Dans ce modèle de reproduction en la dimension de taux de changement, l'absence du secteur financier fait immédiatement référence au *régime de reproduction simple* du modèle de reproduction marxiste. Contrairement à ce constat, un rôle du secteur financier est nécessaire pour la croissance économique au taux de croissance constant, qui est la reproduction élargie d'une économie. Par conséquent, le secteur financier est crucial pour le passage du régime de reproduction simple au modèle de reproduction élargi de ce modèle en raison des time delays. En outre, le mouvement chaotique de ce modèle peut être détecté. La réactivité aux écarts entre le taux de variation réel de output et le taux de variation de output désiré est un paramètre de bifurcation. C'est-à-dire, time delays plus longs de production est associé à des amplitudes plus larges

des cycles conomiques.

Le problème de la gestion des stocks (or supply chain structure) dans la dynamique du système consiste en les structures de stock et de flux pour l'acquisition d'intrants au processus et les politiques de gestion régissant divers flux. Dans cette étude, la structure de stock et de flux est linéarisée, de sorte qu'elle s'exprime sous forme de motifs à deux objectifs avec chaque délai. Par rapport aux problèmes généraux de gestion des stocks, ce système est également construit avec trois règles de décision. '(1) [pour] remplacer les pertes attendues du stock (2) [à] réduire l'écart, et (3) [à] maintenir une ligne d'offre (supply line) adéquate des commandes non remplies "(Sterman 1988: 151). Les gestionnaires en production donnent non seulement des commandes suffisantes pour remplacer la perte, mais aussi de minimiser leurs coûts en réduisant les divergences. Ces performances sont réalisées en maintenant la ligne d'offre.

Surtout, cette étude applique ce cadre au comportement du secteur financier et des autorités centrales. On suppose que le secteur financier dispose d'un mécanisme de rétroaction positive où un écart plus important que le niveau désiré conduit à davantage de prêts. Contrairement à ce secteur, les autorités centrales cherchent à stabiliser l'ensemble de l'économie, de sorte qu'elles disposent de le but-recherchant mécanisme de rétroaction (goal-seeking mechanism). Par conséquent, les gestionnaires des institutions financières cherchent à maximiser leurs bénéfices dans le mécanisme de rétroaction positive, et les gestionnaires publics des autorités centrales tentent de stabiliser le système avec leur objectif dans le mécanisme de rétroaction négative. Comme mentionné ci-dessus, le MSMM est une variante du modèle de la chaîne d'offre dans la méthode de la dynamique du système. J'ai combiné le modèle de la chaîne d'offre avec le modèle d'ajustement des stocks de Metzler (citealt Franke: 1993; citealt Franke: 1996; citealt Matsumoto: 1998) et Duménil et Lévy's model ([Duménil and Lévy, 1993b; 1996](#)) et l'a étendu en un modèle macro intégrant le secteur financier.

La stabilité de ce système est satisfaite par les délais; le système est localement stable. Cependant, si l'un des paramètres change brusquement, la crise, l'effondrement soudain de l'activité générale de l'économie, apparaît. C'est-à-dire que la crise économique n'est pas la conséquence d'une déficience de la demande car il n'y a pas de diminution endogène persistante de la demande, indépendamment des autres variables économiques. Au contraire, les changements dramatiques du comportement managérial et financier entraînent une forte réduction du niveau de la demande. De la même manière, les chocs de la demande stochastique ne peuvent pas être la cause de l'effondrement, car les chocs séquentiels suffisants pour être la cause des crises sont impossibles; il peut être considéré comme du bruit autrement. Une augmentation du niveau de demande suivie de l'effondrement entraîne une forte reprise du taux d'utilisation de la période. Cet effet découle d'un rôle des finances publiques pour ajuster une divergence entre les valeurs réelles et les valeurs cibles. Une réduction du financement privé est compensée par la fourniture des finances publiques.

Dans le MSMM, les progrès de la gestion (un effort pour réduire les écarts entre le niveau réel et le niveau désiré dans la relation production-inventaire) peuvent améliorer ses performances de recherche d'objectif. Cependant, la sur-réactivité de la performance managériale entraîne la modification du modèle oscillant du modèle. Dans le même temps, on suppose que la finance dispose d'un mécanisme auto-renforçant qui peut déstabiliser une économie. Dans le cadre du MSMM, l'interrelation entre le progrès de la gestion et la sensibilité financière détermine finalement le résultat de l'économie et, en cas de crise économique, on comprend qu'une certaine relation entre eux a été formée. Pour décrire une évolution de l'interrelation entre la gestion et la finance, un modèle analogique des mathématiques est introduit. Ce modèle est un modèle d'amour entre Romeo et Juliette.

Le modèle des love-affairs est un système de deux équations différentielles où Juliette ou Romeo peut être un amoureux inconstant. Chaque délai de production et ajustement financier se réfère respectivement au progrès de la gestion et à

la sensibilité financière. On suppose que la relation entre la gestion et la sensibilité financière est similaire à celle de Romeo et Juliette dans le modèle des amours. Si la finance est l'amant inconstant (Juliet), on suppose que la relation entre eux peut être décrite dans un régime dirigé par des finances (finance-led regime). Sinon, c'est un régime dirigé par gestion (management-led regime). Par conséquent, le MSMM peut être influencé par la structure du régime, et sa condition de stabilité peut changer constamment. La crise est générée par des intersections dangereuses de sensibilité managériale et financière. Les valeurs appropriées de chaque sensibilité ou délai liées à la gestion et aux finances assurent la stabilité du modèle macro. La sensibilité de la gestion de l'entreprise domine les mouvements périodiques du modèle; La réponse des finances aux circonstances économiques domine l'amplitude des cycles économiques. Par conséquent, un croisement involontaire des sensibilités peut conduire à l'effondrement soudain de la macroéconomie. J'explore cet état de choses par une analogie de love-affairs entre gestion et finance.

Nous ne pouvons pas imaginer un système macro sans intervention des autorités centrales parce que l'économie perd totalement son activité s'il n'y a pas d'action centrale ou que les autorités ignorent les divergences, c'est-à-dire qu'elles ont de longs délais. Cependant, une réponse trop excessive aux écarts de l'autorité conduirait à une réaction excessive à l'écart. Au contraire, une action trop passive entraînera un état d'activité économique irrécupérable. Si la relation entre la progression de la gestion et la sensibilité financière n'a pas l'orbite fermée (closed-orbit) dans la mesure exacte qui dépend des valeurs initiales et du point fixe que nous avons présenté ci-dessus, mais, avec des mouvements irréguliers, il est difficile pour les décideurs de définir un délai ou une intensité de la politique. Dans le même temps, cette action politique a une impossibilité car il est difficile pour les décideurs de reconnaître la complexité de l'ensemble du système.

Par conséquent, Keynes et Hayek avaient discuté deux aspects contradictoires - deux côtés de la même monnaie - des politiques macro plutôt que de lutter entre elles dans leurs différents camps. Cependant, l'impossibilité que Hayek ait dit ne signifie pas que toutes les tentatives de stabilisation de l'économie

sont impossibles, à mon avis. Il met l'accent sur une institution pour créer une nouvelle conception pour gérer une croissance stable pour la société. Pour éviter les fluctuations importantes de la macro activité, il est nécessaire de contrôler la réponse excessive de la gestion et des finances en plus des interventions des autorités centrales. En particulier, le comportement de la finance privée n'est pas le but-recherchant mécanisme de rétroaction, mais le mécanisme de rétroaction positive menant à une surchauffe et à des récessions.

Le MSMM avec accumulation de capital est une version élargie comprenant la relation de distribution, la fonction d'investissement et les comportements de la décision de tarification. En général, le rythme de l'accumulation de capital dans une économie dépend du profit retenu des entreprises, c'est-à-dire le taux de profit après le paiement ou l'économie des capitalistes. Cependant, l'effet financier sur l'accumulation du capital, c'est-à-dire le financement externe des entreprises, est un autre facteur important pour investir dans de nouveaux capitaux. Dans l'économie sud-coréenne, cela pourrait permettre un rythme plus rapide d'accumulation de capital. Le MSMM avec l'accumulation de capital montre qu'un changement de comportement du secteur financier, par exemple, un environnement commercial plus favorable pour les prêts à la consommation peut fortement influencer le rythme de l'accumulation du capital.

J'ai appliqué ces perspectives à l'histoire de l'économie sud-coréenne, qui a souffert de la crise asiatique en 1997, suivie d'une stagnation prolongée des investissements. Dans le cadre de la dynamique du système, il existe une intersection dangereuse des délais de gestion, de finance et de politique de stabilisation des autorités centrales, ce qui entraîne un effondrement soudain de l'activité générale de la macro économie . Ce cadre ne se limite pas à l'économie sud-coréenne. Cependant, j'ai procédé à cette discussion tout en présentant des données sur l'économie sud-coréenne. En outre, la simulation de la dynamique du système a été utilisée pour étudier la cause du ralentissement relatif du rythme de l'accumulation de capital dans l'économie sud-coréenne depuis la crise en 1997. Les résultats de la simulation assistée par ordinateur par la dynamique du système ont été dérivés d'un changement radical du système financier et les

niveaux d'endettement des entreprises de l'économie sud-coréenne. Je construis un nouveau modèle de dynamique de système pour le processus d'accumulation de capital à long terme, y compris la provision de financement du secteur financier.

Nous devrions prendre en compte un changement de changement technologique et de distribution pour capturer les trajectoires à très long terme d'une économie. En général, pour ce faire, des techniques utilisant la fonction de production ont été utilisées. Cependant, dans cette étude, nous utilisons le modèle de changement technique stochastique où les trajectoires historiques de la technologie sont déterminées par un ensemble de techniques aléatoires donné selon le critère de rentabilité. Tout d'abord, le modèle de changement technique induit (induced technical change) est introduit. Le modèle montre qu'une modification du prix relatif du capital au travail induit l'invention d'un nouveau type de techniques, telles que des techniques de type économes en main-d'œuvre. Duménil et Lévy (1995) ont présenté un modèle qui peut suivre les variables à long terme des variables sans un modèle a priori pour la technologie et la distribution, au nom du modèle de changement technique stochastique. Dans le modèle de croissance endogène, les résultats sont trop sensibles à la façon dont nous définissons l'équation de recherche. En outre, le processus de recherche et de développement comporte beaucoup d'éléments et d'incertitudes exogènes. Cependant, dans le modèle d'un modèle stochastique, le processus R & D est donné par la distribution de probabilité telle que la distribution uniforme. Bien que les techniques qui peuvent être utilisées dans une économie apparaissent comme les résultats du R & D, toutes les techniques ne peuvent être utilisées dans une économie. En d'autres termes, un processus de sélection ou le critère de rentabilité est nécessaire. La méthode de la dynamique du système a également été utilisée pour reconstituer les trajectoires de technologie et de distribution dans l'économie sud-coréenne. En fait, le taux de profit provient des trajectoires à long terme de la technologie et de la distribution d'une approche dynamique de la dynamique du système est un autre outil pour représenter le modèle dans cette étude. Au chapitre 9, j'ai essayé de saisir une relation entre les tendances macroéconomiques, l'inégalité et la dette des consommateurs pendant la période

néolibérale en utilisant des techniques économétriques à time series. Les changements dans les relations dans l'économie américaine et l'économie sud-coréenne avant et après la crise de 2000 pourraient être capturés.

Dans cette thèse, j'ai adopté les arguments des économistes hétérodoxes tels que les économistes marxistes selon lesquels le taux de profit est la variable prédominante pour expliquer l'accumulation du capital et les cycles économiques dans l'économie capitaliste. Pour une étude plus approfondie, il est nécessaire de calculer la variable avec précision. En particulier, il y a eu peu d'études sur le taux de profit de l'économie sud-coréenne en raison du manque de données disponibles. Cette dissertation a cherché à calculer différents types de taux de profit, y compris le taux de profit après impôts et le taux de profit après paiement, et ceux des différents secteurs de l'économie sud-coréenne. En outre, le processus historique à long terme de l'économie sud-coréenne ne peut pas manquer en ce qui concerne la mondialisation et la financiarisation qui progressent régulièrement depuis les années 1980. En plus des divers changements dans le taux de profit, nous devons voir comment la financiarisation et la mondialisation ont affecté le chemin macroéconomique de l'économie sud-coréenne. Nous avons présenté certains indicateurs pour cela. Comme nous l'avons déjà mentionné, la financiarisation a eu un impact profond sur le comportement du secteur financier dans l'économie sud-coréenne. Comme dans d'autres pays, le secteur financier de l'économie sud-coréenne a commencé à opérer principalement pour les prêts à la consommation, et non pour les industries. Au chapitre 7, un nouveau indicateur pour estimer l'impact de la mondialisation sur l'économie sud-coréenne est suggéré. Un écart croissant entre les sources financières et les utilisations de le secteur non financier dans l'économie sud-coréenne depuis 1997, indique un changement à long terme du chemin macroéconomique de l'économie sud-coréenne causé par l'impact de la mondialisation. Par définition, les passifs financiers et les épargne nettes sont destinés à acheter des actifs financiers ou à générer des investissements nets. Il convient de noter que le ratio entre l'investissement net et les ressources financières (passifs financiers + épargne nettes) de le secteur non financier dans l'économie sud-coréenne a fortement diminué. En d'autres termes, une grande partie des ressources financières

sont utilisées pour acheter des actifs financiers plutôt que des investissements nets. Plus important encore, il existe un écart croissant entre les sources financières et l'utilisation, en particulier depuis 2005. Cet écart est l'impact de la mondialisation, ce qui signifie que l'écart signifie l'investissement étranger dans d'autres pays. Ainsi, en fait, l'accumulation de capital dans l'économie sud-coréenne n'est pas entièrement stagnante, mais la récession des investissements intérieurs et l'augmentation correspondante de l'investissement étranger sont entremêlés. Le secteur non financier en Corée du Sud investit principalement davantage dans l'achat et l'exploitation d'actifs financiers.

Quel taux de profit a le plus grand impact sur l'accumulation de capital de l'économie sud-coréenne? Bien sûr, le niveau d'endettement élevé des entreprises sud-coréennes signifie qu'ils ont essayé d'accroître leur capacité d'affaires indépendamment de la rentabilité. Cependant, depuis 1997, le comportement du secteur financier a été affecté par le niveau de rentabilité. La politique fiscale du gouvernement a-t-elle le plus grand impact? Ou les épargne nettes d'une entreprise affectent-elles l'accumulation de capital? Sur la base des résultats du calcul, j'ai mené la relation entre l'accumulation de capital, les cycles économiques et les différents taux de profit dans l'économie sud-coréenne, et j'ai décrit l'histoire de l'économie sud-coréenne. Le VAR sans restriction et les méthodes VAR structurelles ont contribué à saisir la relation dans l'économie sud-coréenne. Pour mesurer cela, deux indicateurs de rentabilité ont été proposés. L'un est le taux de profit après paiement et le taux de profit après impôt. La méthode SVAR permet de distinguer deux indicateurs similaires dans time series. En utilisant la méthode SVAR qui peut imposer des contraintes à court terme, on suppose que le taux de profit après impôt prend un peu plus de temps pour affecter l'accumulation de capital que les autres variables.

Tout d'abord, comme nous l'avons déjà mentionné, la situation qui ne peut pas attirer des fonds extérieurs en raison des changements dans le secteur financier depuis 1997 a eu le plus grand impact sur l'accumulation de capital. En d'autres termes, le taux élevé d'accumulation avant 1997 était dû à la facilité avec laquelle les fonds externes étaient facilement disponibles. Deuxièmement,

elle a également été influencée par la rentabilité, et l'effet du taux de profit après paiement, à l'exception des intérêts et du dividends, sur l'accumulation de capital a augmenté. De cette façon, nous pouvons résumer les aspects du processus de transformation néo-libéral de l'économie sud-coréenne.

La politique gouvernementale a été affaiblie après les années 1980 mais ne s'est pas complètement évaporée. En raison de l'effet d'accélération financière par le système bancaire, les fonds disponibles pour investir dans de nouvelles capitales pourraient être fournis aux entreprises bien qu'ils aient souffert de leurs activités fortement endettées — En d'autres termes, ils devaient supporter le fardeau à intérêt élevé pour ça. Grâce à ce mécanisme, ils pourraient maintenir le rythme rapide de l'accumulation du capital dans une certaine mesure. Cet état de choses dans les années 1990 a été l'emblème entre les deux chocs. Après la crise de 1997, un changement institutionnel dans le système bancaire est important. Les politiques industrielles de l'État se sont considérablement affaiblies parce que la majorité des banques en Corée du Sud ont été privatisées. En outre, cela a entraîné une augmentation du prêt à la consommation parce que les banques hésitent à prêter de l'argent au secteur des entreprises et qu'elles souhaitent fournir des fonds au marché des prêts à la consommation rentable à ce moment-là. Cette transformation a entraîné le transfert de la dette aux ménages. Au lieu de cela, le levier élevé des entreprises a considérablement diminué par rapport au niveau avant 1997; la politique à faible intérêt par l'autorité monétaire dans le pays a atténué le fardeau des intérêts sur le secteur des entreprises. L'accumulation de capital a convergé au niveau du taux de profit après paiement et l'investissement intérieur a été réduit.

Toutefois, bien que les entreprises sud-coréennes aient réduit leurs ratios d'endettement, le montant de la dette a continué d'augmenter avec l'expansion des actifs. Le ratio de l'investissement intérieur à ces dettes et leurs économies nettes ont considérablement diminué, tandis que le reste conserve des actifs financiers. Néanmoins, l'écart entre les ressources financières et l'utilisation se développe, ce qui fait partie des investissements étrangers. Au fait, la plupart des investissements à l'étranger des entreprises sœurs coréennes sont des investissements directs. En d'autres termes, alors que l'accumulation du capital domestique a

diminué, l'accumulation de capitaux étrangers par les entreprises sud-coréennes a augmenté. Par conséquent, il est nécessaire de maintenir un petit investissement en Corée du Sud tout en augmentant l'achat d'actifs financiers. La plupart des ressources financières ont été utilisées pour gérer les actifs financiers ou être investis à l'étranger.

Au cours des dernières décennies, en particulier dans l'économie américaine et sud-coréenne, il y a eu un écart grandissant dans la répartition du revenu entre le groupe à revenu élevé et le groupe à faible revenu. Duménil et Lévy (2011) soutiennent que cette évolution de l'inégalité dans l'économie américaine est associée à la quête d'un revenu élevé basé sur la financiarisation et la mondialisation sous le néolibéralisme. Dans les deux pays, les inégalités croissantes entre les salariés représentent une part importante des écarts de distribution.

En Corée du Sud, le revenu du groupe des salaires les plus élevés n'a cessé d'augmenter régulièrement, mais depuis les années 1980, l'écart s'est accru. Il s'est apparemment modéré entre les années 1980 et le milieu des années 1990, mais il doit être considéré dans les environnements politiques et économiques du pays à cette époque. Surtout, il faut noter la réussite du groupe de revenu 90-99 qui, bien que composé de cadres et de professionnels publics et privés, notamment dans les domaines du droit, de la santé et de la finance, dépendait *moins* de le capital et les revenus d'entreprise par rapport au groupe de 1% supérieur tel que mentionné ci-dessus. Par conséquent, il semble que ce groupe - plutôt que le sommet des grandes classes de revenus, comme le groupe du 1% supérieur, qui dépendait relativement *plus* du revenu du capital - était la classe qui bénéficiait constamment du virage néolibéral. En d'autres termes, même si le revenu global des groupes à revenus les plus élevés (top 1%) et les plus faibles (groupe de revenu 0-90) en Corée du Sud a été fortement influencé par la situation politique et économique, qui dépendent moins du revenu du capital parmi les salariés les plus élevés augmentent leur part. De plus, on constate que leur part se développe de plus en plus récemment.

L'expansion des inégalités et des inégalités salariales est particulièrement remarquable, en particulier dans l'économie américaine et l'économie sud-coréenne. Dans le cadre marxiste des classes sociales, en outre, l'augmentation de l'inégalité salariale indique qu'une nouvelle classe intermédiaire, la classe managériale, émerge rapidement parmi les classes sociales traditionnelles - capitalistes et travailleurs productifs - dans les sociétés capitalistes. Malgré l'augmentation récente de la classe de gestion, l'émergence et le développement de cette classe ont une histoire beaucoup plus longue dans la transformation historique du capitalisme, mais il convient de noter leur réalisation par rapport à la répartition du revenu pendant la période néolibérale (Duménil and Lévy, 2011; Mohun, 2006; 2006; Tavani and Vasudevan, 2014; Vasudevan, 2016).

Le rythme décroissant de l'accumulation de capital a constitué l'un des personnages populaires sur l'évolution de la composition de la demande globale dans de nombreux pays au cours de la période néolibérale, bien qu'il y ait eu un boom de l'investissement dans les années 1990 dans certains pays comme l'économie américaine et sud-coréenne. Dans l'économie américaine, en outre, on observe une augmentation du ratio consommation/PIB, conjuguée à la baisse du taux d'investissement depuis 1980. Ce régime de croissance axé sur la consommation dont les caractéristiques sont le ralentissement du rythme d'accumulation et la tendance à la hausse le ratio de la consommation au PIB a accompagné une augmentation spectaculaire de la dette des ménages aux États-Unis. La tendance à la baisse de l'accumulation de capital dans l'économie sud-coréenne peut être observée depuis la crise financière asiatique de 1997-1998, qui a été l'une des crises les plus sévères de l'histoire du pays. Cependant, l'importance de la consommation dans la composition de la demande de l'économie sud-coréenne depuis 1980 serait douteuse car il y avait une forte tendance à la baisse de la consommation par rapport au PIB au cours de la première moitié des années 1980. Contrairement aux tendances de l'économie américaine, il semble difficile d'extraire une tendance constante relative au rythme de l'accumulation du capital et au ratio de la consommation à la demande intérieure lors de la transition néolibérale dans l'économie sud-coréenne. Nous cherchons à saisir une éventuelle relation à long terme entre l'inégalité salariale croissante, qui a été l'un des résultats

importants de la nouvelle alliance entre les propriétaires capitalistes et le groupe supérieur de la classe managériale et les tendances macroéconomiques depuis 1980 aux États-Unis et en Corée du Sud. C'est pourquoi nous essayons d'estimer le lien à long terme entre l'inégalité salariale et la dette des consommateurs et les principales voies de la macroéconomie domestique.

La base de l'analyse des séries chronologiques est le test racine unitaire (unit root test). Cependant, s'il existe une rupture structurelle dans times series, les tests racine d'unités traditionnels peuvent échouer. Étant donné que les économies américaines et sud-coréennes ont connu la crise économique en 2008 et la crise économique en 1997 ou la crise économique en 2008, respectivement, depuis les années 80, il peut y avoir une ou plusieurs ruptures structurelles dans les séries chronologiques. Par conséquent, un test de racine unitaire qui peut mesurer les ruptures structurelles est effectué. Tout d'abord, un test a été réalisé en supposant une rupture structurelle, et un test a été effectué en supposant deux ruptures structurelles si nécessaire. Deuxièmement, s'il existe une rupture structurelle dans time series, le problème du petit échantillon (small sample problem) peut être rencontré. Par conséquent, une méthode de mesure de cointégration robuste doit être trouvée dans ce cas. L'une d'elles est la méthode ARDL. Au lieu de cela, pour surmonter la taille de l'échantillon trop petit, les données annuelles ont été transformées par interpolation en tant que données trimestrielles.

Dans les estimations basées sur les données annuelles, les deux pays ont montré la direction de la macroéconomie attendue. La consommation (consommation au PIB) a une relation positive à long terme avec l'inégalité salariale et la dette des consommateurs, et l'investissement (investissement net au capital) a une relation négative à long terme avec deux variables. Cependant, compte tenu de la rupture structurelle, un résultat légèrement différent a été obtenu. Premièrement, dans le cas de l'économie américaine, l'investissement est le même que celui tiré des données annuelles. Cependant, compte tenu de la rupture structurelle de 2001, une augmentation de la consommation a été positivement associée à l'inégalité salariale et à la dette des consommateurs avant 2001. Cependant, depuis 2001, il existe une relation négative avec l'inégalité salariale et une relation positive avec la dette des consommateurs. Il y a eu une tendance à la hausse constante

de l'inégalité salariale depuis ces crises, alors que la dette des consommateurs a atteint un sommet en 2008 et a diminué régulièrement. Toutes ces tendances ont eu un impact négatif sur la demande intérieure et, par conséquent, l'économie américaine devait compter sur les dépenses publiques pour éviter de réduire la demande pour l'économie.

Deuxièmement, l'économie sud-coréenne est la même que celle prévue par les données annuelles. La consommation et l'investissement ont des relations négatives à long terme avec des relations positives à long terme avec l'inégalité salariale et la dette des consommateurs, respectivement. Cependant, depuis 1997, la rupture structurelle, à la fois la consommation et l'investissement dans ce pays, a eu une relation négative à long terme avec l'inégalité salariale et la dette des consommateurs. Par conséquent, la demande intérieure du pays dépend entièrement des exportations nettes, à l'exception des niveaux de dépenses gouvernementales historiquement contraints. Cependant, les exportations nettes de ce pays maintiennent un niveau positif à mesure que les exportations et les importations diminuent, tandis que les importations diminuent plus rapidement.

Cette thèse se compose de deux parties: une introduction à la dynamique non linéaire et à la dynamique du système et à leurs applications du chapitre 1 et du chapitre 5; études empiriques pour l'économie sud-coréenne, y compris la simulation assistée par ordinateur du modèle de changement technique stochastique du chapitre 6 et du chapitre 7. Les chapitres 7 à 9 sont consacrés à un travail empirique pour estimer la relation entre accumulation de capital et taux de profit en Corée du Sud et à une analyse économétrique indépendante de l'économie sud-coréenne et de l'économie américaine. L'annexe fournit l'analyse de stabilité supplémentaire pour les modèles mathématiques et les codes informatiques pour les simulations et les résultats statistiques de l'estimation économétrique.

General Introduction

One of the major features of the economic crisis such as the Global Great Recession in 2008 is a sudden collapse of economic activity. In this study, we will not address issues related to such crises as either external supply shocks or demand shocks. Therefore, this study is very much leaning on the discussion of non-mainstream economics called endogenous economic cycle theory. It is not right to treat a simple regular cycle process such as the cyclic fluctuations. It is believed that it should be treated as a nonperiodic and irregular process.

In this dissertation, I tried to reproduce the persistent and irregular aspects of the economic cycles as the sudden collapse of the general level of activity in an economy, namely Crisis. For this research, it is essential to study nonlinear dynamics in mathematics, and it gives us room to interpret such irregular and unpredictable phenomena as a result of deterministic processes, not mere statistical errors or chances. Nonlinear dynamics is an analytical method that assesses fundamental behaviors of using a nonlinear differential or discrete equation system to see whether the system achieves equilibrium or keeps repeating in cycles. More specifically, *dynamics* refers to changes in variables over time; the adjective, *nonlinear*, refers to non-proportional results for the change of input. Therefore, a nonlinear dynamic system allows us to expect that some complex patterns of related variables can emerge. Moreover, this system is very sensitive to change in initial conditions. Subtle changes in the initial conditions can lead to considerably different results.

We introduce several nonlinear models that have been applied to economics. The Goodwin's growth cycle model in economics is the case that applies the famous predator-prey model to a relationship between the wage rate and the employment rate. The model verifies cyclical movements of the two variables by a simple nonlinear system. Kaldor proposed a prototype model to study the effect of non-linearities in economics (Gabisch and Lorenz 1989: 122; Lorenz 1993: 43). His modified IS model gives us a new perspective on balance. Moreover, the equilibrium conditions in the Kaldor model are still widely used in post-Keynesian economics. Metzler's model (1942) was the production-inventory model that similar with the predator-prey model. Moreover, the microeconomic framework of this model can be compared with that of the stock management problem, which is another method that is used to implement nonlinear dynamics in this study. The Macro Stock Management Model (MSMM) is a macroeconomic model that combines the Metzler's production-inventory model with the stock management model in system dynamics under the influence of the central authorities, which perform the macro policies such as the fiscal and monetary policies.

System dynamics is a methodology as well as a method to implement nonlinear dynamic movements. The basic elements of system dynamics consist of system thinking, feedback mechanism, stock and flow structures, time delays, nonlinearities, and computer-aided simulation process. The system thinking in system dynamics refers to feedback thinking contrasted against event-oriented thinking. It is a way of thinking that the behavior of a system arises from the entire system structure. The answer to the problem is not simply found in the process of responding to each event, but only when closely observing the feedback process of the system.

The stock and flow structures with time delays are at the hub of the feedback mechanism and various types of patterns of stock. The goal-seeking structure allows us to observe the adjustment process of discrepancies between actual levels and the desired level. Moreover, the time delays can generate the oscillated pattern of behaviors because the eigenvalues become complex conjugates

due to the changes in time delays. Computer-aided simulation is fundamental for system dynamics to represent various patterns of behaviors. Because of the complexity of the models, the simulation is the only practical way to test those models. The computer packages for the simulation such as VEMSIM helps us to test the complex models.

The framework of the stock management problem intensively shows the viewpoint of system dynamics. The stock management problem refers to managers or policymakers' efforts to achieve their desired rate (e.g., the rate of capacity utilization and the target rate of inventory). A change in the speed of adjustment for discrepancies between the actual rate and the desired rate is associated with the progress of not only private but public management. It is also possible to imagine the process of coordination of the discrepancies in the financial sector, as well as the domain of corporate management. The time delay in the financial sector refers to the responsiveness of the sector to the financial needs of the economy. These overall systemic relationships are represented and simulated by system dynamics.

In the latter part of this study, various time series analysis tools are used to estimate the effects of investment on profit rates and the effects of wage inequality and consumer debt on domestic demand since the global financial crisis of 2008. Because the Structural Vector Auto-Regressive (SVAR) model impose on the long run or short run restrictions on the VAR system, it uses to distinguish two variables with similar characteristics, such as the after-tax rate of profit and the rate of profit after payment of interests and dividends excluding taxes (the after-payment rate of profit). By the short run restrictions of the SVAR, it is assumed that the after-tax rate of profit takes more time to affect corporate investment than the after-payment rate of profit. Instead, capital accumulation contemporaneously responses to a change in the after-payment rate of profit or the external debt of the firms in the Korean economy, because it is assumed that taxation is determined by the state policy, which takes a little bit more time to decide how much to change it.

A lot of time series data have hidden potential breaks. Perron (1989) argues that the traditional unit root tests such as the Augmented Dickey-Fuller test are likely to fail to detect the stationarity or non-stationarity of the data if it has structural breaks. Zivot and Andrews (1992) propose the unit root test of the time series data with a single break in the time series. The Zivot-Andrews test provides the model that estimates an endogenous breakpoint in the data. Lumsdaine and Papell (1997) propose the unit root test model with two endogenous structural breaks. The Gregory-Hansen test provides information about a structural break in a cointegration test. Gregory and Hansen (1996) suggest three models of the structural change in the cointegration relationship: level, trend, and regime shift. If a cointegration equation has a breakpoint in level, trend or regime shift, an additional test for the cointegrating relationship will be needed. The Gregory-Hansen test provides the critical values of whether the cointegrating relationship is valid or not despite the structural break.

The Auto Regressive Distributed Lags (ARDL) model is used to capture long-run relationships between variables. The ARDL model provides a framework for solving the small sample problem that stems from the identified structural break by the Gregory-Hansen test. The ARDL cointegration technique is robust and consistent compared with other cointegration technique even if the data has the small sample problem. Moreover, it can be selected for this study even if the unit root tests with or without the structural breaks are not consistent because $I(1)$, $I(0)$, and the combination of both orders are allowed in the ARDL technique.

Goodwin(1990) presented one of the representative nonlinear dynamics models in economics. The model in 1990 has a little different form with the well-known growth cycle model of him. It consists of three differential equations including a control variable that *secures* system's stability, contrary to the two differential equations of the growth cycle model. By introducing the control variable into the system, chaotic dynamics occur within the system rather than simply repetitive cycles of the growth cycle model, although the First two equations of the model in 1990 is very similar with those of the growth cycle model. Moreover, it has a strange attractor, called the Rossler Attractor, which is an attractor that only

appears around one fixed point (only one manifold) when compared to a Lorenz attractor, called a butterfly attractor. However, the Goodwin's economic model using the Rossler strange attractor has an absolute limit. The model described the variables in levels-dimension where the model implements unrealistic situation, for example, negative levels of production. Thus, I transformed the Goodwin's model into the change-rate dimension, that is the rate of change of variables. This strategy made the strange attractor realistic in the economic situation. Moreover, I applied this approach to the Marxian Reproduction Scheme.

In this growth rate-dimension reproduction model, the absence of the financial sector immediately refers to the simple reproduction regime of the Marxian reproduction model. Contrary to this finding, a role of the financial sector is necessary for the economic growth at the constant rate of growth, which is the expanded reproduction of an economy. Therefore, the financial sector is crucial for the regime shift from the simple reproduction regime to the expanded reproduction model in this model due to the time delays. Furthermore, the chaotic motion in this model can be detected. The responsiveness to the discrepancies between the actual change rate of output and the desired change rate of output is a bifurcation parameter. That is, A longer time delay of production is associated with larger amplitudes of business cycles.

The stock management problem (supply chain structure) in system dynamics consists of the stock and flow structures for the acquisition of inputs to the process, and management policies governing various flows. In this study, the stock and flow structure is linearized, so that it is expressed as two-goal-seeking patterns with each time delay. Compared to the general stock management problems, this system is also constructed with three decision rules. '(1) [to] replace expected losses from the stock (2) [to] reduce the discrepancy, and (3) [to] maintain an adequate supply line of unfilled orders' (Sterman 1988: 151). Managers in production not only give orders enough to replace the loss but also have to minimize their costs by reducing the discrepancy. These performances are accomplished by maintaining the supply line.

Above all, this study applies this framework to the behavior of the financial sector and the central authorities. It is assumed that the financial sector has a positive feedback mechanism where a larger discrepancy than the desired level, which leads to more provision of loans. Contrary to this sector, the central authorities seek to stabilize the entire economy, so that they have the goal-seeking mechanism. Therefore, managers in financial institutions seek to maximize their profits in the positive feedback mechanism, and public managers in central authorities try to stabilize the system with their target in the negative feedback mechanism. As mentioned above, the MSMM is a variant of the supply chain model in the system dynamics method. I combined the supply chain model with the Metzler's inventory adjustment model (Franke and Lux 1993; Franke 1996; Matsumoto 1998) and Duménil and Lévy's model (Duménil and Lévy 1993b; 1996) and expanded it into a macro model integrating the financial sector.

The stability of this system is satisfied by the time delays; the system is locally stable. However, if one of the parameters changes abruptly, the Crisis, the sudden collapse of the general activity of economy, appears. That is, the economic crisis is not the consequence of a deficiency of demand because there is no persistent sharp endogenous decrease in demand independent of other economic variables. Rather, dramatical changes of managerial and financial behavior result in a sharp reduction in demand level. In the same manner, the stochastic demand shocks cannot be the cause of the collapse, because the sequential shocks enough to be the cause of crises is impossible; it can be regarded as noise otherwise. A rise in demand level followed by the collapse leads to a sharp recovery of the utilization rate in the period. This effect stems from a role of the public finance to adjust a discrepancy between the actual and target values. A reduction in the private finance is compensated through the provision of the public finance.

In the MSMM, management progress (an effort to reduce the discrepancies between the actual level and the desired level in the production-inventory relationship) can improve its goal-seeking performance. However, over-responsiveness of the managerial performance causes the change of the oscillating pattern of the model. At the same time, it is assumed that finance has a self-reinforcing

mechanism that can destabilize an economy. In the framework of the MSMM, the interrelationship between management progress and financial sensitivity ultimately determines the outcome of the economy and, if an economic crisis has occurred, it can be understood that a certain relationship between them has been formed. To describe an evolution of the interrelationship between management and finance, an analogical model from mathematics is introduced. This model is a love-affairs model between Romeo and Juliet.

The love-affairs model is a system of two differential equations where Juliet or Romeo may be a fickle lover. Each delay of production and financial adjustment refers to management progress and financial sensitivity, respectively. It is assumed that the relationship between management and financial sensitivity is similar with those of Romeo and Juliet in the love-affairs model. If finance is the fickle lover (Juliet), it is assumed that the relationship between them can be described in a finance-led regime. Otherwise, it is a management-led regime. Therefore, the MSMM can be influenced by the regime structure, and its stability condition can constantly change. The Crisis is generated from dangerous intersections of managerial and financial sensitivities. The suitable values of each sensitivity or time delay relating to management and finance ensure the stability of the macro model. The sensitivity of firm management dominates the periodic movements of the model; The response of finance to economic circumstance dominates the amplitude of business cycles. Therefore, an involuntary crossing of the sensitivities can lead to the sudden collapse of the macroeconomy. I investigate this state of affairs by an analogy of a love affair between management and finance (Chapter 3 and 4).

We cannot imagine a macro system without an intervention of central authorities because the economy entirely loses its activity if there is no central action or the authorities disregard the discrepancies, that is, their actions have long time delays. However, too excessive response to discrepancies of the authority would lead to an over-reaction to the discrepancy. On the contrary, too passive action will cause an unrecoverable state of economic activity. If the relationship between management progress and financial sensitivity has not the closed-orbit with the

exact extent which depends on the initial values and fixed point, but, with irregular movements, it is hard for policymakers to set an appropriate time delay or intensity of the policy. At the same time, this policy action has impossibility because it is hard for policymakers to recognize the complexity of the entire system.

Therefore, Keynes and Hayek had argued two contradictory aspects—two sides of the same coin— of the macro policies rather than struggled with each other within their different camps. However, the impossibility that Hayek said doesn't mean all the attempts to stabilize economy are impossible, in my opinion. He emphasized an institution to make a new design to manage a stable growth for society. To avoid the significant fluctuations of the macro activity, it is necessary to control the excessive response of the management and finance besides the interventions of the central authorities. In particular, the behavior of the private finance is not the goal-seeking feedback mechanism but the positive feedback mechanism leading to overheating and recessions.

The MSMM with capital accumulation is an expanded version including distributional relationship, investment function, and behaviors of the pricing decision. In general, the pace of capital accumulation in an economy depends on firms' retained profit, that is, the after-payment rate of profit or capitalists' saving. However, the financial effect on capital accumulation, that is, the external funding of firms, is another important factor for investing in new capital. In the Korean economy, it could allow a faster pace of capital accumulation. The MSMM with capital accumulation shows that a behavioral change of the financial sector, for instance, a more favorable business environment for consumer loans can strongly influence the pace of capital accumulation.

I applied these perspectives to the history of the Korean economy, which suffered from the Asian Crisis in 1997 followed by prolonged investment stagnation. Within the framework of system dynamics, there is a dangerous intersection of the time delays of management, finance, and the stabilization policy of the central authorities, which leads to the sudden collapse of the general activity of

macroeconomy. This framework is not limited to the Korean economy. However, I proceeded with this discussion while presenting data on the Korean economy. Furthermore, the system dynamics simulation was used to investigate the cause of the relative slowdown in the pace of capital accumulation in the Korean economy since the crisis in 1997. The results of the computer-aided simulation by system dynamics was derived based on a radical change of the financial system and the corporate debt levels of the Korean economy. I construct a new system dynamics model for the long run capital accumulation process including the funding provision from the financial sector.

We should take a change in technological and distributional change into account to capture the very long-run trajectories of an economy. In general, to do this, techniques using production function have been used. In this study, however, we use the stochastic technical change model where historical trajectories of technology are determined by a given random set of techniques by the profitability criterion. First, the model of induced technical change is introduced. The model shows that a change in the relative price of capital to labor induces invention of a new type of techniques, such as labor-saving type techniques. Duménil and Lévy (1995) have presented a model that can track long-term variables of the variables without a priori blueprint for technology and distribution, in the name of the stochastic technical change model. In the endogenous growth model, the results are too sensitive to how we set the research equation. Furthermore, the Research & Development process has a lot of exogenous elements and uncertainties. However, in the model of a stochastic model, the R & D process is given by the probability distribution such as the uniform distribution. Although the techniques that can be used in an economy emerges as the outcomes of the R& D, all the techniques cannot be used in an economy. In other words, a selection process or the profitability criterion is needed. The system dynamics method has also been used to reconstruct the trajectories of technology and distribution in the Korean economy. In fact, the profit rate is derived from the long-term trajectories of technology and distribution of an economy system dynamics approach is another tool to represent the model in this study (Chapter 6). In Chapter 9, I tried to capture a relationship between macroeconomic trends,

inequality, and consumers' debt during the neoliberal period using some time series econometric techniques. In this chapter, changes in the relationships in the US economy and Korean economy before and after the 2000s crisis could be captured.

In this dissertation, I adopted the arguments of the heterodox economists such as Marxian economists that the profit rate is the prominent variable for explaining capital accumulation and business cycles in the capitalist economy. For further study, it is necessary to calculate the variable accurately. In particular, there were few studies on the profit rate of the Korean economy due to the lack of the available data. This dissertation sought to compute various types of the profit rates, including the after-tax profit rate and the after-payment profit rate, and those of the different sectors of the Korean economy. In addition, the long-term historical process of the Korean economy cannot be missed when it comes to globalization and financialization that has been steadily progressing since the 1980s. In addition to the various changes in the rate of profit, we have to see how financialization and globalization have affected the macroeconomic path of the Korean economy. We have presented some indicators for this. As we have already mentioned, financialization has had a profound impact on the behavior of the financial sector in the Korean economy. As in other countries, the financial sector of the Korean economy began to operate mainly for consumer loans, not for industries. In Chapter 7, a new indicator for estimating the impact of globalization on the Korean economy is suggested. A widening gap between financial sources and uses of the nonfinancial sector in the Korean economy since 1997, indicates a long-term change in the macroeconomic path in the Korean economy caused by the impact of globalization. By definition, financial liabilities and net savings are intended to buy financial assets or lead to net investments. It should be noted that the ratio of net investment to the financial resources (financial liabilities + net saving) of the nonfinancial sector in the Korean economy has decreased sharply. In other words, much of the financial resources are used to purchase financial assets rather than net investments. More importantly, there is a widening gap between financial sources and use, particularly since 2005. This gap is the impact of globalization, which means that the gap means foreign

investment in other countries. Thus, in fact, the accumulation of capital in the Korean economy is not entirely stagnant, but the recession of domestic investment and the corresponding increase in foreign investment are intertwined. The nonfinancial sector in S. Korea is mainly investing more resources in purchasing and operating financial assets.

What profit rate has the greatest impact on the Korean economy's capital accumulation? Of course, the large debt level of S. Korean companies means that they have tried to increase their business capacity regardless of profitability. However, since 1997, the financial sector's behavior has been affected by the profitability level. Does the government's tax policy have the greatest impact? Or does the net savings of a company affect capital accumulation? Based on the results of the calculation, I conducted the relationship between capital accumulation, business cycles, and the different rates of profit in the Korean economy, and described the history of the Korean economy. The unrestricted VAR and structural VAR methods helped to capture the relationship in the Korean economy. To measure this, two profitability indicators were proposed. One is the after-payments rate of profit and the after-tax profit. The SVAR method is used to distinguish two similar indicators in this time series. Using the SVAR method which can impose short-term constraints, it is assumed that the effect of the tax rate on the capital accumulation after-tax payment, which has a priority of the tax policy, is slightly longer than the other variables.

First of all, as already mentioned, the situation that cannot attract external funds due to the changes in the financial sector since 1997 has the greatest impact on capital accumulation. In other words, the high rate of accumulation before 1997 was due to the ease with which external funds were readily available. Second, it was also influenced by profitability, and the effect of the after-payment rate of profit, except for both interest and dividend, on capital accumulation increased. In this way, we can summarize the aspects of the neo-liberal transformation process of the Korean economy.

The government policy was being weakened after the 1980s but did not entirely evaporate. In virtue of the financial acceleration effect by the banking system, funds available to invest in new capitals could be provided to firms although they suffered from their highly leveraged business—In other words, they had to put up with the high-interest burden for that. Through this mechanism, they could maintain the fast pace of capital accumulation to some degree. This state of affairs in the 1990s was the *reprieve* between the two shocks. After the 1997 crisis, an institutional change in the banking system is prominent. The industrial policies of the state considerably weakened because the majority of banks in S. Korea have been privatized. Furthermore, this led to an increase in the consumer loan because the banks are reluctant to lend money to the business sector, and they wanted to provide funds to the profitable consumer loan market at that time. This transformation has resulted in the debt transfer to households. Instead, the high leverage of firms hugely decreased compared with the level before 1997; the low-interest policy by the monetary authority in the country mitigated the interest burden on the business sector. Capital accumulation converged to the level of profit rate after payment, and domestic investment was reduced.

However, while Korean companies have reduced their debt ratios, the amount of debt has continued to increase with the expansion of assets. The ratio of domestic investment to these debts and their net savings have decreased significantly, while the remainder is purchasing financial assets. Nonetheless, the gap between financial resources and use is expanding, which is part of the overseas investment. By the way, most of the overseas investment of S. Korean companies are direct investment. In other words, while domestic capital accumulation has decreased, the accumulation of foreign capital by Korean companies has increased. Therefore, it is necessary to maintain a small investment in Korea while increasing the purchase of financial assets. Most of the financial resources have come to be used to manage financial assets or to be invested abroad.

For the past decades, particularly in the US and Korean economy, there has been a widening gap in income distribution between the top income group and the lower income group. Duménil and Lévy (2011) argue that this evolution of inequality in the US economy is associated with the quest for high income based

on financialization and globalization under neoliberalism. In the both countries, rising inequality among wage-earners accounts for a significant portion of the distributional gaps.

In S. Korea, the income of the upper wage group has traditionally been steadily increasing, but since the 1980s, the gap has expanded. It seemingly moderated itself between the 1980s and the mid-1990s, but it must be considered under the political and economic environments of the country at that time. Above all, a note must be made of the achievement of the 90-99 income group that, although it was composed of top public and private managers and professionals, particularly those in the law, health, and finance fields, it was *less* dependent on capital and business income compared with the top 1% group as mentioned above. Therefore, it seems that this group—rather than the top of the top income classes, such as the top 1% group, which were relatively *more* dependent on capital and business income—was the class that constantly benefited from the neoliberal turn without ups and downs. In other words, although the overall income of the highest-income (top 1%) and lowest-income groups (the 0-90 income group) in S. Korea has been significantly influenced by the political and economic situation, the top wage group who are less depends on capital income among the higher wage earners are increasing their share. In addition, it can be seen that their share has been expanding more and more recently.

As we have said, the expansion of inequality and wage inequality is particularly remarkable, especially in the US economy and the Korean economy. Within the Marxist framework of the social classes, moreover, the increase in wage inequality indicates that a new intermediate class, the managerial class, is rapidly emerging among the traditional social classes—capitalists and productive workers—in the capitalist societies (Duménil and Lévy, 2011). Despite the recent rise of the managerial class, the emergence and development of that class have a much longer story in the historical transformation of capitalism, but it is worth noting their achievement relating to income distribution during the neoliberal period (Duménil and Lévy, 2011; Mohun, 2006, 2016; Tavani and Vasudevan,

[2014; Vasudevan, 2016](#)).

The decreasing pace of capital accumulation has constituted one of the popular characters on the evolution of the composition of aggregate demand in many countries during the neoliberal period, although there was an investment boom of the 1990s in some countries like the US and Korean economy. In the US economy, moreover, an increase in the ratio of consumption to GDP can be observed coupled with the falling rate of investment since 1980. This consumption-led growth regime whose features are the slowdown in the pace of accumulation and the upward trend of the ratio of consumption to GDP accompanied a dramatic increase in household debt in the US. The declining trend of capital accumulation in the Korean economy can be observed since the Asian financial crisis of 1997-1998, which was one of the most severe crises in the history of the country. However, the significance of consumption in the demand composition of the Korean economy since 1980 would be questionable because there was a long sharp declining trend of consumption relative to GDP in the first half of the 1980s. Contrary to the trends in the US economy, it seems to be difficult to extract a consistent trend relating to the pace of capital accumulation and the ratio of consumption to domestic demand during the neoliberal transition in the Korean economy. We seek to capture a possible long-term relationship between rising wage inequality, which was one of the important results of the new alliance between the capitalist owners and the upper group of the managerial class, and the macroeconomic trends since 1980 in the US and Korean economy. That is why we try to estimate the long-term relationship between wage inequality and consumer debt and the main pathways of the domestic macroeconomy.

The basis of time series analysis is unit root test. However, if there is a structural break in the time series, traditional unit root tests may fail. Since the US and Korean economies have experienced the economic crisis in 2008 and the economic crisis in 1997 or the economic crisis in 2008, respectively, since the 1980s, so there may be one or more structural breaks in the time series. Therefore, a unit root test that can measure structural breaks is performed. First, one test was conducted assuming one structural break, and a test was performed assuming

two structural breaks as necessary. Second, if there is a structural break in the time series, a small sample problem can be encountered. Therefore, a robust cointegration measurement method must be found in this case. One of them is the ARDL method. Instead, to overcome the sample size too small, the annual data was transformed by interpolation as quarterly data.

In estimates based on annual data, both countries showed the direction of the expected macroeconomy. Consumption (Consumption to GDP) has a positive long-term relationship with wage inequality and consumers' debt, and investment (net investment to capital stock) has a negative long-term relationship with two variables. However, considering the structural break, a slightly different result was obtained. First, in the case of the US economy, investment is the same as the one derived from the annual data. However, considering the structural break of 2001, a rise in consumption was positively associated with wage inequality and consumer debt before 2001. However, since 2001, there has been a negative relationship with wage inequality and a positive relationship with consumers' debt. There has been a constant upward trend of wage inequality since those crises whereas consumers' debt reached a peak in 2008 and fell steadily. All these trends had a negative impact on domestic demand, and thus, the US economy had to rely on government spending to stop shrinking demand for the economy.

Second, the Korean economy is the same as expected from the annual data. Consumption and investment have negative long-term relationships with positive long-term relationships with wage inequality and consumers' debt, respectively. However, since 1997, the structural break, both consumption, and investment in this country have had a long-term negative relationship with wage inequality and consumers' debt. Therefore, domestic demand of the country depends entirely on net exports, except for the historically constrained government spending levels. However, net exports of this country are maintaining a positive level as exports and imports shrink, while imports are shrinking more rapidly.

This dissertation consists of two parts: an introduction to nonlinear dynamics and system dynamics, and their applications from Chapter 1 and Chapter 5; empirical studies for the Korean economy including the system dynamics computer-aided simulation for the stochastic technical change model from Chapter 6 and Chapter 7. Chapters 7 through 9 are devoted to an empirical work for estimating the relationship between capital accumulation and the profit rate in the Korean economy and to an independent econometric analysis of the Korean economy and the US economy. The appendix provides the additional stability analysis for the mathematical models and the computer codes for the simulations, and statistical results of the econometric estimation.

Chapter 1

Nonlinear Dynamics with System Dynamics

1.1 An Introduction to Nonlinear Dynamics

This section provides an introduction to nonlinear dynamics. In Section 1.1.1, basic elements of dynamic problems, such as the famous population growth model with carrying capacity are developed into a model of chaotic motion, are introduced. Dynamic problems have been studied in various forms in the economic literature: three representative models are featured in Section 1.1.2.

1.1.1 Basic structures of Nonlinear Dynamics and Chaotic Motions

Most economic phenomena should be modeled as evolutionary processes. This is because: one of the most prominent features of economic reality is a persistent alteration from an initial state to other states as if 'many problems in natural and engineering science can be modeled based on the evolutions' ([Fečkan 2011:1](#)). In order to understand this characteristic of economic problems, we need to introduce dynamical systems. They can be studied mathematically by using

discrete or continuous dynamic equations, such as systems of different or differential equations. What is the dynamic system or dynamics? It is an analytical method that assesses fundamental behaviors within a system to see whether the system achieves equilibrium or keeps repeating in cycles (Goodwin 1990: 2). First, let us take account of the following continuous differential equation, which is the well-known system of differential equations. The equation models logistic population growth:

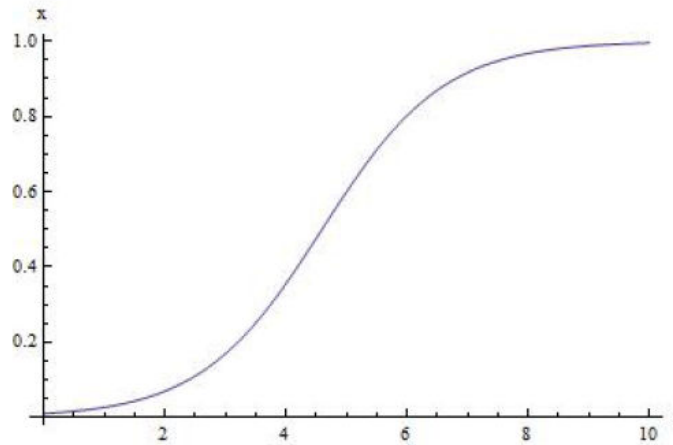
$$\frac{dx_t}{dt} = ax_t - x_t^2 \quad (1.1)$$

where x and t refer to a level of population that is the state variable, and time, respectively. a is a parameter that refers to the rate of growth of the population. In this equation, ax allows trajectories generated from this system to have an exponential growth of population. However, the last term, $-x^2$, leads this system to a specific eventual point that is 1. Therefore, the system displays an S-shape trajectory between 0 and 1 (Figure 1.1). Because there is the nonlinear term, x^2 , within this equation system, the exponential trajectory expressed by the linear term, ax , is corrected endogenously.¹ The stability of this trajectory can be demonstrated by the linearization method. The fixed point of the equation is 0 and 1. If we set $f(x) = ax - x^2$, by using Taylor expansion and the approximation, we can obtain $f' = a - 2x^*$ where x^* is the fixed point. Because this system can have two fixed points, there are two results, $f'(0) = 0$, $f'(1) < 0$. If the fixed point of the equation is 0, it displays a stable trajectory—the S-shape trajectory (Goodwin 1990: 25). Now, we can modify (1.1) into a linear two-dimensional equation system.

$$\dot{x}_t = ax_t - by_t \quad (1.2)$$

$$\dot{y}_t = cx_t - dy_t \quad (1.3)$$

¹In general, the carrying capacity, which is the number of individual organisms that environment can support in Biology, is included in the equation (Sterman 2000: 118). We assume that the capacity is one.

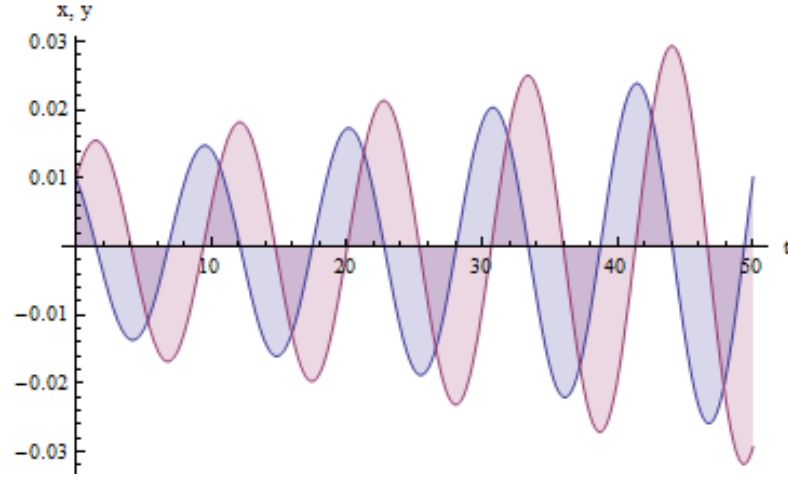
FIGURE 1.1: Logistic population growth $a=1$, $x(0)=0.01$ 

This is the famous predator-prey model that is represented in a linear equation system because the nonlinear term in Equation 1.1 is changed into a function of y . As we can see from the structure in the system, an increase in the number of organism y reduces the number of population x . Thus, the variables, x and y , refer to the population of the prey and the predator, respectively. If we construct the Jacobian matrix of coefficients, it is easy to obtain the trace and determinant in the matrix; it is also possible to perform a qualitative analysis. Particular trajectories in the system will be generated if, for a particular purpose², we assume that the trace ≥ 0 and the determinant > 0 . That is, the roots of the characteristic polynomial equation are pure imaginary values with the fixed point, $(x^*, y^*) = (0, 0)$.³ In particular, if both of the trace and determinant are more than 0, $|a| > |d|$, the trajectory of the variables has a divergent pattern from zero with oscillation (Figure 1.2). That is, the fixed point is unstable. In order to study the bifurcation process and chaotic motion, we need another differential equation including a nonlinear term.

²This is not to build up the specific population model but look into changes in patterns of nonlinear dynamics

³In fact, the well-known system of the predator-prey includes two nonlinear terms as follow: $\dot{x}_t = ax_t - bx_t y_t$, $\dot{y} = -cy + dxy$. This equation system has two fixed points, $(x^*, y^*) = (0, 0)$, $(x^*, y^*) = (c/d, b/a)$. The latter one is very similar to the case $a = d$ or $a = 0, d = 0$ in the linear system, (1.2) and (1.3).

FIGURE 1.2: The movements of x, y in the system of differential equations 1.2 and 1.3, $a = 0.04, b = 0.5, c = 0.7, d = 0.01, x_0 = 0.01, y_0 = 0.01$



$$\dot{x}_t = ax_t - by_t - z_t \quad (1.4)$$

$$\dot{y}_t = cx_t - dy_t \quad (1.5)$$

$$\dot{z}_t = e + z_t(x_t - c) \quad (1.6)$$

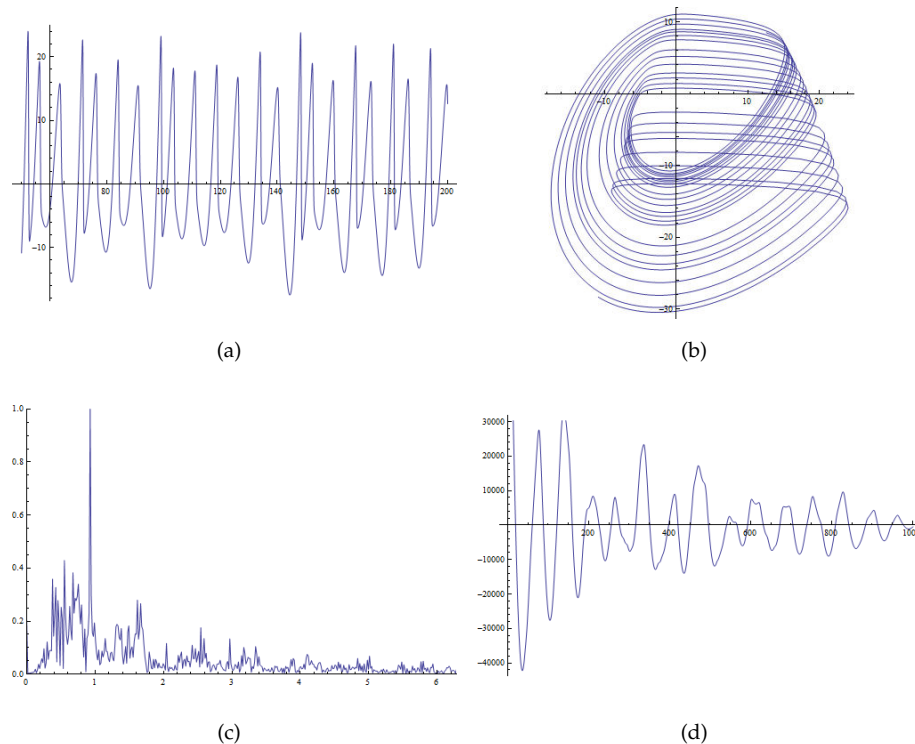
where z is a control variable, and c and e are constants, which are newly added in this system. The *control* means that the global stability of the equation system is secured by inserting z into the system. As we described just above, the nonlinear term, zx , is included in this system. Figure 1.3a shows the trajectory of x , which has an irregular oscillated pattern around the fixed point. As we can see from the system of differential equations, (1.4), (1.5), and (1.6), as well as its coefficients: it is *globally* stable because of the existence of the control variable although the system is locally unstable. In particular, the important role of $-z$ in Equation 1.4 alters patterns of the system. Furthermore, there is a negative feedback mechanism in Equation 1.6 to operate the stabilizing force. Around a certain value of a particular parameter, the character of the system may change. This is the bifurcation process from locally unstable equilibria via limit cycles to attractors.

In studying bifurcations of nonlinear dynamical systems, you have

encountered the important concept of systems that have locally unstable equilibria, but are globally stable. Limit cycles, such as those that arise from a supercritical Hopf bifurcation, are a good example. When the bifurcation parameter is in the unstable region, the system converges toward a limit cycle around an equilibrium point which is itself unstable. If we perturb the system from the limit cycle, it tends to return to it, so the limit cycle is an attractor for the system. (Foley 2005: 27)

'An attractor is a set to which all neighboring trajectories converge' (Strogatz 1994a: 324). Figure 1.3b shows the attractor between x and y . We call it the *strange* attractor which means that it 'exhibits sensitive dependence on initial conditions' (Strogatz 1994a: 323). The strange attractor has chaotic motion. The *chaotic*

FIGURE 1.3: The strange attractor, $a = 0.4, b = 0.5, c = 0.7, d = 0.06, e = 0.015, c = 8.57, x_0 = 0.2, y_0 = 0.3, z_0 = 0.5$: (a) The time series of x ; (b) The phase space between x and y ; (c) The power spectrum of the system; and, (d) The autocorrelation function



trajectories can be characterized by an unpredictability of movements, which

is generated by the nonlinearity and sensitivity on initial conditions. However, this is not the same thing as statistical randomness. In appearance, it is difficult to distinguish the chaotic character from randomness; however, the chaotic trajectories are not undetermined but fully determined. Indeed, 'randomness does not occur in nature' (Moskovitz, 2013: C1). Therefore, nonlinear dynamics does not measure the degree of uncertainty but studies unpredictable but fully determined events (Moskovitz, 2013).

The damped oscillation system is one of the representative behavioral patterns found in the real world. It decreases the number of errors from the initial period as time progresses (Foley 2005: 41). The strange attractor, however, is very different from the damped system because it has a locally unstable fixed point. That is, its trajectory tends to move away from that point consistently. Unlike the linear system, the superposition principle is not satisfied in the nonlinear system; thus, it leads to unpredictability.

There is good reason to suppose that real economies, to the degree that they exhibit deterministic regularities, are nonlinear dynamical systems with a large number of degrees of freedom, and thus are very likely to exhibit chaotic behavior. The limits to predictability we have just explored are therefore likely to apply to economic dynamics as well. As in the case of meteorology, even if we have confidence in our ability to identify key parameters governing economic dynamics, any specific predictions we make based on these findings will deteriorate in accuracy over time. (Foley 2005: 45)

The persistent and irregular movements of business cycles or the character of other economic time series can be represented in the properties of the nonlinear system. In order to do this, we need a new method that is more suitable for the qualitative properties of nonlinear dynamics.

1.1.2 Nonlinear Dynamics in Economic Literatures

Analytical threads of the economic literature have addressed nonlinear dynamics in the field. In these analytical threads, we will examine three major works: Kaldorian, Goodwinian, and Metzlerian model. In particular, Metzlerian models are particularly apposite to the issues discussed in this dissertation.

Nicholas Kaldor's Model: Kaldor's business cycle model is 'the first attempt or a prototype model to study the effects of non-linearities in dynamical economics' (Gabisch and Lorenz 1989: 122; Lorenz 1993: 43). We find a limit cycle in this model according to the Poincaré-Bendixson theorem. The typical Kaldorian business cycle model can be written as follows (Lorenz 1993: 44).

$$\begin{aligned}\dot{Y} &= \alpha(I(Y, K) - S(Y, K)) \\ \dot{K} &= I(Y, K) - \delta K\end{aligned}$$

where Y , K are income and capital stock, respectively. A change in income, \dot{Y} , can be defined as the difference between investment, I , and saving, S . Capital accumulation or net investment is realized by investment minus depreciation of capital, δK . The overall stability of this system depends on numerous assumptions based on different definitions. If the trace of Jacobian in this system is positive like Kaldor's assumption, $\alpha(I_Y - S_Y) + I_K - \delta$, the fixed point becomes unstable. Chang and Smith demonstrated that this system fulfilled the Poincaré-Bendixson theorem for the existence of limit cycle according to Kaldor's assumptions (Gabisch and Lorenz 1989: 132-135). In recent years, Kaddar and Alaoui (2008) presented the existence of a Hopf bifurcation process in this system with Kaleckian time delays.

Richard M. Goodwin's Predator-Prey Model: This is one of the most famous models in the field of nonlinear economic dynamics. The model takes the form of Lotka-Volterra's predator-prey model, which serves as the origin of mathematical biology. Goodwin transformed the predator-prey model à la Lotka-Volterra into

a relationship between the employment rate and wage share in the economy. In the equation, real wage, w , depends on the employment rate, e .

$$\dot{w} = \delta(e - e_0)w$$

where δ is an adjustment coefficient and e_0 is an equilibrium level of the employment rate. Thus, it has a positive feedback mechanism that the difference between an actual and equilibrium level of the employment rate leads to changes in real wage.⁴ The differentiation of the wage share, ω , is as follows.

$$\dot{\omega} = [\delta(e - e_0) - l]\omega \quad (1.7)$$

where l is the rate of growth of labor productivity. If capital productivity, P_K , is constant as \bar{P}_K , the differential equation of employment rate is as follows.

$$\dot{e} = [s(1 - \omega)\bar{P}_K - l - n]e \quad (1.8)$$

Goodwin's real wage-employment rate system in nonlinear economic dynamics is composed by equations (1.7) and (1.8). Since one of the fixed points in this system is e_0 and $1 - (l + n)/s\bar{P}_K$, the trace of Jacobian that is established by the linearization of this system is zero when the fixed point is as above.

If we mitigate the assumption about the technical change composed of P_K and l , it can develop into a more sophisticated form. Indeed, Shah and Desai (1981) and van der Ploeg (1987) have developed it into models with induced technical change.

Metzlerian Model

Metzler (1941) suggested the inventory adjustment model that has been developed with various forms in the field of nonlinear economic dynamics. This model will play a crucial role with a more sophisticated form in this study. In the

⁴This equation concerning a relationship between the employment rate and real wage is brought from Foley(2003)

post-Keynesian view of macroeconomics, it has provided a microfoundation of macrodynamics (Franke and Lux 1993; Franke 1996; Matsumoto 1998; Chiarella et al. et al. 2005). Progressive research in the field of not only occurred in mainstream fields (Holt et al. et al. 1960; Blinder 1982) and Marxian economics (Duménil and Lévy 1990), but also in management science (Thompson and Sethi 1980) and even system dynamics in the name of stock management (Sterman 2000; 1988; 1989).

In 1990, Goodwin produced a nonlinear dynamic model (Goodwin 1990). The simple prototype Metzlerian model in nonlinear economic dynamics can be presented in a relationship between output, Y , and inventory, S , as follows.

$$\begin{aligned}\dot{Y} &= \gamma(S - \bar{S}) \\ \dot{S} &= Y - aY\end{aligned}$$

where γ is a coefficient to adjust a discrepancy between the actual and target level of inventory, \bar{S} , and aY refers to effective demand. This system has zero trace of Jacobian in the above linear system—although we are able to change it into a nonlinear one if we define the coefficient like γ as a function with regards to output. Put differently, we can assume that the adjustment speed of the discrepancy or the reciprocal of the adjustment coefficient, depends on levels of output. Goodwin has added an additional equation with a nonlinear term in the above system and transformed it into Rössler attractor, which is one of the strange attractors (Goodwin 1990).

1.2 Fundamentals of System Dynamics

Little is known about system dynamics in economics, although it can play an important role in handling key issues of nonlinear dynamics. Sections 1.2.1 and 1.2.3 contribute to an introduction of its basic structures, and a standard model such as the simple production-distribution model, which has mainly developed in management science rather than in economics, and introduce an application of nonlinear dynamics in the system dynamics approach. Other examples applicable in economics are suggested in Section 1.2.3.

1.2.1 Basic Elements of System Dynamics and A Simple Production-Distribution Model

'System dynamics is a method to improve understanding of complex system' (Sterman 2000: 4). Jay W. Forrester at the Sloan School of MIT helped to develop the field 'as a method for building computer simulation models of problematic behavior within corporations' (Radzicki 2011: 727). This approach has been widely applied to disciplines ranging from management science, biology, and mathematics to ecology.

The basic elements of system dynamics are composed of: feedback thinking (or, often, system thinking) and feedback mechanisms, stock and flow structures, time delays, nonlinearities, and computer-aided simulation process.

Stocks and flows structures. Stocks are accumulated at the change rate of net flows. 'It is helpful to think of stocks as bathtubs of water. The quantity of water in your bathtub at any time is the accumulation of the water flowing in through the tap less the water flowing out through the drain. . . ., stocks accumulate or integrate their flows' (Sterman, 2000: 193-194), for example, information and materials. This can be mathematically expressed as follows.

$$Stock(t) = \int_{t_0}^t [Inflow(s) - Outflow(s)]ds + Stock(t_0)$$

$$d(Stock)/dt = Inflow(t) - Outflow(t)$$

where '*Inflow(s)*' represents the value of the inflow at any time *s* between the initial time *t*₀ and the current time *t*' (Sterman, 2000: 194) and *Inflow* – *Outflow* is the net flow that we described above. Overall, 'In mathematics, system dynamics, control theory, and related engineering disciplines, stocks are, . . . , known as *integrals* or *state variables*. Flows are also known as *rates* or *derivatives*, . . . , In manufacturing settings, stocks and flows are also called *buffer* and *throughput*. In economics, stocks are also known as *levels* and flows as *rates*' (Sterman 2000: 197).

Event-oriented thinking versus feedback thinking, and feedback mechanisms with time delays. Feedback thinking is contrasted against event-oriented thinking. The latter is 'linear—from problem-as-event to solution-as-fix' ([Morecroft 2010: 26](#)).

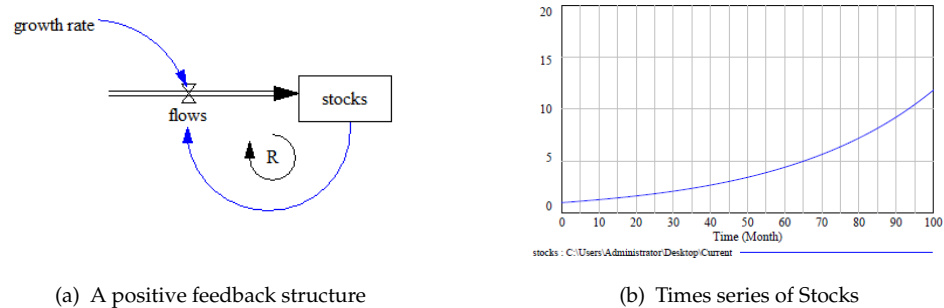
Suppose that a firm's manager reduces ordering of inventory due to poor sales. Tepid consumer demand is the cause of stagnation in sales. However, the manager's decision to reduce ordering of inventory may, in itself, lead to a further decline in demand. As a result, sales could potentially decrease even more; if production decreases and the rate of unemployment increases due to the manager's decision—total incomes available to consumers may diminish. This result stems from the problem-as-event to solution-as-fix. In other words, 'people see a problem, decide on an action, expect a result, and believe that is the end of the issue' ([Forrester, 2009: 5](#)). They did not, however, see the process as a whole. This is the reason why System dynamics has emphasized the feedback thinking. 'Problems do not stem from events, and solutions are not implemented in a vacuum. Instead problems and solutions coexist and are interdependent ([Morecroft 2010: 28](#)). Thus, it is necessary to think of them within a system, which means 'an independent group of items forming a unified pattern' ([Kirkwood 2013: 2](#)).

The behavior of a system arises from its structure. That structure consists of the feedback loop, stocks and flows, and nonlinearities created by the interaction of the physical and institutional structure of the system with the decision-making processes of the agents acting within it. . . . The basic modes of behavior in dynamical systems are identified along with the feedback structures generating them. ([Sterman 2000: 107](#))

Feedback thinking can be represented in feedback mechanisms. From these feedback mechanisms, behaviors of a system are generated. The mechanism is composed of a positive or self-reinforcing and negative or goal-seeking loop, and the combination of two feedbacks. Furthermore, we can combine time delays with mechanisms.

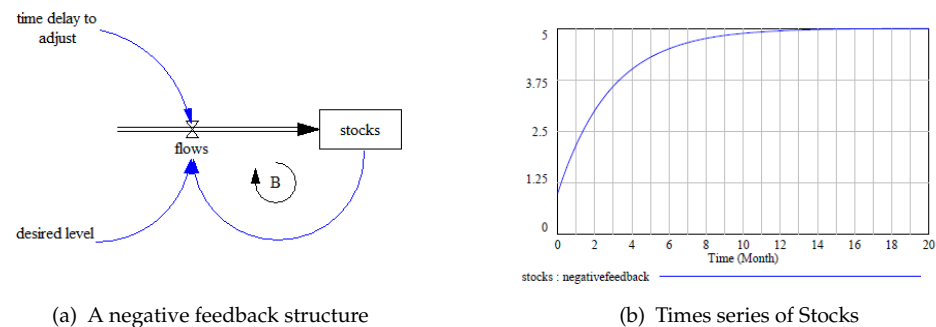
A positive and negative feedback with time delays, and their combination. A positive feedback mechanism represents an exponential growth pattern of stocks. Thus, this expresses a self-reinforcing behavioral pattern; that is, 'some

FIGURE 1.4: The positive or self-reinforcing feedback



quantity "feeds on itself" to generate ever increasing growth' (Kirkwood 2013: 29). Figure 1.4 shows a positive feedback structure where the identifier, **R**, refers that this structure represents the self-reinforcing process and the trajectory of stocks over time. In contrast, negative feedback mechanisms are 'self-correcting' (Sterman 2000: 13). 'Every negative loop includes a process to compare the desired and actual conditions and take correction action' (Sterman 2000: 112). That is, policymakers see discrepancies between actual states and desired levels, and give direction to correct the gaps. Figure 1.5 shows a typical self-correcting action and behavioral pattern.

FIGURE 1.5: The negative or self-correcting feedback



The identifier, **B**, in Figure 1.5a refers to a balancing—goal seeking— structures. The feedback loop on the left of Figure 1.5 represents a classic linear structure of a negative feedback loop. Besides, we can take account of a combination of the positive and negative feedback structure. It is the logistic population growth in Section 1.1, which is a representative example of this case. We will elaborate more upon nonlinear dynamics on this system from a dynamics point of view in the next section.

Furthermore, it would be a negative corrective action with time delays. Mathematically, this action with time delays ‘allows the eigenvalues to become complex conjugates, yielding oscillatory solution’ (Sterman, 2000: 23). The behavioral pattern generated by this mechanism is often called a goal-seeking behavior. Figure 1.6 illustrates one of the combinations that we mentioned. Each of the stock levels is determined by an interrelation with each other. However, it is the combination of different feedback loops: the positive and negative feedback to adjust gaps.

$$\begin{aligned} d\text{Stock1}/dt &= \text{discrepancy1} \\ d\text{Stock2}/dt &= -\text{discrepancy2} \end{aligned}$$

where the $\text{discrepancy1} = (\text{Stock2} - \text{target1})/\text{Timedelay1}$ and $\text{discrepancy2} = (\text{Stock1} - \text{target2})/\text{Timedelay2}$. While stock1 depends on the growth of stock2 , a proliferation of stock1 beyond a desirable level(target2) would be the cause of decreasing the stock2 . This reciprocal relationship between stock1 and stock2 represents the oscillating trajectories that are shown in Figure 1.6.

Computer-aided simulation. It is crucial for system dynamics to represent various patterns by experiments using computers. Although there are various strong methods analyzing qualitative characters of complex dynamics, they are less intuitive or visual than this simulation process.

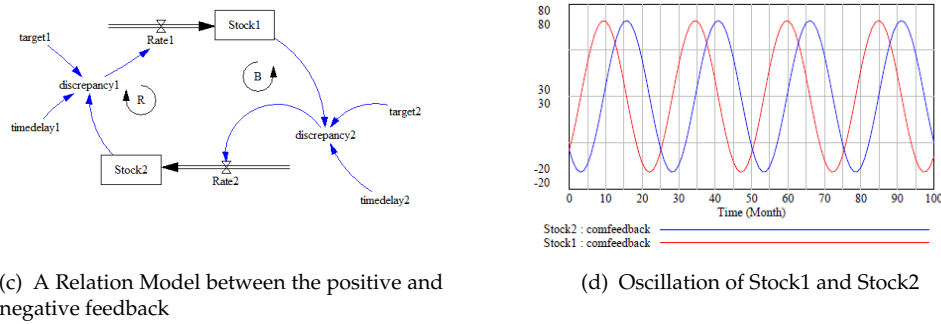


FIGURE 1.6: Oscillation process

Simulation is the only practical way to test these models. The complexity of our mental models vastly exceeds our capacity to understand their implications. . . . Without simulation, even the best conceptual models can only be tested and improved by relying on the learning feedback through the real world. . . . this feedback is very slow and often rendered ineffective by dynamic complexity, time delays, inadequate and ambiguous feedback, poor reasoning skills, defensive reactions, and the cost of experimentation. In these circumstances, simulation becomes the only reliable way to test hypotheses and evaluate the likely effects of policies. (Sterman 2000: 37)

Packages for system dynamics, such as VENSIM, POWERSIM, or STELLA facilitate experimentations relating to our hypotheses or complex models. These packages perform simulations based on the following algorithms.

- *Euler Method.* If we suppose the following ordinary differential equation,

$$dy/dt = f(t, y) \quad (1.9)$$

Euler's method is as follows.

$$\begin{aligned} y_{k+1} &= y_k + hf(t_k, y_k) \\ t_{k+1} &= t_k + h \end{aligned}$$

where h is a time step, $0 < h < 1$. Equation (1.7) is approximated as $y(t_k) \cong y_k$ at t_k . This is the Euler's method in general used in the simulation packages.

- To reduce possible errors in the Euler's method, we mostly use *Runge-Kutta 2th order method*. Under the assumption that the ODE is (1.7),

$$\begin{aligned} t_{k+1} &= t_k + h \\ s_l &= f(t_k, y_k) \\ s_r &= f(t_{k+1}, y_k + h s_l) \\ y_{k+1} &= y_k + h(s_l + s_r)/2 \end{aligned}$$

- However, we mainly use *Runge-Kutta 4th order method* in this literature to minimize errors in the above two methods.

$$\begin{aligned} t_{k+1} &= t_k + h \\ s_1 &= f(t_k, y_k) \\ s_2 &= f(t_k + h/2, y_k + h s_1/2) \\ s_3 &= f(t_k + h/2, y_k + h s_2/2) \\ s_4 &= f(t_k + h, y_k + h s_3) \\ y_{k+1} &= y_k + \frac{h}{6}(s_1 + 2s_2 + 2s_3 + s_4) \end{aligned}$$

Between these methods, the consequential relations exist by their time steps (Table 1.1). Furthermore, these simulation processes can be represented by anybody ([Rahmandad and Sterman 2012: 396](#)). In other words, the reproducibility is crucial. Thus, one can see all the simulation codes (the so-called VESIM equations) in Appendix D.

A competing relationship between system dynamics and econometric approach should also be mentioned. Although not excluding the econometric method, system dynamics studies tend to put more emphasis on qualitative analysis. Rather than fitting models to real time series data, it explores various patterns and characters of systems generated from an interaction of behaviors. It is consistent

TABLE 1.1: Same Time-Step of Calculation

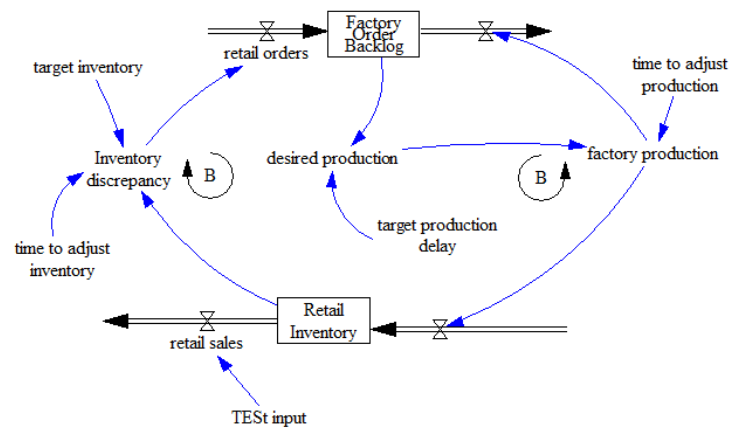
Method Name	Time Steps		
Euler	1/4	1/8	1/16
Runge-Kutta 2th	1/2	1/4	1/8
Runge-Kutta 4th	1	1/2	1/4

source: [Yamaguchi 2014](#): 57

with the nonlinear dynamics approach to business cycles because the kind of cycles has a sensitivity of the initial conditions, that is, unpredictability. 'System dynamics follows a pattern modeling approach and do not believe that models should be judged in a binary fashion as either valid or invalid. Rather, they argue that confidence in models can be generated along multiple dimensions' ([Radzicki 2011](#): 733). Therefore, reconstructing real movements in our present study mostly refer to representing real patterns of cycles—the *unpredictability* of the process, and, in particular, a sudden collapse of macro trajectories, namely *economic crises*, which unexpectedly come on the economic scene. Consequently, our final goal of this present study is to suggest better policy designs to improve a system's performance

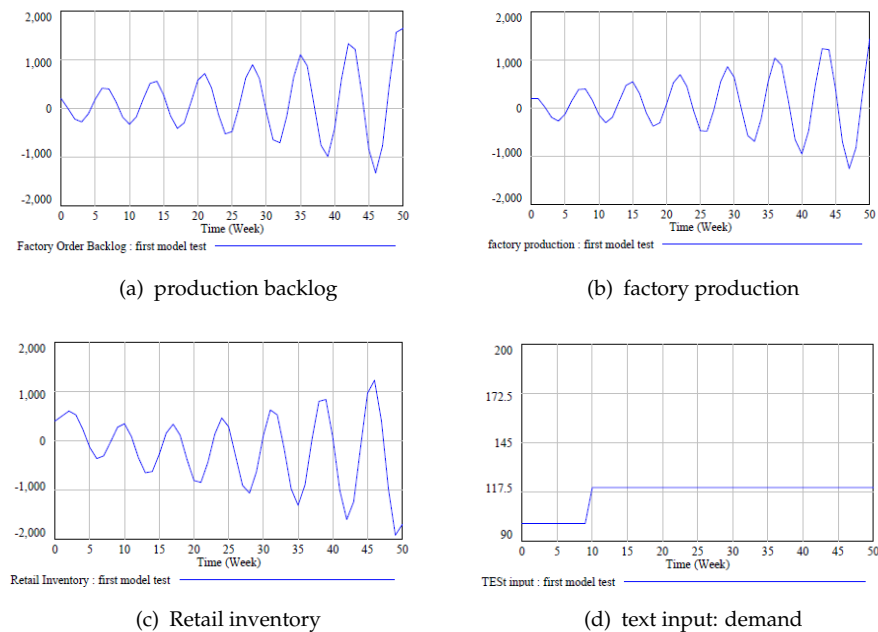
A Simple Production-Distribution Model Figure 1.7 shows a simple production-distribution model presented by Jarmain ([Jarmain, 1963](#): 118-124). In this simple model, two negative feedback loops or goal-seeking behaviors are included. Therefore, managers place orders to the factory according to discrepancies between the level of actual and desired inventory. Managers, however, do not radically change orders but seek to narrow the gap smoothly. Similarly, the production procedure on the right side of Figure 1. 7 represents the goal-seeking mechanism. 'The philosophy underlying this production system is that the retail orderer should be able to predict the length of time it will take to receive an order that is placed. Thus if the target production delay is two weeks, the factory will attempt to set production so that the current factory backlog will be cleared in two weeks [in our simulation here, one week]' ([Kirkwood, 2013](#): 46). The parameter, *time to adjust production*, refers to how long it takes time to reach the desired level. This is related to another goal-seeking behavior, represented by the

FIGURE 1.7: The simple production-distribution model



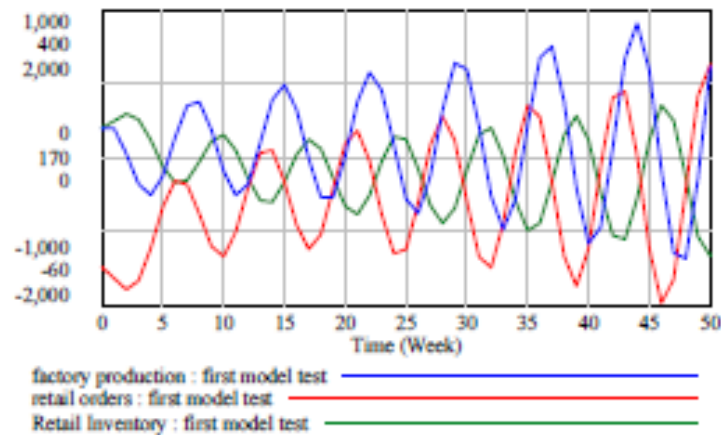
SMOOTH function of the Ventana Vensim package in this section. Production has an exponentially smoothed process. The existence of goal-seeking behaviors with time delays can generate oscillating patterns of each variable within a significant range of the time delays (See Appendix D).

FIGURE 1.8: The simple production-distribution model



Each Subfigure, (a), (b), (c) in Figure 1.8 shows the oscillating movements of the levels of factory order backlog, factory production, and retail inventory; Figure 1.8d illustrates a change in demand level. This simple model shows how the oscillation process is generated in a production-distribution process without fluctuations of demand. As Figure 1.8, the oscillating pattern without regard to demand levels stems from the existence of time delays related to the production and ordering mechanisms. As the number retail orders are reduced due to a high level of the inventory over the target level, production would be decreased. However, a downward trend of production leads to a contraction of the inventory level; orders are reduced. In particular, a change in the factory backlog over time is the primary cause of the fluctuating process in the production-inventory system. In Figure 1.9, we can see an interrelation between factory production, inventories, and orders.

FIGURE 1.9: The Interrelation between production, orders and inventory



1.2.2 An Interpretation of Nonlinear Dynamics in System Dynamics

In this section, we provide an example of a system dynamics interpretation of nonlinear dynamics. The nonlinear model in Section 1.1.1 is being transformed into system dynamics style modeling, and it may lay a foundation for our remaining studies. Figure 1.10 shows a diagram of the equation system, (1.2)

and (1.3), which can be suggested in the system dynamics approach. For this new interpretation, they are little renewed as feedback loops with time delays according to the stock-flow structures and feedback rules in Section 1.2.1 as follows.

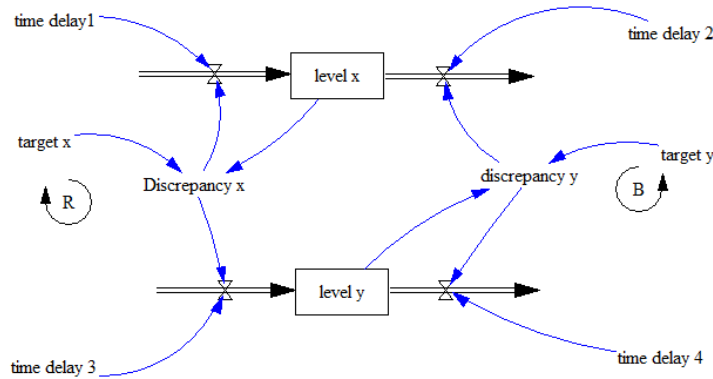
$$\dot{x} = 1/a(x - x^*) - 1/b(y - y^*) \quad (1.10)$$

$$\dot{y} = 1/c(x - x^*) - 1/d(y - y^*) \quad (1.11)$$

where a, b, c, d are time delays, and they are not the simple coefficients in the original differential equation system, Equation 1.2 and 1.3. Divergences of each stock, x, y , from their fixed point are generated by two discrepancies between the actual and target or desired level of each stock. That is, each of equations holds two feedback mechanism—positive and negative mechanisms, respectively.

For example, Equations 1.10 is composed of a self-reinforcing feedback for its

FIGURE 1.10: Transforming the equation system, 1.2 and 1.3 into the form of system dynamics

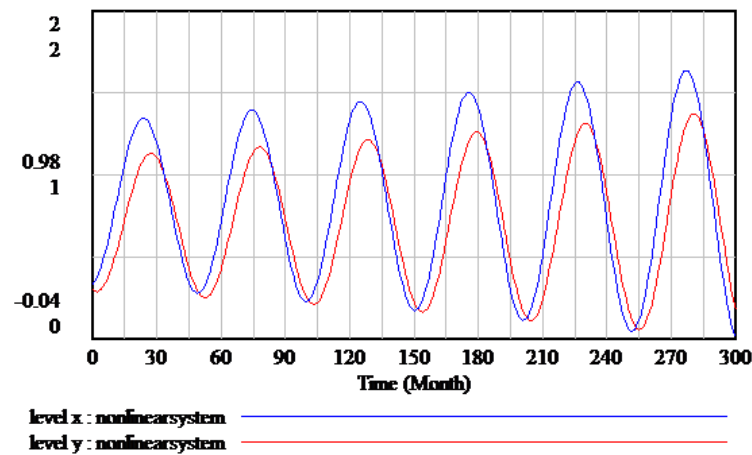


gap, $(x - x^*)$, and balancing feedback for the other stock's gap, $(y - y^*)$. This means an increase over the target or desired level of y has a negative feedback effect on the stock, x . On the other hand, the stock, y , in Equation 1.11 has a negative effect on its gap, $(y - y^*)$, and positive effect on the discrepancy of the other stock, x . The viability of y depends on the growth of x if $y^* = 0$. Similarly, the superfluous position of y stems from the excess of the stock, x , over the

desired level if with the fixed point or set of the desired level, (x^*, y^*) . With certain values of time delays, the following relationship between the stocks may appear (See Appendix D).

Instead of the Euler method, we use the algorithm, *Runge-Kutta 4th order* (RK

FIGURE 1.11: The relationship between x and y in Figure 1.12



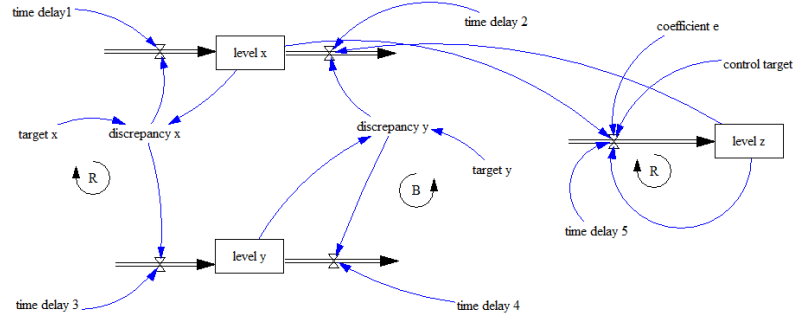
4 AUTO in Vensim software) method. This is because: measurement errors are excessively amplified over time when unstable systems are handled with the Euler method. This pattern may be analogous to a myriad of phenomena in ecology, social science, and other disciplines. For example, not only is the predator-prey relationship in ecology similar, but also the production-inventory structure in management or economics.

Furthermore, we can apply this pattern to an investment-debt relation à la Minsky (Keen 1995; Asada 2014).⁵ This linear system expressed by feedback mechanisms with time delays can be classified into various types depending upon the combinations of time delays.⁶ The above system, however, has not yet included a nonlinear term. We introduce a new differential equation with a nonlinear term; Its insertion makes it possible to display strange movements on phase space. As already explored, one of the representative three-dimensional

⁵In the literature cited here, the models were built in nonlinear relation among variables contrary to the linear system of (1.10) and (1.11)

⁶Concerning the configurations of this linear system, See **Love affairs between Romeo and Juliet** in Section 4.3.1 or the interesting description with regard to two-dimensional linear differential equation system by Strogatz (1988).

FIGURE 1.12: The Diagram à la System Dynamics of Nonlinear Systems in Section 1.1.1



equation system is Lorenz's Attractor, which is often called *Butterfly Attractor*. However, this system has two nonlinear terms. It is not impossible for us to handle the attractor like this but a system holding a more simple form with one nonlinear form has also been demonstrated to appear the chaotic motion (See Chapter 2). The new system with one nonlinear term is as follows.

$$\dot{x} = 1/a(x - x^*) - 1/b(y - y^*) - z \quad (1.12)$$

$$\dot{y} = 1/c(x - x^*) - 1/d(y - y^*) \quad (1.13)$$

$$\dot{z} = e + (1/\xi)(x - \tilde{x})z \quad (1.14)$$

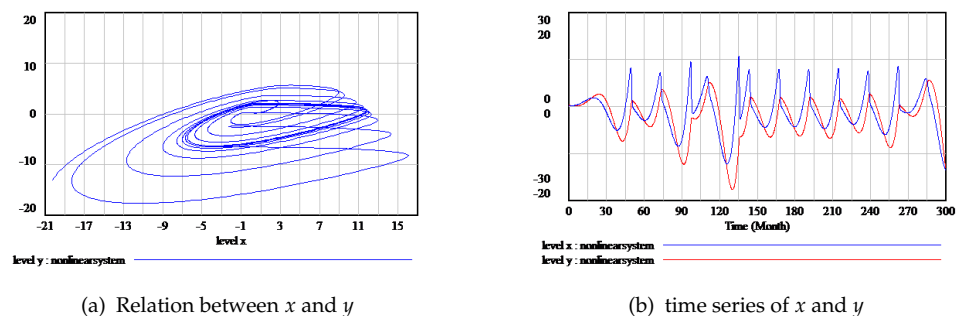
Just like z in Equation (1.6), z in (1.14) is also the control variable. This variable plays a role that the movement of x does not allow to diverge from the desired level but to move within a certain range. The new equation (1.14) holds a new positive feedback loop, $x - \tilde{x}$. In other words, a gap between x and \tilde{x} has a positive feedback effect on the stock, z . If the level of x increases beyond the target, \tilde{x} , the stock, z , rises together with the growth of x . Thus, the increase in z would contribute to the reduction in x . Figure 1.12 shows this structure as the diagram à la system dynamics.

As shown in Figure 1.12, there is an additional mechanism compared to the above linear system. This positive feedback on the stock, z has a negative effect on the growth of x . It is easy to find a nonlinear relation through the existence

of the nonlinear term, zx , in Equation 1.14. As a result, it is similar to the well-known nonlinear relation: *Rössler Attractor* (Rössler, 1976; 1979). This type of nonlinear relation has rarely been applied to the economic relation. However, irregular and unpredictable trajectories that could be generated in this relation would be well-matched with the character of the real economic time series (See Section 1.1.1). It could be represented persistent but asymmetric fluctuations of levels as follows.

We observe a simulation process based on system dynamics in Figure 1.13: one

FIGURE 1.13: Persistent fluctuations in the nonlinear system



that also realizes the nonlinear trajectories. Moreover, it helps to specifically define the related relation and behavioral patterns using the stock-flow structure and feedback loops with time delays. Therefore, the system dynamics approach is a useful computer-aided method to not only represent nonlinear relations, but also to trace the origin of the movements. System or feedback thinking is another important analytical element emerging from this analysis. Indeed, this is not a simple *mimic* process but a new thinking instrument for understanding social and economic phenomena. The primary goal of system dynamics modeling is to represent or *mimic the basic character of the data*, rather than to simply fit the past values or to forecast future values *point-by-point* (Radzicki, 2011: 733). This analytical exercise helps to improve performance for decision making and contemplate new design for better policies.

With proper refinement, an insightful system dynamics model can be transformed into a real typology called a “generic structure.” A generic structure is a model that captures the fundamental causal

relationships that appear in a variety of pattern models within a particular category. When properly parameterized, a generic structure can mimic the behavior of any pattern model within its category. (Radzicki, 2003: 151)

If one can find *the generic structure with proper refinement*, it allows one to represent unknown structures with nonlinear relations, and then to realize the pattern of the edifices. However, an evolutionary process of real economies would be inconsistent with the constructed model; this would compel one to place it into a new model to newly make a decision, once again. If a process doesn't have asymptotical stability or a predictable path like the damped oscillations, the best action to enhancing stability is to impose a condition for securing the stability. However, *If it were possible, the observed data of real economies would not have the irregular and unpredictable patterns.*

1.2.3 System Dynamics in the Economic Literature

Only a few strands of the economic literature address system dynamics in economics. One of the representative models is Sterman and Mosekilde's business cycle model (Sterman and Mosekilde 1992). They represented short-term business cycles and long waves (construction cycle) by using multiple feedback or behavioral structures with a nonlinear relationship in system dynamics approach. This paper features many of the hallmark analytical themes of system dynamics. In this paper, most of the main issues in system dynamics: time delays, stock and flow structures, feedback mechanisms to adjust disequilibrium, bounded rationality, and nonlinearities.

Forrester (2013), one of the founders of the approach, has also made seminal contributions to system dynamics perspective. He posited that 'economics has failed to adequately explain what happens in the real world and drifted toward a conceptual structure that is narrow, is based on unrealistic assumptions, emphasizes equilibrium conditions, and is committed to mostly linear mathematical methods (Forrester 2013: 27)'. He believed that, in order to 'return to theories based on observation of the real world' (Forrester 2013: 28), the simulation process aided by

computer was necessary. Thus, he suggested that the system dynamics economic model could be used as 'a general theory of economic behaviors' (Forrester 2013: 30) that 'captures fundamental causal relationship' (Radzicki 2003: 151). We can represent specific economic situations, for example, in each country or cyclic conjunctures by changing parameters or structures in the model. Above all, he regarded a unified approach between microbehaviors and macrobehaviors in system dynamics as the advantage of the modeling.

There is little connection between the two: microeconomics does not explain the parts of the system interact to create the combined behavior. In the system dynamics model that we are discussing, the microstructure creates the macrobehavior. (Forrester 2013: 32)

Despite his efforts, finding analytical strands of system dynamics literature in the field of mainstream economics is difficult. The system dynamics approach in economics has mainly been integrated more heterodox economic fields, such as 'Post Keynesian economics, institutional economics, ecological economics, and behavioral economics, in which it fits quite harmoniously' (Radzicki 2011: 735) because

Historically, the economists in these schools have rejected many of the tenets of traditional economics, including most of its formal modeling methods, yet have failed to embrace alternative modeling techniques because they were all seen as inadequate for representing the concepts they felt were important. (Radzicki 2011: 735)

As Radzicki (2003), who referred to David Hamilton⁷'s contribution to the history of economics, combined Hamilton's work with J. Forrester's achievement in system dynamics, he described links to system dynamics while adding other schools, such as Austrian School, agent-based modeling, or Radical Political

⁷He 'argued that classical economics, which first came of age during the intellectual revolution of Isaac Newton, is based on the notion of Newtonian change, and that institutional economics, which first came of age during the intellectual revolution of Charles Darwin, is based on the notion of evolutionary change' (Radzicki 2003: 133).

Economics including Marxian and Sraffian Economics. He also suggested a system dynamics modeling process based on Hamilton's concept of evolutionary change and an example model that exhibits path-dependency, the self-organizing behavior of three manufacturing firms with identical products. In a relationship with econometrics or fitting of simulation process to historical data, system dynamics approach has a skeptical response. As Forrester stated:

A past path of some variable is known up to the decision time. Because stocks in the system change slowly, we can expect the near future to be an extrapolation of the past because nothing can quickly divert the path. But the likely range of the future value of the path diverges with time due to randomness and the dynamics inherent in the system structure. (Forrester 2013: 34)

Besides this specific point of view concerning forecasting, the school has avoided using historical data for the estimation of parameters. Thus, 'it is important for a model to mimic the basic character of the data, rather than fit it point-by-point' (Radzicki 2011: 733) Finally, Forrester suggests:

The most effective use of a system dynamics model lies in a different kind of forecasting. A system dynamics model should be used to forecast how the nature of the behavior of a system would be altered by consistently following an alternative policy. Such a forecast of the ongoing effect of an enduring policy change can be done and can lead to improved systems (Forrester 2013: 34).

In this study, we also follow this methodological advice. Thus, our research represents patterns of macroeconomic behaviors generated from microbehaviors, rather than specific historical points. Despite these warnings, Radzicki (2004) tried to fit results from Harrod's growth model to historical data from 1929-2002 in the Post Keynesian-Institutional economic point of view using Full Information Maximum Likelihood with Optimal Filtering (FIMLOF). Currently, this type of data-fitting method is featured in system dynamics software packages for

commercial or professional use (e.g. VENSIM).

In the post Keynesian school of economic, several scholars have applied system dynamics modeling to their own model. The Radzicki's paper is on recent example. Tymoigne (2006) tried to establish a Minskian model with both system dynamics modeling and Stock-flow consistent approach developed in the post-Keynesian School. As exploring a similarity between post Keynesian approach and system dynamics modeling, in particular, with Forrester's methods, J. T. Harvey (2013) has represented the trade cycle model outlined in chapter 22 of Keynes' *General Theory*.

1.3 Supplement: The Mainstream Business Cycle Models

1.3.1 Introduction

Over the past two decades, the new Keynesian model has provided the mainstream framework for understanding business cycles (and monetary policy) within both academia and policymakers. This model is also called the New Consensus Macroeconomic model or the New-NeoClassical Synthesis because it accommodated the bulk of major achievements of the new Classical macroeconomic approach such as the so-called RBC (Real Business Cycle model), which features 'Dynamic Stochastic General Equilibrium (DSGE) models as a central tool for macroeconomic analysis and rational expectations' (Galí 2008: 2).

However, not only practices on the basis of the models but theories underpinning the models are criticized from both of insiders (Stiglitz 2014; Solow 2010; Bigo and Negru 2014) and outsiders due to its inability to forecast the contemporary crisis. Despite a lot of efforts for overcoming these obstacles of the models.

The new Keynesian model is the direct successor to the RBC models. It has incorporated the main features of the RBC models, such as intertemporal choices of representative agents and business fluctuations by exogenous shocks like TFP shocks, into the New Keynesian framework. In Section 1.3.2, a relation between

the RBC and the new Keynesian model is described in terms of the historical development of the models. Basic characters and critical appraisals of the RBC models are presented in Section 1.3.2.1. In Section 1.3.2.2, the historical transition from the RBC to the new Keynesian models is discussed.

In Section 1.3.3.1, we discuss major drawbacks to the new Keynesian model in a mathematical manner. It is argued: the model has a fundamental instability in the mathematical sense; the model can be solved only by jump variables and terminal conditions. Therefore, it is a virtual static model rather than a dynamic model. In Section 1.3.3.2, a diminishing effectiveness of monetary policy in this contemporary crisis is discussed on the basis of the basic model. Finally, a new model considering credit flows to agents including the procyclicality of the banking sector is presented in Section 1.3.3.3.

1.3.2 RBC as a Direct Predecessor of DSGE

1.3.2.1 The Emergence of RBC

The Real Business Cycle (RBC) model refers to a macroeconomic model that emphasized *real shocks* such as technological shocks, which emerged after the first model of Kydland and Prescott (Kydland and Prescott, 1982; Rebelo, 2005: 217). These models not only used the dynamic stochastic general equilibrium (DSGE) model but replaced 'ad-hoc assumptions on the formation of expectation' with the rational expectation process (Galí, 2008: 2). On the background of this development, there was the Lucas Critique that criticized the lack of microfoundations in previous models. Above all, one of the striking features of the RBC models is an application of a rational agents' individual decisions framework to the macro modeling (Snowdon and Vane 2005: 308). Thus, economic fluctuations are shown as 'an equilibrium outcome resulting from the economy's response to exogenous variations in real forces' (Galí, 2008: 3).

The RBC approaches were paid attention due to 'their ability to replicate the main statistical features of U.S. business cycles' (Rebelo, 2005: 218; Snowdon and Vane, 2005: 20). Thus, the calibration played a crucial role in representing the properties of the business cycles in the models; its successful performance led

to a wave of researches based on the RBC approach over the last decades (King and Rebelo, 1999: 360). On the other hand, the dynamic stochastic general equilibrium framework of the RBC model has been accepted by various researches in a different perspective. Even researchers who took a skeptical position on the RBC research acknowledged it as a methodological approach (King and Rebelo 1999: 961).

These achievements of the RBC notwithstanding, the RBC was still in dispute, particularly in the empirical aspect. Although the RBC researchers dealt with technological shocks as the central motor force of business cycles in their early model: Edward Prescott (1986) used total factor productivity (the Solow Residual) as 'a measure of exogenous technology shocks' (Rebelo 2005: 222), many economists did not consider the fluctuation of the Solow Residual as an evidence of changes in the rate of production technology (Mankiw 1989: 430-431; Rebelo 2005: 222). That is, changes in the Solow Residuals came to be considered as effects rather than the causes of economic boom and recession (Mankiw 1989). 'This evidence suggests that TFP, as computed by Prescott, is not a pure exogenous shock, but has some endogenous components (Rebelo 2005: 222)'.

Indeed, there is a much more fundamental dispute about the measurement of the exogenous technological shock through the aggregate production function. It suggested that the production function for measuring TFP or the Solow Residuals are an artificial product for mathematical elegance: it needs too many assumptions to be established, such as perfect competition and constant returns to scale for any given capital and labor. Furthermore, they are just an accounting identity rather than a genuine production function representing specific technical or distributional conditions (Reati 2001). Although this criticism can be applied to all theoretical works using the production function framework, it has not been seriously accepted in the mainstream economics.

1.3.2.2 From the RBC to the New Keynesian Model

Above all, 'it [the RBC model] had a very limited impact (if any) on the central bank and other policy institutions. The latter continued to rely on large-scale macroeconometric model' (Galí 2008: 3) without regard to the criticisms of the

arbitrary characters of the models. As said above, however, there has been a lot of efforts incorporate the DSGE framework into the New Keynesian model although it does not take account of capital accumulation of the original RBC models and has different points of view on the macroeconomic policies with them.

Nowadays, the new Keynesian model is the *RBC (or DSGE) model with stick prices* because: the new Keynesian model shares the dynamic stochastic assumptions and an infinitely-lived representative household's intertemporal choice between consumption and leisure, with the RBC model; the RBC model is incorporated into the new Keynesian perspectives, such as monopolistic competition or nominal rigidities (Galí 2008: 2-6).

The novelty of the new generation of monetary models has been to embedded those features in a fully specified DSGE framework, thus adopting the formal modeling approach that has been the hallmark of RBC theory (Galí 2008: 6).

This result originates in the efforts to incorporate the effectiveness of monetary policy into the dynamic framework of the RBC. However, the canonical framework of the RBC contradicted lots of empirical evidence as well as the general belief in the ability of macroeconomic policy. Thus, the basic elements of the RBC such as the perfect competition and the flexible adjustable price were inappropriate for studying the effect of monetary policy. The new Keynesian model should focus on the nominal rigidities and the effect of monetary policy. In order to avoid the Lucas Critique, however, the new Keynesian perspectives was combined with the dynamic properties of RBC. Notwithstanding this fact, the new Keynesian model still has 'important differences with respect to RBC models (Galí 2008: 6)'.

The economy's response to shocks is generally inefficient. Second, the non-neutrality of monetary policy resulting from the presence of nominal rigidities makes room for potentially welfare-enhancing interventions by the monetary authority in order to minimize the existing distortions (Galí 2008: 6).

Thus, the DSGE models used by many institutions including the central banks in each country are classified as the New Keynesian models with the stochastic dynamic characters in the general equilibrium framework expressed in the intertemporal choices of representative individuals between consumption and leisure. In the following sections, the basic model of the new Keynesian approach is examined.

1.3.3 The Basic New Keynesian Model and the Contemporary Crisis

1.3.3.1 The Structure of the New Keynesian Model

Consider the basic new Keynesian model in continuous time. Three equations can be suggested as follows ([Edmond 2014](#); [Moll 2014](#)).

$$\dot{x} = i - r - \pi \quad (1.15)$$

$$\dot{\pi} = \rho\pi - \kappa x \quad (1.16)$$

$$\dot{i} = i^* + \phi_x x + \phi_\pi \pi \quad (1.17)$$

where x and π refer to output gap and inflation rate, respectively; κ and ρ are positive coefficients that refer to price stickiness, that is, the price adjustment becomes flexible as $\kappa \rightarrow \infty$, and a discount rate, respectively. The first equation (1.15) is the IS Curve derived from a maximizing problem of consumer's choice between consumption and labor supply, and r is the natural rate of interest. Equation 1.16 is the famous new Keynesian Philips curve with the staggered price adjustment. This continuous time style model is introduced by Werning ([2012](#)), and it can be compared with Gali's model ([2008](#)). Last but not least, Equation 1.17 represents policy responses of the central authorities. That is, the central authorities are trying to cope with overheating or recessions by adjusting their reference rate, and the policy coefficients, ϕ_x, ϕ_{pi} , which are both positive. If (1.17) is substituted into (1.15), a differential equation system can be obtained

as follows.

$$\begin{aligned}\dot{x} &= i^* + \phi_x x + (\phi_\pi - 1)\pi - r \\ \dot{\pi} &= \rho\pi - \kappa x\end{aligned}\tag{1.18}$$

The Jacobian matrix of the above system is as follows.

$$\mathbf{J} = \begin{pmatrix} \phi_x & (\phi_\pi - 1) \\ -\kappa & \rho \end{pmatrix}$$

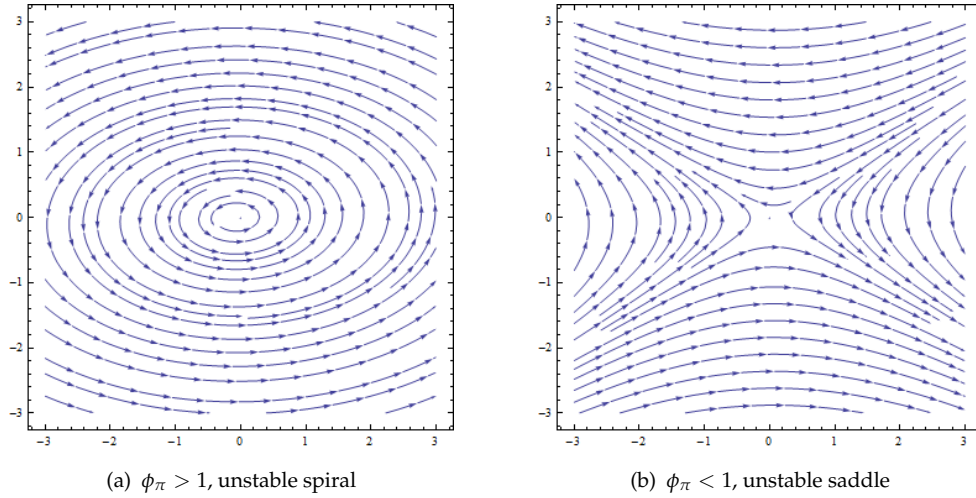
The trace, $tr(J)$, and determinant, $Det(J)$ of the matrix are $\phi_x + \rho$ and $\phi_x \rho + (\phi_\pi \kappa)$, respectively. If assuming $\phi_x = 0$ for simplicity, the fixed point, x^* and π^* can be obtained as $(\rho(r - i^*)) / (\kappa(\phi_\pi - 1))$ and $(r - i^*) / (\phi_\pi - 1)$. This system is always *unstable* because the trace is greater than 0. However, the fixed point would be saddle or spiral in accordance with ϕ_π .

PROPOSITION 3.1. (1) The system (4) is unstable because the trace, $\phi_x + \rho > 0$ by definition. (2) If $\phi_\pi > 1$, it has an unstable spiral fixed point. Otherwise or $\phi_\pi < 1$, it has an unstable saddle fixed point.

PROOF 3.1. (1) If $\phi_\pi > 1$, then $Det(J) > 0$, and $tr(J)^2 - 4Det(J) < 0$. Therefore, the eigenvalues of the system are complex conjugates with positive real part. This is the condition that a differential equation system has an unstable spiral point. (2) If $\phi_\pi < 1$, then $Det(A) < 0$, and $tr(A)^2 - 4Det(A) > 0$. Thus, the eigenvalues are two distinct real ones with opposite signs. A differential system under this condition has a saddle point ([Strogatz, 1994b](#): 129-137).

These results are same as Asada's ones concerning the discrete-time type of the basic New Keynesian model ([Asada, 2013](#)). In any case, the new Keynesian system loses its stability. However, new Keynesian economists, in general, tend to solve this problem by using a determinacy or indeterminacy of the model rather than the stability or instability in more mathematical sense. They rule out the case, $\phi_\pi < 0$, because it refers to multiple equilibria in the system. Thus, a

FIGURE 1.14: The vector fields of the system (4): $i^*=0.05$, $r=0.03$, $\phi_x=0$, $\kappa=0.8$, and $\rho=0.03$; horizontal axis $\rightarrow \pi$ and vertical axis $\rightarrow x$

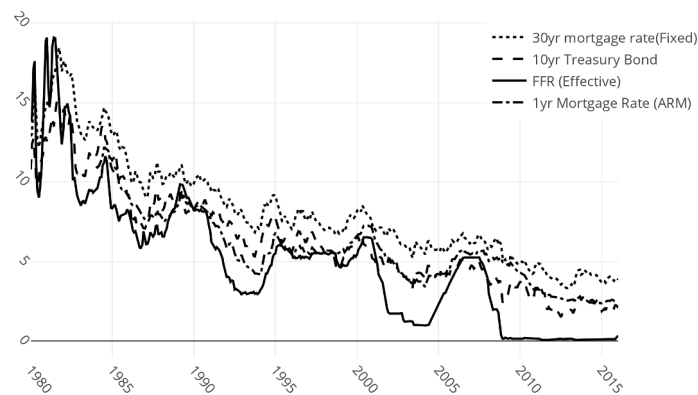


unique equilibrium can be achieved in the case, $\phi_\pi > 0$. It would be the first best on the policy-makings, $x^* = 0$ and $\pi = 0$, as the unique equilibrium with $i^* = r$. As a matter of fact, this is not a dynamic problem but a static analysis generated by exogenous shocks including the TFP shock, which is transmitted through the rate of real interest.

Consider the term, ϕ_x , a necessary condition of the *determinacy* is $\phi_x \rho + \kappa(\phi_\pi - 1) > 0$. This means, in our analysis, a pattern of the fixed point must not be the saddle. In other words, the response of the policy authorities on changes in output and inflation must have the *sufficient strength* to guarantee this condition (Galí, 2008: 77). However, this statement is rather ambiguous because an over-reaction to changes in the output gap, that is, a too-large ϕ_x , cannot secure the stability of this system (See Figure 1.14).

In summary, the excessive response of the central authorities to the output gap represented by increasing ϕ_x could expand an instability of the system. However, their insufficient action on changes in the inflation rate, that is, a smaller ϕ_π , could lead to multiple equilibria or the indeterminacy of the system. Notwithstanding this finding, they solve this problem by treating the output gap and inflation rate as jump variables, which are not predetermined but freely chosen by agents. However, this is an unreliable statement because the inflation rate does not move discontinuously (Asada, 2013: 10; Mankiw, 2001: C54; Tsuduki,

FIGURE 1.15: Interest Rates (01/1980-12/2015): U.S. Economy (percent, monthly)



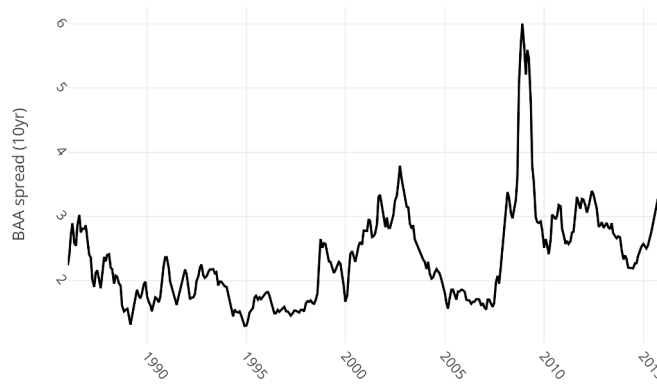
Sources: FRED Database, Freddie Mac Mortgage Rates Survey

2014: 8).

1.3.3.2 Diminishing Effectiveness of Monetary Policy before and after the Contemporary Crisis

It is worth noting that, before and during the contemporary crisis, a ripple effect of monetary policy on the interest rates and credit flow had significantly reduced. Figure 1.15 shows the movements of the Federal fund rate and other interest rates in the United States: The effective federal fund rate (FFR (effective)), 1 year ARM mortgage rate (1yr Mortgage Rate (ARM)), 10 year fixed-rate mortgage rate (10yr Mortgage Rate (Fixed)), and 10 year treasury bond rate (10yr Treasury Bond). The rates move in single file, but their patterns just before and after the Crisis were quite different. The gap between the FFR and other interest rates broadened while the FFR is sharply declined after 2001. In particular, 10 year fixed-rate mortgage rate had a slight hint of movement as compared with the drastic fluctuation of the FFR after 2001. This fact means that the effectiveness of monetary policy on the other interests, in particular, the long-term rates of mortgages, diminished before and during the Crisis.

FIGURE 1.16: The Spread between BAA Corporate Bonds and 10yr Treasuries (01/1986-01/2016): U.S. Economy (percent, monthly)



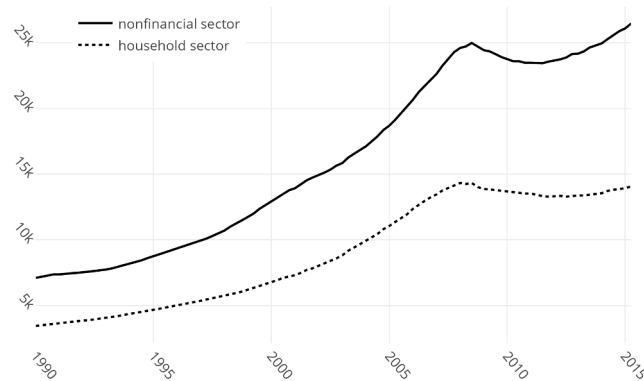
Source: FRED Database

There is another aspect of the ineffectiveness of monetary policy. Figure 1.16 describes the spread between BAA corporate bonds and 10-year Treasury bonds. During the early stage of the Crisis, this spread dramatically rose. This increase in the gap 'between the risky and safe rates' is referred to as the financial friction by some commentators ([Hall, 2013](#): 157). 'Business lending dried up, and even when loans could be obtained, the interest rates on those loans increased sharply' ([Jones, 2014](#): 381).

This increasing ineffectiveness of monetary policy has a decisive effect on credit flows. Before the Crisis, the household debt continued to increase despite the effort of the monetary authority to moderate it. A recovery of credit flows to households or nonfinancial firms is much delayed as compared to the desperate policy actions during the crisis (See Figure 1.17).

These observations can be represented in the model described in the above section. The increasing ineffectiveness of monetary policy could be translated into an increase in time delays of the monetary authority's response to the macroeconomic activities, which makes ϕ_x and ϕ_π smaller. The model remains unstable because ϕ_x is more than zero by definition. Instead, it leads to the indeterminacy

FIGURE 1.17: Total Credit to Nonfinancial Sector and liabilities of Households and Nonprofit Organizations (Credit Market Instruments): U.S. Economy (Billions of Dollars, Quarterly)



Source: FRED Database

of the model if ϕ_π becomes less than zero as the time lags increases.

In the following section, the credit inflows, in the households' maximizing problem, which is one of the important factors to explain the contemporary crisis, is taken into account in the new Keynesian framework

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1.3.3.3 A Model with the Credit Flows

In this section the credit flows in households' maximizing problem is fundamentally considered because the weakening of the monetary policy to regulate the flows is prominent during the Crisis. As mentioned in the previous section, the credit flows had a quite independent character on monetary policy although regulating the flows is the ultimate goal of the policy (See Figure 1.16 and 1.17. In order to take the credit flows into account, the household's budget constraint is transformed as follows.

$$PC + \dot{B} = iB + WN + (1 - i)D \quad (1.19)$$

where C is consumption and P is price level. i is the nominal interest rate. Therefore, households' consumption, PC , and additional savings, \dot{B} , are dependent on property income, iB , labor income, WN , where N is labor, and net credit flows, $(1 - i)D$ where D is credit flows available. D is assumed that it is proportional to aB where $a = D/B$. IS curve can be derived from this setting as follows (See Appendix G1 for details).

$$\dot{x} = i + (1 - i)a - r - \pi \quad (1.20)$$

Substituting (1.17) into (1.20), a new equation system can be obtained as follows. For the simplicity, $\phi_x = 0$.

$$\begin{aligned} \dot{x} &= (1 - a)i^* + a - r + ((1 - a)\phi_\pi - 1)\pi \\ \dot{\pi} &= \rho\pi - \kappa x \end{aligned} \quad (1.21)$$

The critical point of this system is $\pi^* = [r - (1 - a)i^* + a] / [(1 - a)\phi_\pi - 1]$ and $x^* = \pi^* \rho / \kappa$. This fixed point means that the monetary authority must set much larger target interest rate than the above system (4) to achieve the first best, $x^* = 0, \pi^* = 0$. In addition, the sensitivity of monetary policy, ϕ_π , is much greater than 1. That is, their response must be much stronger than the case that does not take account of the credit flows.

Consider the proportion, a , that is, the ratio of the credit flows to holdings. If the ratio increases under the constant ϕ_π , it weakens the effectiveness of monetary policy to achieve their best goal. The ratio can also be described as an endogenous variable. It is no longer a constant but a function of the output gap, x , that is to say, $a = f(x)$. The Jacobian matrix of this new system that takes into account the proportion as the endogenous variable of the output gap is as

follows. If $\phi_x = 0$,

$$\mathbf{J} = \begin{pmatrix} f'(1 - i^* - \phi_\pi \pi^*) & (1 - f')\phi_\pi - 1 \\ -\kappa & \rho \end{pmatrix}$$

Therefore, the stability of this system around the first best, $x^* = 0, \pi^* = 0$, is ensured under the condition, $f' < 0$ and $f'(1 - i^*) > \rho$. Thus, the pace of credit increase following the changes in the output gap must be reduced in order to guarantee the stability, and thus $f' < 0$ becomes an ultimate condition to ensure the macroeconomic stability without regard to the sensibility of monetary authorities on the general activity of economy like ϕ_x and ϕ_π (See Appendix G2 for details). On the contrary, if $f' > 0$, which means the procyclicality of the financial system (Borio et al., 2001), this system is unstable, and the patterns of critical points depend on ϕ_π as the system without the credit flows works. A positive relationship between the propensity, a or f and output gap, that is, $f' > 0$, can be seen before and after the Crisis: While it led to the diminishing effectiveness of monetary policy, it added to the instability of the economy during the period. In conclusion, the achievement of the first best outcome requests an ability to regulate the credit flows as well as to adjust the policy rate. Financial globalization and deregulation would seriously violate the competence of the policy authority. That is, the time delay of the policy lengthened despite all their efforts to control the macroeconomic situations. Therefore, the sufficient policy response would be insufficient to cope with the Crisis.

Chapter 2

A Strange Attractor of Business Cycles in System Dynamics

2.1 Rössler Attractor in Business cycles

The Rössler Attractor is one of the representative strange attractors such as Lorenz's attractor, which emerged in the 3-dimension differential equation system. As compared to the famous Lorenz butterfly nonlinear model, it has one nonlinear term ([Strogatz 1994a](#): 434). In economics, Richard M. Goodwin (1990) has provided with an example of the business cycle modeling with the Rössler strange attractor, which is incorporated with the Metzler's inventory adjustment model, in chapter 9, *A Fresh Look at Traditional Cycle Models*, of his book in 1990 ([Goodwin 1990](#))¹.

The basic structure of the G-M (Goodwin-Metzler) model is introduced in Section 2.1.1. The model is composed of three differential equations referring to the differentiations of the three stock variables, the level of output, inventory, and a control variable for macro stability with respect to time, t , respectively. Furthermore, this structure can be analyzed over some steps. Section 2.1.2 is devoted to the representation of the dynamic trajectories that are generated

¹From now on, we call this the G-M (Goodwin-Metzler) model. His book in 1990 introduced various models with the Rössler attractor, such as the extension of the traditional Goodwin model and capital accumulation model with a particular technical assumption ([Goodwin 1990](#))

in the system and section 2.1.3 reveals some problems of the model á la Goodwin.

2.1.1 The Simple Goodwin-Metzler Model

The Metzler model describes *a posteriori* quantity adjustment behaviors under given distributional and technical conditions (Metzler 1941). It was incorporated into Goodwin's study concerning nonlinear dynamic business cycles with Rössler band. The business cycle model with Rössler band can be described as follows.

$$\dot{Q} = \beta(\bar{S} - S) - eZ \quad (2.1)$$

$$\dot{S} = Q - aQ \quad (2.2)$$

$$\dot{Z} = \delta + Z(Q - c) \quad (2.3)$$

Where the state variables, Q , S , Z are output, inventory, and the policy variable, respectively, and \dot{Q} , \dot{S} , and \dot{Z} are the derivatives with regard to time, t . All these stock levels are endogenously determined in each of the continuous time state equations, (2.1), (2.2), and (2.3).

The bar on the stock, for example, \bar{S} , refers to the target level of inventory that Goodwin defined as the function of the output level, $\bar{S} = \alpha Q$ where α is an auxiliary variable or parameter. Other parameters are β , a , and δ that we can respectively translate into a reaction coefficient to the inventory discrepancy, demand parameter², and an inflow rate of Z , such as tax revenue; $Z(Q - c)$ is a positive feedback relation depending on current macroeconomic circumstances such as discrepancies between an actual and target output level. Not finding what c exactly means in Goodwin's paper, we can guess it as a target output level for macro stability of the central authorities because differences between the output levels and c affect the rate of change in the policy variable.

²In other words, aQ refers to the demand level. The parameters and variables in this model were not specifically defined in Goodwin's book. I translate all these things in line with economic theory.

Consider this equation system over the following two steps.

In the first step, let us take account of the first two equations or variables Q, S ; Equation 2.1 represents a production determination process by an adjustment of inventory discrepancies to maximize their profits or minimize their costs and, on the other hand, the changes in the inventory level are governed by the difference between the output level and an actual demand level, aQ .

To begin with, the fixed point in this system composed of the two state variables that we firstly take into account is unstable because the trace of the Jacobian of the system is a positive value, $\alpha\beta > 0$. This aspect refers to *instability embodied in the private macroeconomic system*.

If we take the variable, Z , into account as the second step, this system does not diverge from the fixed point; however, it fluctuates around the fixed point. We will specify the (in)stability analysis in some mathematical manners and visualize the trajectories of the system in the next section.

2.1.2 Dynamic properties of the G-M model

In this section, the dynamic properties of the G-M model over the two stages are explored. Let us consider the interaction between output and inventory, Q, S , at first. The Jacobian matrix of the system where a relationship between Q and S is represented is very simple as follows.

$$\mathbf{J} = \begin{pmatrix} \alpha\beta & -\beta \\ (1-a) & 0 \end{pmatrix}$$

As shown above, the trace and determinant are $\alpha\beta$ and $\beta(1-a)$, respectively. By definition, they have positive values, $\alpha, \beta > 0$, and $0 < a < 1$. Therefore, both of the trace and determinant must be a positive in this linear equations system, meaning that the eigenvalues in the characteristic equations are either real with a same sign or complex conjugate. Since, however, α of the desired inventory is less than a that represented the demand level, these eigenvalues must be a pair of complex numbers with a positive real part.

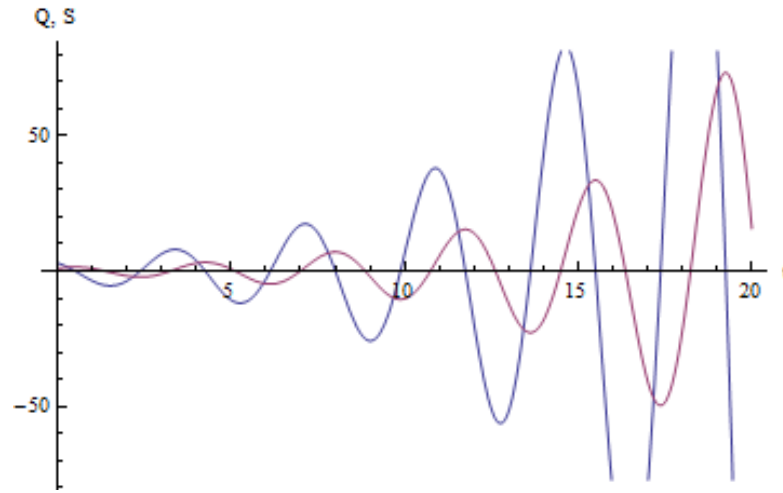


FIGURE 2.1: The trajectories of Q and S in $\beta = 5.0$, $\alpha = 0.0833$, $a = 0.429$, $Q_0 = 3.0$, $S_0 = 0.1$.

Figure 2.1 shows trajectories of Q and S when we take into account the only two variables relationship in the G-M model. To reconstruct the G-M model, the initial conditions given by Goodwin are endowed in this model. Since this system is fundamentally unstable, it is difficult to be used to realize permanent business cycles in the economy. Only if introducing the variable, Z , it may apply to representing patterns of the *real* business cycle. In the G-M model, Z plays a role for controlling instability by being inserted in Equation 2.1. As above, it can regulate the oscillation of output by perceiving discrepancies between the target and actual output. If the target output level is greater than the actual output, the rate of change in Z is decreasing and, as a result, the derivative of Q with regard to time is increasing. The Jacobian of the G-M model is as follows.

$$\mathbf{J} = \begin{pmatrix} \alpha\beta & -\beta & -e \\ (1-a) & 0 & 0 \\ \frac{\delta}{c} & 0 & -c \end{pmatrix}$$

The fixed points in the system are $Q^* = 0$, $S^* = 0$, $Z^* = \delta/c$. As shown in the Jacobian, this system is unstable if the trace of the Jacobian has a positive value. However, the trajectories of Q and S don't diverge from the fixed points like Figure 2.2 due to the nonlinear term, ZQ ; in Equation 2.3, Z is thus a kind of a control variable in the entire system.

In Figure 3³, we can see that the well-known Rössler attractor is realized in the G-M model. As shown in Figure 2.3, the time series of each variable in the system with the strange attractor has an irregularity and aperiodicity—neither a limit-cycle nor closed-orbit. As described in Chapter 1, the nonlinear character is one of the most important factors for studying business cycles; patterns of business cycles such as the movement of the capacity utilization rate or the rate of change in output are very similar with those of the strange attractor. Thus, It could represent persistency or unpredictability of business cycles by neither a stochastic nor statistical way that just estimates the degree of accidents—this statement does not mean that statistical method is excluded— but a deterministic method. That is, the persistency of the business cycles is generated by an intrinsic nature of the prevailing economic system. This is not static but *dynamic problems*; however, Goodwin (1990) could not describe it enough to be consistent with economic theory, and it tends to reveal its strange aspects when it applied to economies in the real world. For these reasons, lots of people against this modeling process have often blamed that this type of modeling with a nonlinear character had been based on *ad-hoc* assumptions (Lorenz 1993: 192). Therefore, the severe inconsistencies that the G-M model holds should not be overlooked although the models can be still useful to give an insight into the study of business cycles.

2.1.3 Strange Aspects in the G-M model

The G-M model has a high likelihood to represent more realistic trajectories of business cycles, but it has several unconvincing aspects in the view of the economic theory. Three questionable points can be addressed as follows.

- One of the fixed points in the G-M model, the equilibrium point of production, is zero but it is unreasonable. Concerning the trajectory of production in the system, we can make sure that there is negative production in the process, which may mean the destruction of their products occurs in the

³This numerical simulation is performed with a few adjustments of some coefficients to show the attractor much clearer than the Goodwin model, and the changed values can be identified.

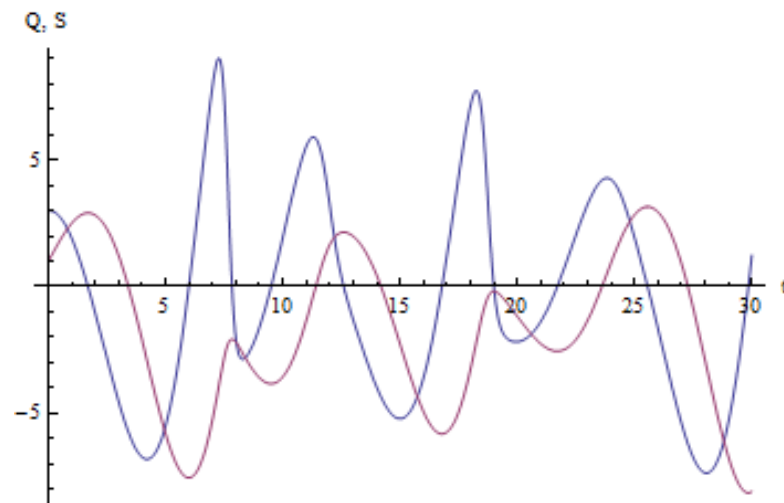


FIGURE 2.2: The trajectories of Q and S in $\beta = 1.0$, $\alpha = 0.4165$, $a = 0.429$, $e = 3.0$, $\delta = 0.30$, $c = 4.0$, $Q_0 = 3.0$, $S_0 = 0.1$, $Z_0 = 0.05$.

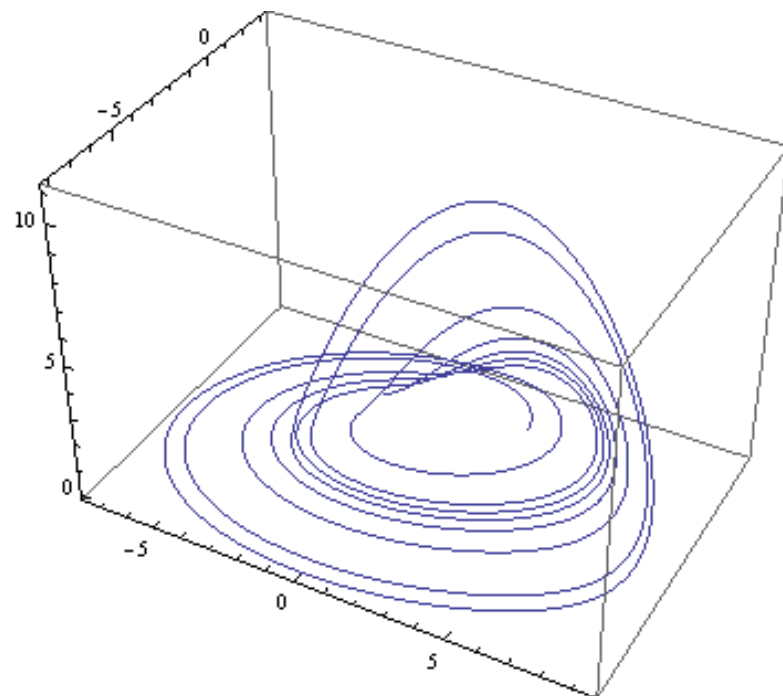


FIGURE 2.3: Rössler Attractor between Q , S , and Z

economy. It is *the strangest aspect* in comparison to other economic models. Is it possible to be negative output levels in the real economy? It is unusual that the fixed point of the output level is supposed as zero because Goodwin naturally called it "levels" although we could understand that he described an oscillating pattern using this mathematical form.

- The First two equations in the G-M model represents the firms' production determination (Equation 2.1) and economic circumstances that they are confronted with—the aggregate demand level in Equation 2.2. However, Goodwin assumed that the public management has a *direct* effect on the private management of their stocks and production by inserting the control variable, Z , into this system (Equation 2.3). It seems that he suggested something like an automatic procyclical tax system in his model. This may lead to describe *the built-in-stabilizer* in the economy. However, it is a more realistic assumption that the tax-cut affects demand rather than the production process in the formal economic theory. Even if government's tax revenues are reduced automatically corresponding to the economic circumstance, it is unreasonable that every producer makes a decision to product more directly. In other words, the governments purchase goods and services produced by firms or provide their funds to stimulate aggregate demand.
- Overall, the model reconstructed in the Rössler system gives a possible form for irregularity and unpredictability in the business cycle theory; however, it is insufficient to explain how the change in microeconomic behaviors is transformed into the macroeconomic field. In addition, most the assumptions take a rigid form only for the mathematical modeling rather than the economic reality.

In the next section, an alternative to the G-M model is presented. First, the G-M model must be transformed from the (production and inventory) level-dimension to a growth-rate-dimension to avoid the negative production and inventory in the G-M model. Second, the control variable should be taken into account as monetary policy or credit supply of the central authority or financial

institutions in the new model. As a result, the public management controls macro levels of demand in an economy.

2.2 A Reproduction Model with the Chaotic Motion

There are few kinds of literature about the Rössler attractor in economics. One of the extraordinary cases is Abraham and Nivala's paper ([Abraham and Nivala 2013](#)), which specifically refers to Goodwin's book in 1990 as the direct subject of discussion. In Marxian Economics, however, we can find a more suitable example of the chaotic motion with Rössler band than the G-M model. Marx suggested a two-sector macroeconomic model, which has been called the famous *Marxian Reproduction Schemes*. In fact, 'the model is composed of two *departments*. Department I is the sector producing means of production, and Department II the one producing consumption goods' ([Reuten 1998](#): 194). Foley ([1986a](#)) developed this Marx's schemes into a sophisticated mathematical form using the system of the time-delay differential equations and solve it by *Convolution*, which is one of the methods to find solutions of the differential equations. However, a model that we present here is not the typical two-sector macroeconomic model but a one-commodity (or sector) model of the circuit of capital that Foley has represented Marx's idea ([Foley 1986a](#); [1986b](#): 62-90). In the Foley's model, not only an interrelation between the commercial, product capital, and finance capital (the circuit of capital) but also time delays that each sector may hold are included.

2.2.1 A Simple and Expanded Reproduction Model with the Chaotic Motion

For simplicity, income distribution and capital accumulation under a given (or constant) technical and distributional condition are abstracted from this modeling process according to Marx's definition of reproduction: a constant organic composition of capital; the rate of surplus value justify this abstraction.

Simple Reproduction means that an economy reproduces itself with a constant

scale. Profits appropriated by capitalists are not reinvested but consumed all with wages received by workers. Because, in *Expanded Reproduction*, profits are reinvented at a certain proportion, an economy grows increasingly. Marx demonstrated that the expanded reproduction converges toward the same growth rate of each department irrespectively of any given initial values in his numerical examples. Furthermore, Foley (1986a;1986b) reconstructed it as the circuit of capital with time lags and showed the necessity of new borrowing for constant growth. According to Marx, consider the circuit of social capital in a closed circuit with distinct forms of capital: financial capital, productive capital, and commercial capital (Foley 1986b: 66; Duménil 2009: 240). In this production process, two social capitals—commercial capital (orders) and productive capital (production)—can be taken into account.

Firstly, *commercial capital* holds inventory stocks and places an order based on changes in their holding stocks.

$$\dot{o} = -[v/\nu]$$

where o is the rate of change in orders and v is the rate of change in inventory stocks, $v = ds/dt$ where s is inventory stocks. If a previous inventory level is larger than the current one, managers make a decision to increase orders. However, it takes time to fulfill the needed order. Thus, there is a time lag, ν , in the commercial capital. When the inventory level does not change anymore, $v = 0$, additional orders don't be placed. We can also interpret this mechanism into an adjustment to reduce a gap between the actual and target growth rate. If the target growth rate of inventory is zero, the above description can be still held.

Second, the productive capital also has a similar process with the case of the inventory adjustment. It produces commodities along with the commercial capital's orders, but it also has a time delay to achieve their own goal. On the one hand, they take orders from the commercial capital, and if a previous output level is greater than the current one, they increase production of final goods. It is

because this system seeks to maintain a proper rate of growth.

$$\dot{u} = -[u/\epsilon] - [v/\nu]$$

where u is the rate of change in output. Contrary to the G-M system, all endogenous variables are expressed in the small letters. This means that all these variables are the rate of change in level.

$$\dot{m} = [\rho u - (1/\zeta)(u - u_d^t)]m$$

where m is a financial variable, the change rate of new loans. So $u_d^t = \alpha r$ is the rate of capital accumulation where α is the ratio of the profits recommitted to capital accumulation. Moreover, there is a time delay to adjust this gap, ζ . In particular, $u_d^t = \alpha r$ refers to the *Cambridge Equation*, which means a balanced growth rate. Thus, this system holds one negative feedback system, which may lead to the desirable level, namely the balanced growth path. The financial sector would provide loans for high growth rates but they are reduced if the growth rate of output, u , is higher than the desired growth rate.

Admittedly, this equation represents the behaviors of *financial sector*, which is the most important part of this system. Because, if the financial sector does not exist in the system, the fixed point of this system is $(u^*, v^*) = (0, 0)$. Thus, this is a no-growth regime corresponding to the case of *simple reproduction* that Marx mentioned. That is, the zero-loan from the financial sector means that economy does not grow but replaces itself with the same scale. Consequently, it is necessary for the growth process with a positive rate of growth if there are *time delays* within the system. Therefore, a new reproduction scheme can be suggested as follows.

$$\dot{u} = -[u/\epsilon] - [v/\nu] \quad (2.4)$$

$$\dot{v} = (1 - a)u - bm \quad (2.5)$$

$$\dot{m} = [\rho u - (1/\zeta)(u - u_d^t)]m \quad (2.6)$$

Equation 2.5 represents a formation of new demand, which is a linear function of u , and m with parameters, a and b . In the next section, we makes it clear whether the irregular persistent cycles are generated in this equations or not, and if so, where the cycles come from.

2.2.2 A Stability Analysis of the Reproduction Model

For studying stability and properties of this N-G-M model, a more sophisticated method can be used. First of all, fixed points are obtained when the derivative terms are zero and solve the equations.

$$(u^*, v^*, m^*) = (0, 0, 0) \quad (2.7)$$

$$= (-u_d^t / (\zeta\rho - 1), u_d^t v / (\zeta\rho - 1), (a - 1)u_d^t / b(\zeta\rho - 1)) \quad (2.8)$$

As shown in Equation 2.8, the non-zero fixed point has a different sign due to $\zeta\rho \geq 1$. If linearizing at the origin, $\dot{u} = u/\epsilon - v/\nu$, $\dot{v} = (1 - a)u - bm$, $\dot{m} = -u_d^t m$, where the nonlinear term has disappeared. m converges towards 0 exponentially. The Jacobian can be obtained as follows.

$$\mathbf{J} = \begin{pmatrix} -1/\epsilon & -1/\nu \\ (1 - a) & 0 \end{pmatrix}$$

where the trace and determinant of the Jacobian are $-1/\epsilon$ and $(1 - a)/\nu$, respectively. Because $0 < a < 1$ and $\nu > 0$, this fixed point is a stable node if $\epsilon \neq 0$. As explored in the previous section, the fixed point at the origin, $(0, 0)$, means that both of the growth rates of output and inventory are all zero, which can be defined as the no-growth regime or simple reproduction. Therefore, this system

remains at a constant scale, without financial sector.

If $0 < a < 1$, can't this system represent Marx's simple reproduction case? The answer is yes. Since this system takes into account the rates of change, it describes a convergent process towards the simple reproduction regime. Thus, this is a dynamic process that surplus that economic agents do not consume is adjusted by the change in inventories—Inventory investment. If it converges to the zero growth-rate, it is the case of simple reproduction. We shall show that a role of financial sector is necessarily required for the economic growth at the constant rate of growth, that is, the expanded reproduction

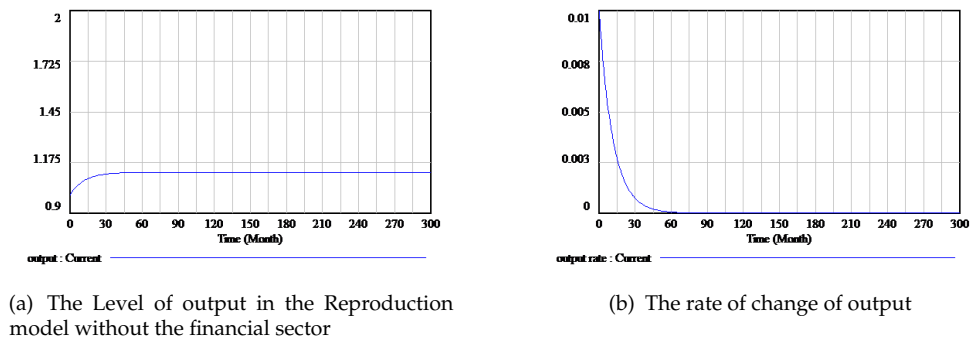
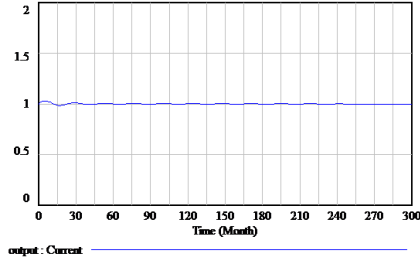


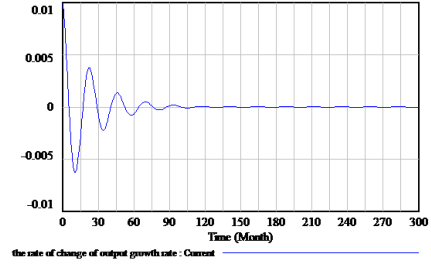
FIGURE 2.4: Reproduction model without the financial sector, $a = 1$

Figure 2.4 shows an example where the simple reproduction can be represented. Since the initial values of the growth rate of inventory and output are set as 0 and 0.01, the trajectory of the output growth rate converges towards the equilibrium point, 0, but the rate of change in inventory stays at the initial point, 0, because $a = 1$. As Figure 2.4b, the level of output reaches a certain level and remains, which presents a dynamic property that leads to the case of the simple reproduction scheme.

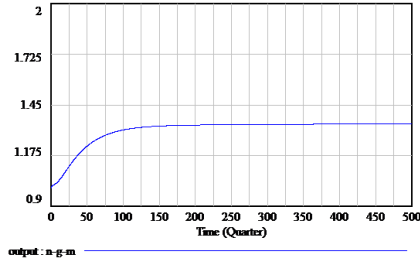
If $a \neq 1$, can be maintained the case of the simple reproduction? Figure 2.5 shows that the simple reproduction is realized with $a = 0.7$. Compared to $a = 1$, the trajectory of the growth rate of output displays a damped oscillation process towards the fixed point because of the time delays. In the expanded reproduction, it becomes an unconvincing argument that the fixed point of the growth



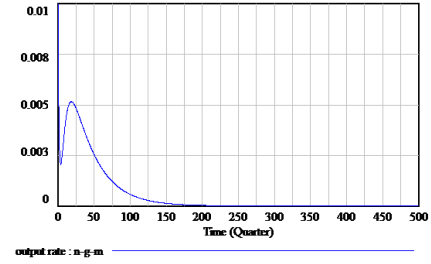
(a) The Level of output in the Reproduction model without the financial sector



(b) The rate of change of output

FIGURE 2.5: Reproduction model without the financial sector, $a = 0.7$ 

(a) The level of output in the Reproduction model with the financial sector



(b) The rate of change of output

FIGURE 2.6: Reproduction model with the financial sector, $a = 0.7, b = 0.3$

rate of output is negative. Thus, under the condition of $\zeta\rho < 1$, $u_d^t > 0$, it has to be analyzed.

$$J = \begin{pmatrix} -\frac{1}{\epsilon} & -\frac{1}{nu} & 0 \\ (1-a) & 0 & -b \\ (\frac{\rho\zeta-1}{\zeta})m^* & 0 & (\frac{\rho\zeta-1}{\zeta})u^* + \frac{u_d^t}{\zeta} \end{pmatrix}$$

$$\lambda^3 + A\lambda^2 + B\lambda + C = 0 \quad (2.9)$$

$$A = (1/\epsilon) - (\Gamma u^*) - (u_d^t/\zeta), B = (\epsilon\zeta(1-a) - (u_d^t + \Gamma u^*\zeta)v)/\epsilon\zeta v, \\ C = (a-1)u_d^t + ((a-1)\Gamma u_d^t - \Gamma m^*b)\zeta/\zeta v$$

where $\Gamma = (\rho\zeta - 1)/\zeta$. The stability condition is $A > 0$, $B > 0$, $C > 0$, $AB - C > 0$. Since $\zeta\rho < 1$ as we supposed above, B and $C > 0$ but the sign of A is not obvious. If ϵ and ut_d/ζ increase, this system becomes unstable. As a result, the conditions under which the strange attractor is generated are $\epsilon \gg 0$, $v > 0$, $\zeta\rho < 1$ and $u_d^t > 0$. This condition is coincident with the case of expanded reproduction. That is, the average (or equilibrium) growth rate of output is positive, and it takes some time to fulfill production in private firms and achieve the policy target of central authorities, at least, it is very hard to reduce the time even towards *zero*. Furthermore, there is a counterintuitive fact that the central authorities do not *too much sensitively* seek to accomplish their target because this overreaction may amplify instability of the system.

Figure 2.7 illustrates the stability of the expanded reproduction system. Each

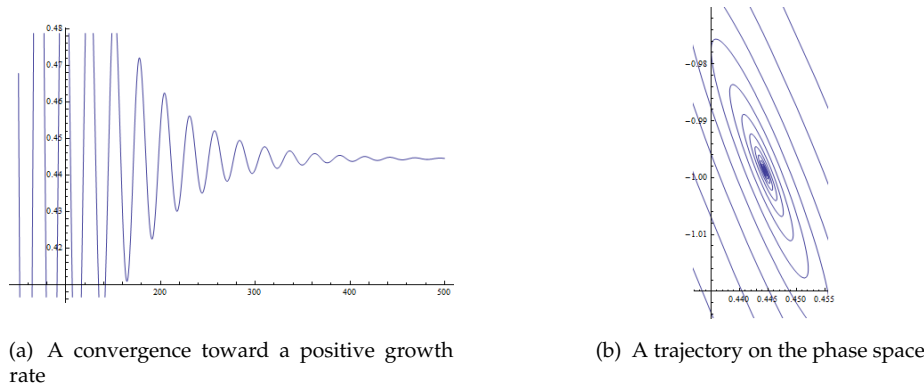


FIGURE 2.7: Stability of Expanded Reproduction Scheme, $a = 0.7$, $b = 0.3\epsilon = 1.82$, $v = 4.09$, $\zeta = 0.5$, $\rho = 1.9$, $u_0 = 0.3$, $v_0 = 0.2$, $m_0 = 0.3$

Subfigure shows a damped oscillation and a spiral type of convergence towards the fixed point with a positive growth rate of output. It will thus lead to an exponential growth pattern of the output level. This is what Marx demonstrated using his numerical examples in his book, *Capital* Vol. 2. As we have already known, he and his followers have focused on this aspect of the model. However, let us note the case of the simple reproduction again. Even if a certain portion of output are reinvested, $0 < a < 1$, the thesis of Marx's expanded reproduction does not hold anymore if the financial sector does not exist in this system due to the time delays. Thus, the growth rate converged towards zero even in the case of $0 < a < 1$. New loans by the financial sector are indispensable for the

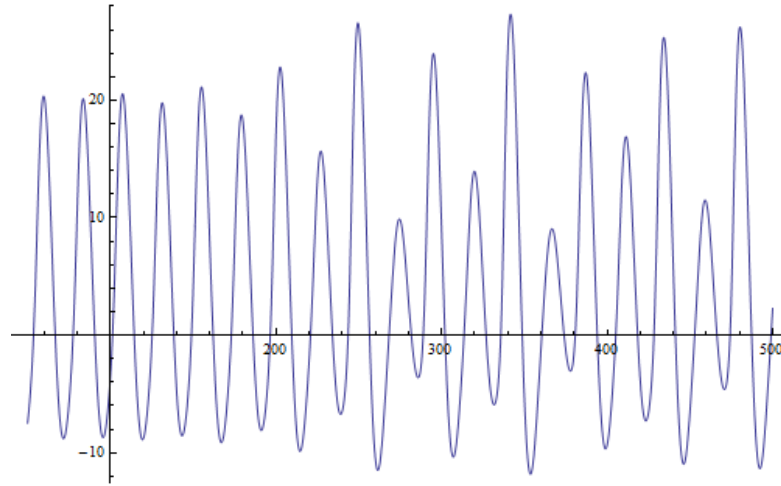


FIGURE 2.8: The chaotic motion of u . $a = 0.7, b = 0.3, \epsilon = 7.17, v = 4.09, \zeta = 0.5, \rho = 1.9, u_0 = 0.3, v_0 = 0.2, m_0 = 0.3/$

expanded reproduction in the system.

We see that new borrowings by the capitalists to finance capital outlay can close the gap between demand financed by past sales and the level of demand required to maintain reproduction. ... The sustainable rate of growth of the system obviously depends on the level of such new borrowing. (Foley 1986b: 89)

However, our interest goes further. When ϵ increases under the constant other conditions of the numerical simulation in Figure 2.7, there may be Hopf bifurcation in the reproduction model. That is, the parameter, ϵ , is very likely to be a bifurcation parameter because a very small value of the parameter guarantees the stability in the model and, on the contrary, a more delayed production process is going to make the system unstable.⁴ Figure 2.8 shows the chaotic motion with the Rössler attractor (Figure 2.9), which shows an oscillating but irregular pattern of the trajectory.

⁴Concerning the critical value of ϵ for Hopf bifurcation, see Appendix A.

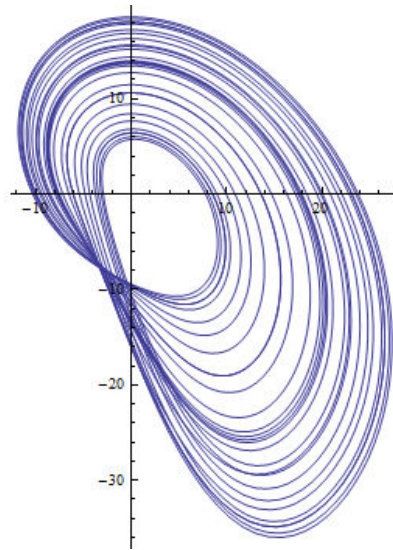


FIGURE 2.9: The phase space between u and v . $a = 0.7, b = 0.3, \epsilon = 7.17, \nu = 4.09, \zeta = 0.5, \rho = 1.9, u_0 = 0.3, v_0 = 0.2, m_0 = 0.3/$

2.2.3 Finding Chaotic Motion

Figure 2.9 illustrates the Rössler attractor generated in the case of the expanded reproduction and we can expect the motion of u is chaotic. To distinguish the chaotic motion from periodic or quasi-periodic motion, we need an additional mathematical and visual method. It is *power spectrum analysis* to capture the phenomenon (Crutchfield et al. 1980; Valsakumar et al. et al., 1997; Lorenz 1993 1993: 202-204). Although Lorenz (Lorenz 1993: 202) described this method as the attempts to draw a line between the (quasi) periodic and random behavior, this statement is more or less *inaccurate*. The chaotic motion in a deterministic system is fundamentally different from randomness being used in econometrics or stochastic model (Butler 1990).

The power spectrum refers to the Fourier transform of an autocorrelation function of the state variable (Valsakumar et al. et. al 1997: 71-72; Lorenz 1993 1993: 202-203). That is, the Fourier transform process brings the state variable changing over time into a frequency space. Given specific parameters, the chaotic motion is generated. Figure 2.10 shows typical patterns of the power spectrum the Rössler strange attractor. It has an extraordinary spike and then an exponential decline followed by a more slow decay (Valsakumar et al. et al. 1997: 72;

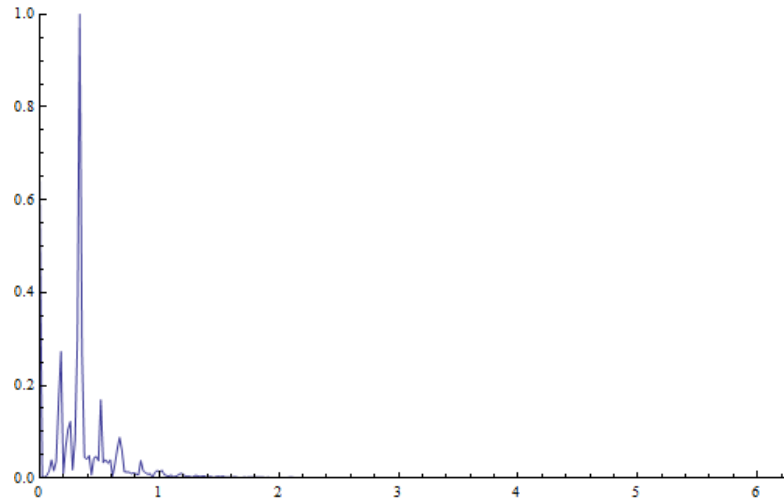
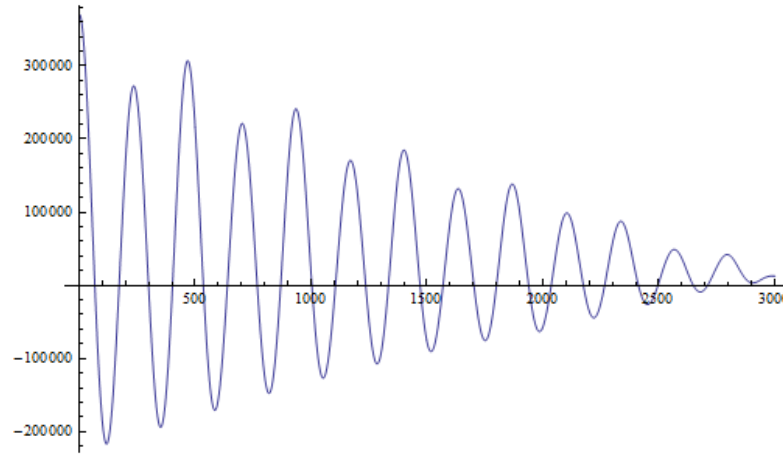


FIGURE 2.10: The power spectrum of the trajectory, u . $a = 0.7, b = 0.3, \epsilon = 7.17, \nu = 4.09, \zeta = 0.5, \rho = 1.9, u_0 = 0.3, v_0 = 0.2, m_0 = 0.3/$

See Appendix B). When, moreover, the system has the chaotic motion, the autocorrelation function converges towards zero with damped oscillations (Figure 2.11).

The time delay, ϵ , in the production behavior is one of the most important parameters to affect its stability. A longer time delay of production is associated with larger amplitudes of business cycles. The *permanent irregular cycle pattern* in the real economy refers to the existence of the time delay in production processes. On the contrary, the extent of oscillations could decrease if the time delay reduced. Another time delay, ν , also affects the period of the business cycle in the system. As the time delay to adjust inventory discrepancies is shortened, the cycles arrive earlier. Second, the parameters in the financial system interact with each other because they have the constraint, that is, $\zeta\rho < 1$. If one of two parameters increases, another parameter has to be decreased. One call this a *financial constraint* for the reality.

As you have seen, our strategy in this representation goes from an abstract mathematical model to realistic specificity. In the stability analysis, the parameters set up by the economic circumstances, that is, the positive average growth rate or reinvested surplus, time delays to adjust inventory and production, and the financial constraint.

FIGURE 2.11: The autocorrelation function of u

2.2.4 A Sectoral Configuration in the Reproduction Model

The reproduction model is arranged into each decision field according to the pattern of the feedback mechanisms in this section. Figure 2.12 shows the Causal Loop Diagram among the variables. There are four feedback nodes in the reproduction model: two negative relations between the rate of change in the output growth rate, the growth rate of output and inventory; one positive relation between loans provided by the financial sector and the actual rate of change in output; another negative feedback loop to adjust a gap between the actual growth rate of output and the desired (or equilibrium) growth rate presented by Cambridge equation, $u = \alpha r$. The above two negative relations for production determination are goal-seeking mechanisms to accomplish their desired growth rates, which are always ones in the previous period. That is, they take the form of the *adaptive expectation*. If the discrepancy in the previous time is greater than zero, they seek to produce less than in the previous time.

$$u_{t+1} - u_t = -\frac{1}{\epsilon} \Delta y_t - \frac{1}{\nu} \Delta s_t$$

where Δy_t is $u_t = y_t - y_{t-1}$ with y referring to output. Thus, this system can be considered as a feedback loop of which the target level is y_{t-1} like the adaptive expectation. Furthermore, the financial sector plays two roles at the same time.

Above all, they positively respond to the additional demand for funds required at a higher growth rate, which refers to (positive) feedback loops with the adaptive expectation. It is a financial mechanism to fulfill firms' future expansion of production capacity and consumers' demand for their new consumption corresponding to an economic boom. Financial institutions themselves do not concern the stability of the whole economy. The only target that they want to achieve is maximizing their profits, and further loans to the economy are going to enlarge them. These behaviors are associated with a self-reinforcing process of the financial mechanism that destabilizes the system: *finance instability constraint*

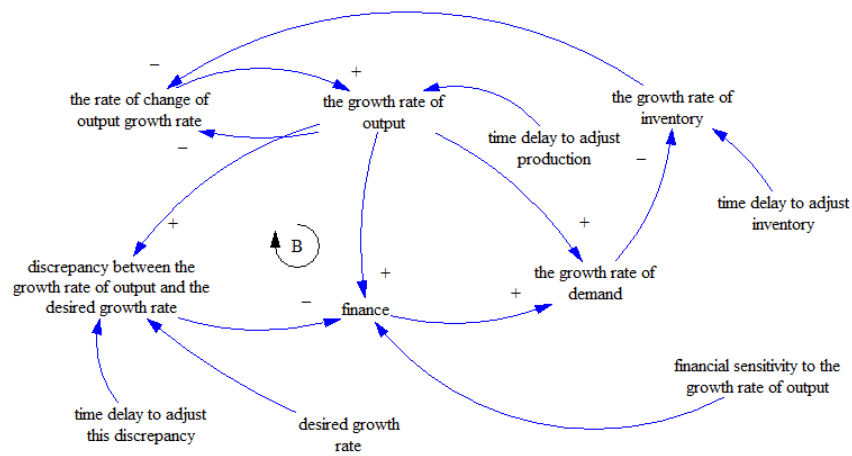
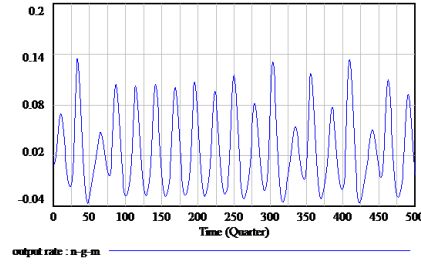
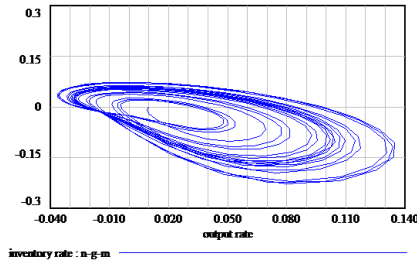
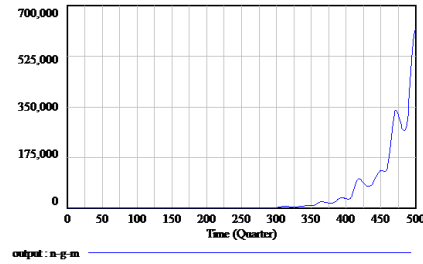


FIGURE 2.12: Causal Loop Diagram of the reproduction model

It is worth examining another feedback mechanism in the third equation. It is a negative feedback loop to enhance stability within this system. If the actual growth rate of output surpasses the accumulation rate, αr , the provision of new loans are ceased. There are central authorities whose goal is to stabilize the economy. However, the adjustment process also has its time delays that are a key to open a more complex world. If the time delay to adjust the equilibrium gap of growth is shortened, the growth rate of output has largely fluctuated. This result is an irony because the time delay is shortened as monetary policymakers strongly response to stabilize an economy.

This structure with multiple loops is a critical mechanism for representing the permanent irregular and unpredictable fluctuations of the growth rate in the economy. At this moment, the growth of output, the trajectory of the growth

(a) The movements of u (b) The phase space of u and v 

(c) The growth of output level in the Expanded Reproduction

FIGURE 2.13: Expanded Reproduction with the chaotic motion(System dynamic modeling): $a = 0.7, b = 0.3, \epsilon = 5, \nu = 5.3, \zeta = 0.025, \rho = 0.675, u_d^t u_0 = 0.01, v_0 = 0, m_0 = 0.03$

rates, and the phase space between the growth rates of output and inventory can be reproduced by system dynamics approach (Figure 2.13).

2.3 Discussion

The dynamic model with Rössler attractor represents irregular and permanent movements of a time series. However, the Goodwin model with the attractor is less convincing because he represents the model on the level-dimension. Thus, it is reconstructed on the growth-rate-dimension; it is translated into the Marxian Reproduction Scheme with time delays. On the growth-rate-dimension, the large-scale fluctuation in the system, which was the most unconvincing aspect of the Goodwin model in the light of the economic reality, can be explained. Above all, the time delays in each feedback node are a crucial factor in generating chaotic motion in this system. Within a certain range of each time delay, it can

transit from certain stable states to chaotic movements through a bifurcation process.

To build the model on the growth-rate-dimension however, we assume target values in decision making as actual values in the previous period. However, the target values need to be given as exogenous constants because they would depend on a techno-organizational structure in the economy.

This study suggests that the realistic irregular movements of the growth rate can be represented by not exogenous shocks outside the system but endogenous interactions within the system. Reproduction Scheme constitutes an example of the endogenous business cycle modeling, which is more improved than the G-M model in the light of the economic reality.

Chapter 3

Management Progress and Business Cycles

3.1 Introduction

The stock management problem, which is often called the supply chains structure, is one of the representative research subjects in system dynamics. The framework of the supply chains consists of: the stock and flow structures for the acquisition of inputs to the process; management policies governing the various flows ([Sternan 2000](#): 663). Therefore, this approach allows us to specify the production behavior and distribution mechanism and to make it possible to transit from micro behaviors of firms to macro dynamics. However, the supply chain study of system dynamics has not taken account of the financial mechanisms and macro policies. It is necessary to include financial behaviors and monetary controls of central authorities because it is one of the important factors affecting the macroeconomic system's (in)stability.

The stock management problem takes into account two parts of feedback mechanisms: positive and negative feedback mechanism. The positive feedback mechanism is a self-reinforcing behavior whose goal achieves a higher level than before. If there are managers in an organization which has to take this type of behavior, they always invest more inputs when the actual product goes over

their targets. They may not have any targets—an exponential growth with a constant growth rate. Secondly, the negative feedback loop is a kind of goal seeking process. It is a very ordinary case in everyday life, such as to fill a cup of water as much as you want or to adjust a degree of water to the desired level to take a shower. Moreover, there is a combination of these feedback loops. These processes are fundamental behavioral patterns of system dynamics of which an endogenous connection builds the Macro Stock Management Model in this study.

These feedback loops or the combination among them can be constituted as a learning process with bounded rationality in which managers in the private or public sphere make a decision with not global but local information. In other words, it is impossible for them to know the structure as a whole economy; whereas they have their target that is suitable for their objects. Thus, this bounded rationality makes it possible to set different targets among the managers, in particular between the private and public managers.

Section 3.3 contributes to the exploration of the feedback mechanisms; it is devoted to the construction of a primary system of equations for the Macro Stock Management model with behaviors of financial sectors and central authorities for macro stability. This system allows us to represent patterns of general activities in macroeconomy in Section 3.4, in which we give body to a sudden collapse of those activities, *Crisis*, by changes in coefficient values. At the conclusion, a microfoundation of the Macro Stock Management Model is revisited, and a classification of business cycles over time horizons by the Macro Stock Management model is discussed.

3.2 Basic Feedback Mechanisms and the Stock Management Problem

In Section 3.2.1, feedback mechanisms or thinking in system dynamics are suggested: It is a necessary process in order to understand the stock management problem of the next section, which provides a microfoundation of the Macro

Stock Management Model, which includes financial activities and behavior of central authorities that seek to control the economy for the stability.

3.2.1 Basic Feedback Mechanisms

Many people tend to think linearly—from problem-as-event to solution-as-fix (Forrester 2009: 5; Morecroft 2010: 16). For example, when being faced with a traffic jam, we are certainly sure that its solution is to build bigger and better roads. However, these new roads will be attractive to drive, and the congestion would not be thus relieved ultimately (Morecroft 2010: 27). This problem results from a myopic perspective that just focuses on the event-by-event rather a structure as a whole.

In feedback mechanisms, problems and solutions coexist in a loop, and thus they are independent of each other (Morecroft 2010; 28). People in the feedback loop found a discrepancy from their goal in a certain situation. They make a decision to solve the gap, and the resultant circumstance leads to a next situation that they are faced with. In addition to this process, there is a time delay to achieve goals. Morecroft(2010: 33-34) suggested three labels relating to the lags: ideal, common sense, most likely. In the ideal world, we might accomplish our goal instantly, but common sense says that it is hard to happen. It would be smoothly accomplished in the common sense world but, in the real world, it is unlikely to occur. Instead, what is most likely to happen is a trial and error process, that is, an oscillated course to arrive at a target.

First of all, the feedback mechanism can be divided into two types of typical patterns: a positive feedback and negative feedback. Positive feedback means a self-reinforcing process like an exponential growth form a positive link among elements. In the economic theory, this feedback effect was translated into an accelerator; for example, there may be a self-reinforcing behaviors of the private banking system because larger private banking loans cause more earning of banks if they not only play a role of intermediaries between available funds but are an institution that pursues its interests as Minsky said (Minsky 1986: 218-220; Keen 1995 : 611-14; Duménil and Lévy 2012a : 196-197). Second, it is also worth examining a negative feedback process, which is one of the most

important factors when we are studying in dynamics. It is the goal-seeking behavior where *agents seek balance, equilibrium and stasis* and this behavior leads to correcting action. (Sterman 2000: 111) More important aspect of this behavioral pattern can be included time delays in the process. The negative feedback loop with time delays causes fluctuating trajectories around the target value because the eigenvalues are changed into the complex conjugates by adding the delays (Sterman 2000: 23).

3.2.2 The Stock Management Problem

The stock management problem is a major area of interests within the field of system dynamics. This method helps us to deal with the supply line, determination of demand level, and macro policy at the same time. First of all, management progress is deeply related to the time delay problem. To understand the managerial process, the stock management problem, which has been widely discussed in management science, is also be introduced. This study may provide an opportunity to advance our understanding of business cycles with time delays in an economy.

The stock management problem is associated with managers' efforts to achieve their target or desired rate in a given business circumstance. As Sterman(1988: 149) noted, 'the generic stock management control problem may be divided into two parts:(1) the stock and flow structure of the system; and (2) the decision rule used by the manager'. Therefore, the following statements was prepared according to the procedure used by Sterman.(Sterman 1988:149-155; Sterman 1989: 322-326; Sterman 2000: 666-684)

$$S_t = \int_{t_0}^t (A_\tau - L_\tau) d\tau + S_{t_0} \quad (3.1)$$

where 'S is the accumulation of the acquisition rate, A, less the loss rate L' (Sterman 1988: 149). Thus, Equation 3.1 can be translated into the differential

equation form between inventory ratio, s , demand, $d = au$, and the capacity utilization rate, u ¹

$$\dot{s} = u - au + e_t, e_t \sim \mathcal{N}(0, \sigma^2) \quad (3.2)$$

where a is the expenditure propensity of firms and consumers. And exogenous shock, e with mean and variance, $0, \sigma^2$ is included in the equation, additionally. Now, decisions rules have to be defined. Managers are available to use local information because they have *bounded rationality*. That is, 'it does not presume that the manager has global knowledge of the structure of the system' and this is coincident with 'the behavioral foundations of system dynamics modeling' (Sterman 1988: 151). The acquisition rate depends on the supply line, SL .

$$SL_t = \int_{t_0}^t (O_\tau - A_\tau) + SL_{t_0} \quad (3.3)$$

where O is the order rate. Thus, the supply line is an integration of the order rate minus the acquisition rate. In this stock management problem, the order rate depends on a gap between the target rate, \bar{s} , and actual rate, s , of inventory; a time delay, ν , as follows.

$$O_t = f(s; \bar{s}, \nu) \quad (3.4)$$

Likewise, the acquisition rate is a function of the target capacity utilization rate, \bar{u} , actual capacity utilization rate, u , and time delay, ϵ .

$$A_t = g(u; \bar{u}, \epsilon) \quad (3.5)$$

If Equation 3.4 and 3.5 linearize around the targets, Equation 3.3 can be transformed into the differential equation.

¹All variables in small letters refer to a ratio of capital stock which is supposed as 1 in this section, unless specifically noted.

$$\dot{u} = -\frac{\partial f}{\partial u}(u - \bar{u}) - \frac{\partial g}{\partial s}(s - \bar{s}) \quad (3.6)$$

where $\partial f / \partial u$, and $\partial g / \partial s$ are adjustment speed coefficients of the order and acquisition, respectively. Thus, they can be translated into the inverse of the time delays: $\partial f / \partial u = 1/\epsilon$; $\partial g / \partial s = 1/\nu$. In Equation 3.6, the negative signs mean a goal seeking pattern, that is, the negative feedback mechanism. Although the target values may be variables, we assume the targets remain constant during a period because, even in the long run, they are seldom changed in the real economic world. After all, the discrepancies of production and inventory ratios are divided by each of the coefficients, ϵ and ν , which refers to *time delays* to adjust each of the gaps. The existence of time delays is a crucial factor that makes a difference from other models developed from the Metzlerian line. They have identified the coefficients as the adjustment speed in the studies of the Metzler model (Franke and Lux 1993; Franke 1996 ; Matsumoto 1998). However, our terminology may be better than that because the coefficient symbolize not only *constraints* but *costs* needed to gather information or resources.

In the financial mechanism, the order rate is proportional to the additional demand of the private sector such as firms or consumers, which is perceived by discrepancies of the capacity utilization rate. Thus, it is a positive feedback mechanism. This type of positive feedback may be regulated by a target adjustment behavior of the public management, such as the macro policy of the central authorities. The financial mechanism in the macroeconomy can be described by using Equation 3.3 as follows.

$$\dot{m} = (\rho(u - \bar{u}) - \frac{1}{\zeta}(u - \tilde{u}))m \quad (3.7)$$

where m , \tilde{u} is real money balance and the target capacity utilization rate of policies, and thus, \dot{m} can be translated into new loans or credits: the reaction coefficient of the private financial mechanism and the time delays of the macro policy are ρ and ζ , respectively. Thus, this equation is composed of the credit supply by private financial institutions and the macro policy by public management or central institutions. Since the production ratio that is greater than the

target leads to the additional demand of purchasing consumption and capital goods for consumers and producers, the financial system may inject more credit but how much quantity of credit is provided depends on, ρ , which is a reaction coefficient of the private financial mechanism. The public management behavior should be described by a negative feedback mechanism corresponding to the discrepancy between the actual and the target. However, it may be reasonable that the firms and central authority have different values of the target. As this equation being introduced, Equation 3.2 is transformed into $\dot{s} = u - au - bm$.

$$\dot{u} = -\frac{1}{\epsilon}(u - \bar{u}) - \frac{1}{\nu}(s - \bar{s}) \quad (3.8)$$

$$\dot{s} = u - au - bm + e_t, e_t \sim \mathcal{N}(0, \sigma^2) \quad (3.9)$$

$$\dot{m} = (\rho(u - \bar{u}) - \frac{1}{\zeta}(u - \tilde{u}))m \quad (3.10)$$

like the general stock management problems, this system is also constructed with three decision rules. '(1) [to] replace expected losses from the stock (2) [to] reduce the discrepancy, and (3) [to] maintain an adequate supply line of unfilled orders' (Sterman 1988: 151). Managers in production not only give orders enough to replace the loss but also have to minimize their costs by reducing the discrepancy. These performances are accomplished by maintaining the supply line. Furthermore, managers in financial institutions seek to maximize their profits in the positive feedback mechanism, and public managers in central authorities try to stabilize the system with their target in the negative feedback mechanism.

Consequently, the oscillating pattern of business cycles in the real economy proves the existence of the time delays in an economy; whereas no fluctuations if no time delay or perception gap. Therefore, the public and private management progress depend on how we treat the time lags and bounded rationality. It is easy to find the evidence about this problem in management, such as JIT (Just-In-Time) production method of Toyota Motors (McConnell and Perez-Quiros

2000)² or cases of policy resistance (Sterman 2000: 7-12).

3.2.3 Business cycles in the MSMM

Now we represent business cycles in the real world using the Macro Stock Management Model (MSMM), which is a variant of the N-G-M model on the change-rate dimension in Chapter 2. The stability of the MSMM depends on the time delays of the supply line, ϵ and policy performance, ζ , and the monetary reaction parameter, ρ .

Figure 3.1 illustrates the monthly data series of the utilization rate in the Korean Economy between 1990 and 2014. It leads to three observations. 1) The rate of capacity utilization in the Korean economy has been stabilized around the target or normal rate for economic activities in the long term, 2) There have been its significant wave movements in the midterm, 3) and disturbances in the short-term. Besides, there are two deep valleys during the observation period. Thus, this means the stock management mechanism that may lie in hiding behind the background of the profile is a damped oscillating system within the stability frontier or may be being progressed toward the direction that ensures stability. That is, this system is *locally stable* in the long term. Second, the mid-term fluctuation can be caused by not stabilizing factors or the target values but destabilizing factors, such as the private financial reaction parameter. Third, there is short-term noise like stochastic exogenous shocks. Nevertheless, the randomness cannot displace deterministic trajectories but only means that it refers to omitted variables or the change in the parameters.³

The Figure 3.2a shows the local stability of the MSMM with $\epsilon = 0.9$, $\nu = 5.75$, $a = 0.7$, $b = 0.3$, $\rho = 0.025$, $\zeta = 1.275$ without demand shocks.⁴ A possible evolution of the financial reaction coefficient, which displays a steady upward trend of u started from the period 75 in the subfigure (d), is illustrated in Figure 3.2b. If this trend collapses suddenly around the period 150 like Figure 3.2b and,

²McConnell and Perez-Quiros argued improvement of management methods resulted in the reduction of the volatility of output in the US economy in the 1990s (McConnell and Perez-Quiros 2000; Romer 2010: 644)

³Concerning the stability analysis of the MSMM, see Appendix B.

⁴See Appendix D about the computer simulation codes.

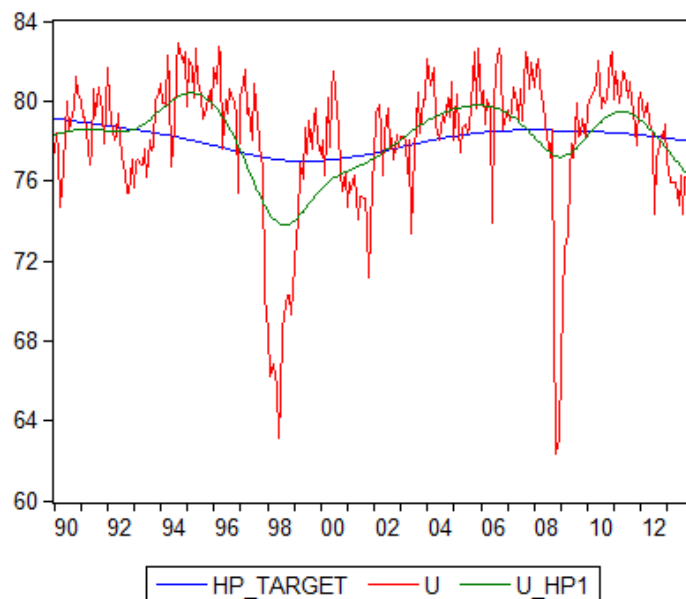


FIGURE 3.1: The capacity utilization rate in the Korean economy(1990:1-2014:1), Monthly data, Statistics Korea, <http://kostat.go.kr>, u: actual utilization rate, hptarget: Hodrick-Prescott coefficient, 1440000, u-hp1: Hodrick-Prescott coefficient, 14400

at the same time, the time delay has a sudden rise as the firms face with the financial and time delay constraints that we just labeled above. Although this unexpected shock dissipated, there remains some large fluctuation during the certain period following the *Crisis*. Particularly, this type of economic process has an analogy with the second valley in Figure 3.1. In this way, the MSMM can be demonstrated to have potential to represent the patterns of business cycles in the real economy that Figure 3.1 has ever shown.

As shown in Figure 3.3, the *very* short term noise does not influence the overall trajectories of the MSMM. At least in this model, however, the sudden collapse of the general level of economic activity is not the consequence of a deficiency of demand because there is no persistent sharp endogenous decrease in demand independent of other economic variables in this model. Rather, dramatical changes of managerial and financial behavior result in a sharp reduction in demand level. In the same manner, the stochastic demand shocks cannot be

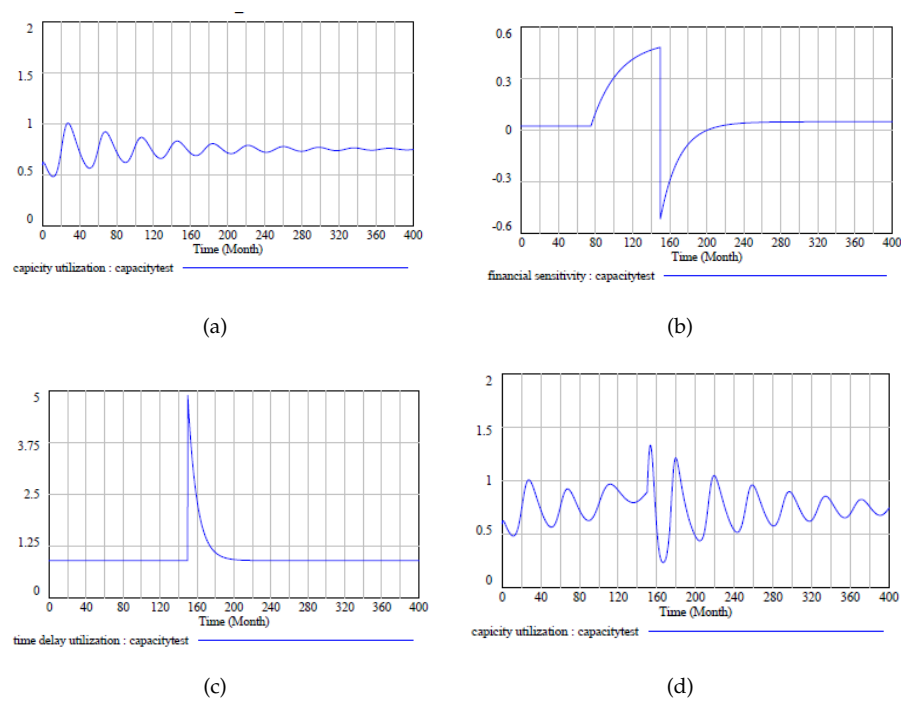


FIGURE 3.2: A set of four subfigures: (a) The local stability of the MSMM; (b) The evolution of the financial sensitivity; (c) The adjustment speed (time delays) to the utilization discrepancy; and, (d) The sudden collapse and recovery of the MSMM.

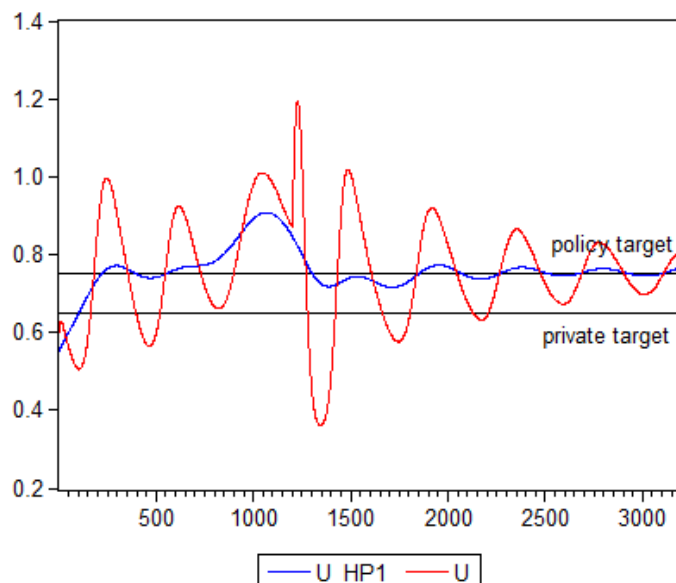
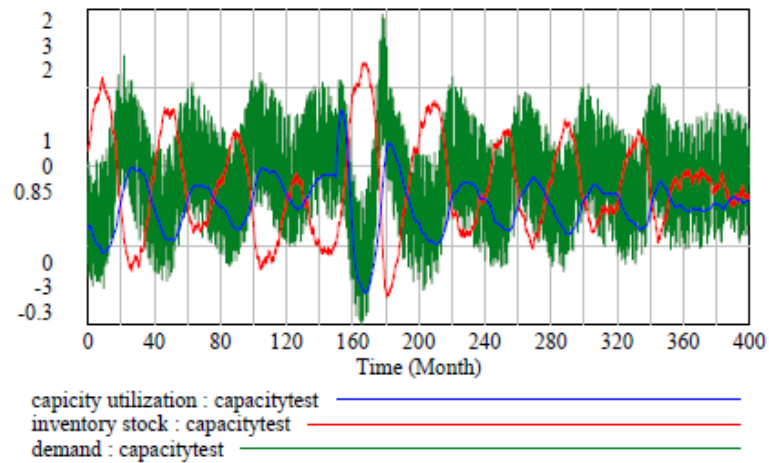


FIGURE 3.3: The MSMM with exogenous shocks

FIGURE 3.4: The trajectories of u , s , and d

the cause of the collapse, because the sequential shocks enough to be the cause of crises is impossible; it can be regarded as noise otherwise. As can be seen in Figure 3.4, a rise in demand level followed by the collapse leads to a sharp recovery of the utilization rate in the period. This effect stems from a role of the public finance to adjust a discrepancy between the actual and target values. In Figure 3.5, the reduction in the private finance is compensated through the provision of the public finance. An intersection between the private and public finance in Figure 3.5 stems from the existence of time delays in the policy performance, ζ .

Consequently, the (periodic) evolution of financial sensitivity could play a crucial role in this performance. This observation suggests that there may be a link between the evolution process and the progress of the financial management. When this coefficient is increasing, consumers and firms may be able to fulfill an additional requirement for further consumption or investment more quickly. This fact refers to an ability to provide their clients a loan in financial institutions is increasing whatever channels related to the process are: financial deregulation; development of financial operation methods. Furthermore, the managerial progress is combined with the self-reinforcing feedback mechanism, which is not a goal seeking feedback but an unlimited positive feedback. However, the perpetual growth(or negative growth) of the reaction degree is not possible in the real world—in the MSMM, if it is possible, the model is going to enter the

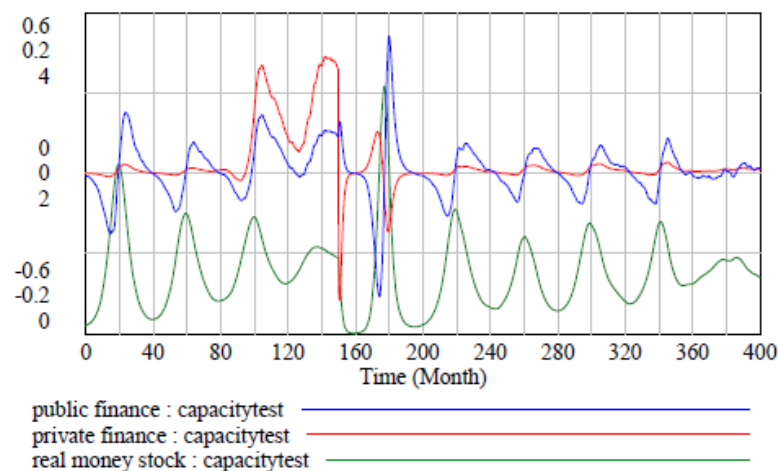


FIGURE 3.5: Movements of Real Money balance: public finance and private finance

unstable state, which contradicts with the local stability of the system. Thus, the evolution of the financial sensitivity can be probably reconstructed into the endogenous progress like S-shape growth with carrying capacity but is given exogenously in this research only for representing the dip of the general level of economic activity.

3.3 Discussion

3.3.1 Microfoundation of the MSMM Model

The persistent movements of business cycles in the MSMM do not originate in insufficient demand levels or exogenous shocks⁵ but the time delays of firms or financial system or their perception gap. The microfoundation of Equation (3.7) has been well known by [Holt et al.](#) et al. (1960), [Blinder](#) (1982). Moreover, [Thompson and Sethi](#) (1980) completely solved this type of problem using the popular optimal control theory and [Duménil and Lévy](#) (1990) also developed

⁵We do not exclude the exogenous shocks systematically as already mentioned.

this microfoudation setting in the discrete time dimension.⁶

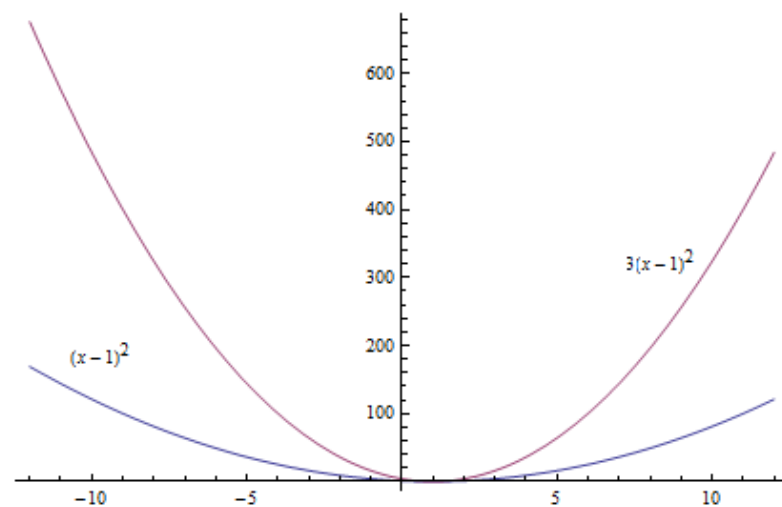
The coefficients of the behavior equations are connected with the penalty cost of holding inventories and backlogs. In general, a large gap between the actual and target increases the cost, because the cost function has the symmetric quadratic form, for example $C(x) = a(1/2)(x - \bar{x})^2$, as well as the larger a allows it to reach at the larger penalty cost much faster than before (Figure 8). Likewise, increasing the time delay augments the costs, and it is a circumstance that the economic agents cannot avoid because of the constraint of resources and information.

These behaviors of firms, in fact, can be described as the goal seeking feedback mechanism forming a negative loop with the time delay. However, the financial system has a combination of positive and negative feedback patterns. The private finance, by such as banks, have a positive reaction to additional requirement from firms or individuals if the actual output rises over the target, which is the self-reinforcing pattern but, from the point of view of public managers, namely policymakers, will have to exert a counteractive force needed to achieve their goal, the policy target, in order to stabilize the economy contrary to the private banking behaviors. As shown above, we assume there is a discrepancy between the targets of the private and the public, $u_d^t > 0$, permanently because the economy does not grow at any rate without this assumption although the discrepancy may disappear in a certain period. If they aim to a higher growth rate, it will allow them a larger discrepancy.⁷

There is also a time delay in the macro policy, which means an attitude taken by the central authorities. If they have a tight position to cope with the gap, the time delay may become shorter. And this speed can reflect their confidence in an ability to achieve their object. Thus, this behavior can be explained as a sensitivity of the monetary authorities and when this sensitivity is rising, the

⁶On the other hand, It is easy to find the studies about the Metzlerian line of business cycles related to the inventory management. Lorenz(1993) gave a comprehensive explanation of the business cycle model in a continuous time formulation developed by Gandolfo. Regarding the relation between cyclic patterns of the cycles and parameters, we can refer to Franke and Lux(1993), and Franke 1996. Furthermore, Chiarella et al. et al. (2005) expanded the model to include macroeconomic policies.

⁷The target value of the private behavior cannot be recognized by the policymakers *a priori*. Furthermore, we assume they establish little bigger target than the private manager for maximizing employment.

FIGURE 3.6: Examples of cost function, $(x - 1)^2, 3(x - 1)^2$

time lags will be decreased (Duménil and Lévy 1996: 158-159).

3.3.2 The MSMM over time horizons

As shown above, the MSMM is classified as four movements on the distinct time horizons (Figure 3.3) **In the very short term**, there are *noises* on the overall trajectory with normal distribution (mean: 0, standard deviation: 1, minimum: -0.5, maximum: 0.5). These exogenous shocks have no influence on the pattern of business cycles. However, it is also possible to generate big demand shocks from the outside, such as a sudden contraction of export sector depending on economic circumstances in the rest of the world. Nevertheless, those events are not only totally different from the noises like the *i.i.d.* shock in the very short term but also should be evaluated with the other factors, namely, other variables or effects on the coefficients of finance and production. 2) **In the short term**, it is *the quantity adjustments* to be crucial. The economic agents in the stock management problem adjust their quantities to minimize their costs and maximize the profits. Likewise, the public managers do their best to avoid rapid growth of inflation or deflation and significant unemployment. 3) Under the condition of the constant progress in management, the financial sensitivity is the important parameter for stability **in the mid-term**. As mentioned above, it

is very likely to happen because the parameter is related to the self-reinforced mechanism. 4) This system has a *local stability in the long term*. If the system had been unstable, the trajectory of the capacity utilization rate couldn't have been illustrated as above. Moreover, it provided information that the sudden change in the parameter is adjusted toward values within the local stability rapidly or smoothly at least up to date. The result of this study indicates that *nonlinearities* or periodic movements of financial sensitivity should be included in the business cycle studies (See Chapter 4).

3.3.3 The MSMM with External Shocks

In Figure 3.1, it is reasonable for the Korean Economy to be affected by exogenous shocks from the rest of the world, since the country's economy has strongly depended on the global economy. In particular, the two severe economic recessions are related to two big external shocks; Foreign Exchange Crisis in 1997; Subprime Crisis in 2008. These facts mean that we cannot overlook these significant events from the outside of economies due to the existence of the crucial factors that result in a sudden and drastic change in parameters. This problem can solve if we take account of them as endogenous variables or nonlinearities in the model. Before studying these effects, however, we have to establish or represent results of a possible intersection between the parameters or time delays over time, that is, their cyclic movements in the system in more detail. In the next section, periodic movements of parameters, which are called *Love affairs between management and finance*, are thus inserted in the system. This is not a rule but hypothesis about a relationship between them for studying "real" business cycle movements with persistence and irregularity in a locally stable system.

Chapter 4

Managerial Progress and Financial Sensitivity with Macro Instability

4.1 Introduction

Finance has a dual character for the macroeconomy. On the one hand, it is one of the important factors to stabilize the MSMM model. However, the private financial institutions such as commercial banks holding their interests to maximize their profits positively respond to demand of households. Thus, on the other hand, they can be a destabilizing factor in economies. Hyman P. Minsky has well defined this destabilizing aspect of the financial sector. Robert Polin said,

For Minsky, the key to understanding financial instability is to trace the shifts that occur in investors' psychology as the economy moves out of a period of crisis and recession (or depression) and into a phase of rising profits and growth. Coming out of a crisis, investors will tend to be cautious, since many of them will have been clobbered during the just-ended recession. For example, they will hold large cash reserves as a cushion to protect against future crises. But as the economy emerges from its slump and profits rise, investors' expectations become increasingly positive. They become eager to pursue risky ideas such as securitized subprime mortgage loans. They also

become more willing to let their cash reserves dwindle, since idle cash earns no profits, while purchasing speculative vehicles like sub-prime mortgage securities that can produce returns of 10 percent or higher.

But these moves also mean that investors are weakening their defenses against the next downturn. This is why, in Minsky's view, economic upswings, proceeding without regulations, inevitably encourage speculative excesses in which financial bubbles emerge. Minsky explained that in an unregulated environment, the only way to stop bubbles is to let them burst. Financial markets then fall into a crisis, and a recession or depression ensues ([Polin 2008](#): 6).

Therefore, the financial sensitivity should be considered as not a fixed parameter but a variable over time. For this reason, additional nonlinearities are needed but even Minsky 'does not perform the task' ([Duménil and Lévy 2012a](#): 197). The expectation of investors or a certain degree of the financial deregulation (or financial liberalization) may be reflected in levels of the sensitivity. Gérard Duménil and Dominique Lévy described an interrelation between them as studying the management progress of the U.S. economy at the beginning of 20th century, and after the 1980s ([Duménil and Lévy 2011](#); [2014](#)).

In this chapter, we introduce a relationship between management and finance into the MSMM. To do so, we describe it from a historical perspective in Section 4.2. Not only Minsky's Keynesian view but Alfred Chandler's historical research of the growth of big American enterprises in management science helps to find the interrelation between the management progress and financial development. In Section 3.3, we build a model based on the discussion of Section 3.2. To establish the mutual relations, we borrow a *Love affairs* analogy for explaining the stability of the linear differential equation system from mathematical science. And a new model including the management progress and financial sensitivity is suggested in Section 3.3.2. Because this model is composed of five equations and variables, so very hard to analyze its dynamic properties, it is performed by the help of the system dynamics modeling. Lastly, we conclude that the quotidian business cycles or even severe economic recession and depression can

be represented not by exogenous shocks or Markov processes but by endogenous changes of variables, in particular, relating to the financial sensitivity and management progress in a deterministic way.

4.2 Management and Financial Progress from a Historical Perspective

As Minsky said, the capitalist economy is fundamentally a monetary (or financial) economy ([Mehrling 1999](#): 139). Besides a more or less one-sided version of finance in the mainstream economics, there is, however, a dual opinion about it in economics, particularly, in Keynesian economics. Minsky suggested that 'a financially robust environment' makes it possible to achieve a higher level of investment. This 'leads to an increase in profits, which then creates expectations of future increased profits' ([Orhangazi 2011](#) : 5). As a result, this is the positive feedback mechanism to business situations that 'could be self-reinforcing' ([Orhangazi 2011](#) : 5). Nevertheless, this force could cause the bubble-burst movements and even lead to more severer economic depression than a previous one, as Polin said above. Thus, a recent economic boom may be the cause of the next economic recession.

Likewise, management progress can perform the formation of techno-organizational *capability* that allows business to have access to the profitable opportunities ([Teece 2010](#) : 303; [Lazonick 2010](#) : 318-319), and finance stimulate it. Alfred Chandler described a historical process related to the rise of the large-scale enterprises in the American industries (citealtO'Sullivan:2010: 560-572). The establishment of the big firms accompanied not only the transformation of the characteristic features in the capitalist ownership—the separation between the ownership and management (the corporate revolution) and the development of large banks and the financial instruments (the financial revolution)—but also the progress of management. This is the three revolution—the corporate revolution, management revolution, and financial revolution—that emerged in the U.S. economy from the late of the 19th century to the very beginning of 20th century ([Duménil and Lévy 2011](#) : 12-13; [Duménil and Lévy 2014](#) : 33-34; See Chapter 1).

In another side of the relationship, the development of finance may threaten the management progress, although the former feeds the latter with funds that the firms could innovate and enlarge their units. This aspect of finance echoes a perspective of the Chandlerian as well as Keynesian economics. Finance is indispensable for the management progress of which self-reinforcing force has a negative effect on the enterprises' performance. Particularly, 'Chandler didn't see changes of ownership as inherently good or bad' but 'where decisions and actions have been motivated by the desire to obtain . . . profits based solely on the transactions involved in the buying or selling of companies . . . they appear to have reduced and even destroyed the capabilities essential to compete' (Chandler 1990 : 627). Thus, in the financialization of the large enterprise, Chandler saw a potential source of the decline in the U.S. economy (Teece 2010 : 312). Before the Great Depression in the 1930s, there was a heterogeneity in the US economy—a separation between the large-scale and innovative firms backed by the big finance and old-fashioned firms supported by a legal protection, such as the Sherman Act of 1890—'When the recession began in 1929, the backward sector was all set to fall, and its collapse added to the cumulative contraction of output' (Duménil and Lévy 2011 : 272). That is, management progress is raised by the financial investment, but an over-reaction of finance to the business circumstance, such as an expansion of speculative behaviors, leads to economic instability.

From these facts, however, we can expect a nonlinear relation with a feedback mechanism rather than a linear relation. To study this mechanism, a model between management progress and financial sensitivity will be introduced in the next section. The management progress and financial sensitivity refer to a change in parameters relating to them rather a change in the level of production and credit flows.

4.3 Management Progress and Financial Sensitivity in Love-Affairs

In this section, we present a mathematical modeling of the interrelation between management progress and financial sensitivity. A possibility by which financial sensitivity can be changed is given through various pipelines, such as an increase in financial propensity to confirm additional funding requests of firms and households, which are amplified by financial deregulation. If financial sensitivity is decreasing, managers have no choice but to be confronted with a financial constraint and corresponding technical difficulty to perform their tasks or corresponding to a reduction in demand. Due to describe this "tragic" story between management and finance, an analogical model from mathematics is introduced. This model is a love-affairs one between Romeo and Juliet presented by Steven Strogatz (1988; 1994a: 138-139) at Department of Mathematics, Cornell University. In Section 3.3.2, this model will be transformed into an interrelation model between management progress and financial sensitivity.

4.3.1 Love Affairs between Romeo and Juliet

Strogatz introduced 'a simple model for the dynamics of love affairs' to classify linear differential equation systems (Strogatz 1988 ; 1994a : 138-139).

Romeo is in love with Juliet, but in our version of this story, Juliet is a fickle lover. The more Romeo loves her; the more Juliet wants to run away and hide. But when Romeo gets discouraged and back off, Juliet begins to find him strangely attractive. Romeo, on the other hand, tends to echo her: he warms up when she loves him, and grows cold when she hates him (Strogatz 1994a 1994: 138).

The love affairs between Romeo and Juliet can be represented in a matrix form as follows. Let $R(t)$, $J(t)$ be Romeo and Juliet's love, respectively.

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x}$$

where

$$\mathbf{A} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}, \mathbf{x} = \begin{pmatrix} R \\ J \end{pmatrix}$$

The fixed point of this system, $(R^*, J^*) = (0, 0)$. Otherwise,

$$\mathbf{x} = \begin{pmatrix} R - R^* \\ J - J^* \end{pmatrix} \quad (4.1)$$

where R^* and J^* are the non-zero fixed point. If $b > 0, c < 0$, it is a 'star-crossed romance' (Strogatz 1994a: 138). Stability of this system depends on the trace of the matrix \mathbf{A} , $tr(\mathbf{A}) = a + b$. If $tr(\mathbf{A}) = 0$, the system has a closed orbit because the characteristic roots are a pair of pure imaginary. Thus, simultaneous love between them is achieved during one-quarter of the time (Strogatz 1994a : 138). Furthermore, the initial values lie in the boundary frontier of the orbit because the trajectory between their love (or hate) draw a circle on the phase plane. There is not the case of the *saddle* that strongly depends on the initial values if Juliet maintains her first attitude —she was a fickle lover. This characteristic feature of the system makes it easier to handle to represent the relation between them.

It is worth examining other combinations of the coefficients. In this linear system, we can classify Romeo's attitude as an 'eager beaver' or 'cautious lover' according to whether a is positive or not. If $a > 0, b > 0$, Romeo is the eager beaver because his love will constantly grow though Juliet does not love him. If $a < 0$, he is the cautious lover. He loves her only if she loves him. Consequently, we can suppose that there is a kind of *regime* that make a pattern between their love. If, moreover, they had not lived an ephemeral life, their affection for each other should have little by little changed. By the column vector (4.1), this system represents not only an indifferent-with-each other regime, $(R^*, J^*) = (0, 0)$, but attractive-with-each other regime, $(R^* > 0, J^* > 0)$

4.3.2 Management Progress and Financial Sensitivity

In this section, we translate the love affairs between Romeo and Juliet into an economic phenomenon between management progress and financial sensitivity. However, it is difficult to determine the relationship *a priori*; for example, is management Romeo or the fickle lover? Instead, it is possible to classify this system as various types of regimes. In this section, four regimes are presented: If management is a cautious lover or an eager beaver (Romeo), Juliet is finance; If Romeo is finance, Juliet is management. As a result, this relationship is not a rule but an analogy for representing the periodic sudden collapses of economic activities.

To do this, we transform the Romeo-Juliet system on the space between management progress and finance sensitivity as follows.

$$\dot{M} = \theta(M - M^*) + \iota(F - F^*) \quad (4.2)$$

$$\dot{F} = \kappa(M - M^*) + \zeta(F - F^*) \quad (4.3)$$

As above, this system has four feedback mechanisms. M and F refer to the management progress (the inverse of time delay to adjust production and inventory discrepancy) and financial sensitivity in MSMM; M^* and F^* are average values of management progress and financial sensitivity. Thus, both M^* and $F^* > 0$ —but, for the case of the financial sensitivity, the actual level might be a negative, $F < 0$, which is also consistent with the negative and positive feedback mechanisms in production and finance of MSMM. Coefficients, $\theta, \iota, \kappa, \zeta$, which can be translated into the time delays to adjust discrepancies of each feedback in the system, may have different signs according to each regime. θ is the growth rate of management progress, and ι is the dependency rate of management on finance. On the other hand, κ is the dependency rate of financial sensitivity on management and ζ is the self-reinforcing rate of financial sensitivity. As above, the four cases can be classified: the two regimes with two different attitudes of either management or finance.

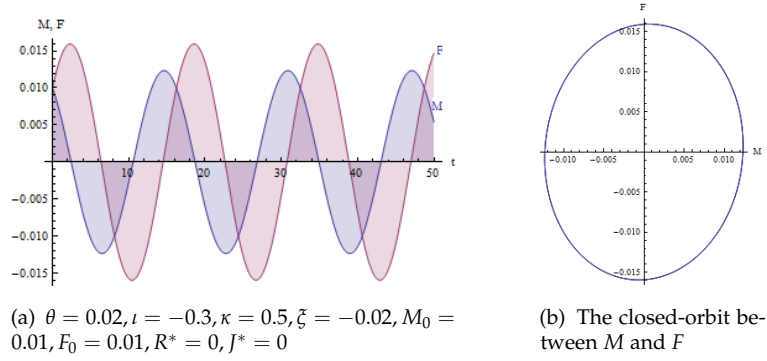


FIGURE 4.1: Management-led Regime

Management-led Regime. Finance is Romeo, and Juliet is *management*: $\iota < 0$; $\kappa > 0$. The closed-orbit between M and F is generated if $\theta, \xi = 0$ or they have a same common value with opposite signs. If finance is thus the eager beaver, $\kappa > 0, \xi > 0$, the growth rate of management progress, θ , must be a negative sign. Otherwise, in order to ensure stability, $\xi < \theta$ with opposite signs or $\xi, \theta < 0$, and vice versa, if finance is the cautious lover, $\kappa > 0, \xi < 0$. As seen from Figure 4.1, movements of management may lead to fluctuations of financial sensitivity with large amplitude.

Finance-led Regime. Now, management is Romeo and *Finance* is Juliet. For management, finance's love that is their amicable funding to progress management is needed: $\iota > 0$; $\kappa < 0$. If management progress is the cautious lover, $\theta < 0, \iota > 0$, it means that the progress occurs only if there is financial support. Thus, if we assume that there is a constant growth rate of the progress, $\theta > 0$, finance decays towards its equilibrium point, J^* , exponentially, $\xi < 0$, without regard to the management progress. Overall, an excessive self-reinforcing rate in comparison to the growth rate of management progress makes the system as a whole unstable if the growth rate is positive.

A Simple Stability Analysis. For simplicity, let us suppose that $\theta = \xi$ and $\iota = \kappa$. To describe movements in the phase plane, the phase plane of M and F is transformed into the polar coordinates, r, ϕ . When it is a finance-led regime,

$$M = r \cos \phi \quad F = r \sin \phi \quad (4.4)$$

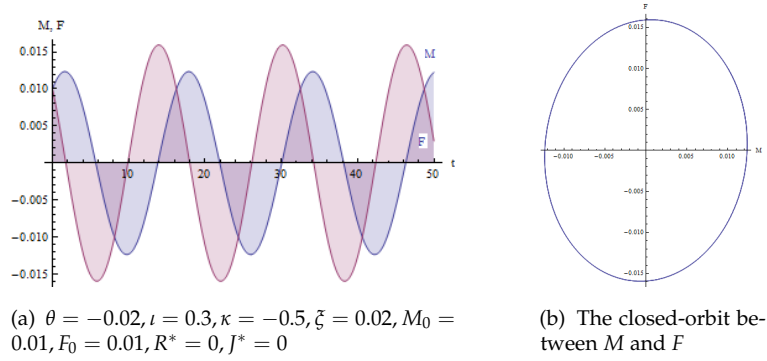


FIGURE 4.2: Finance-led Regime

Furthermore, $M^2 + F^2 = r^2$ and so $M\dot{M} + F\dot{F} = r\dot{r}$.

$$r\dot{r} = M(\theta M + \iota F) + F(-\iota M + \theta F) = \theta r^2$$

$$r^2\dot{\phi} = M\dot{F} - F\dot{M} = M(-\iota M + \theta F) - F(\theta M + \iota F) = -\iota r^2$$

Thus, $r = r_0 \exp -\theta(\phi - \phi_0)/\iota$. If $\theta = 0$ or $\theta + \zeta = 0$ when $\theta \neq \zeta$, the type of the fixed points is centre. The system is asymptotically stable if $\theta < 0$ or $\theta + \zeta < 0$, that is, the trace of a coefficient matrix is negative.

4.4 The MSMM Model with Management Progress and Financial Sensitivity

In Section 3.4.1, according to each regime using system dynamic modeling method, the feedback mechanisms between management and finance can be specified. Then, the new model is combined with the MSMM in Section 3.4.2. Finally, it reconstructs a good approximation to real movements of the capacity utilization rate in Section 3.4.3, and Section 3.4.4 contributes to policy implications in this modeling process.

4.4.1 Feedback Mechanism between Management Progress and Financial Sensitivity

The system of differential equations, (3.2) and (3.3), can be translated into a model with four feedback loops using system dynamics modeling. Thus, each coefficient in the system is translated into the time delays to adjust discrepancies.

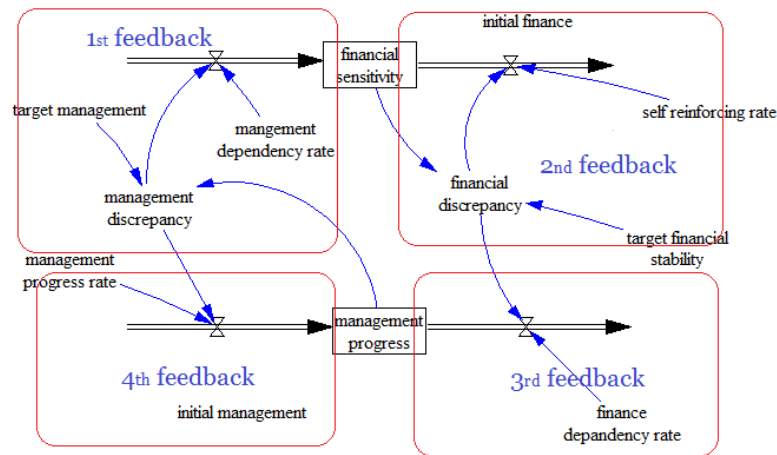


FIGURE 4.3: Feedback loops in the Relationship between Management and Finance

Management-led Regime. In this regime, the 1st and 3rd feedback mechanisms in Figure 4.3 must take forms of positive and negative feedbacks respectively. It assumes that the 2nd and 4th feedback mechanism have opposite signs with the same value to represent a periodicity of this relationship, but its stability is ensured if both of them have negative signs and a certain value of two is smaller than another negative one with an opposite sign.

Suppose a case that the 2nd feedback and 4th feedback have a negative and positive sign, respectively. In this case, management progress takes a form of the self-reinforcing feedback; it is improved in response to a gap between its actual levels and average capacity, namely the fixed point, M^* . On the contrary, finance has the goal-seeking behavior. Despite its dependency on management progress, finance also makes a decision responding to its discrepancies. The stability of this system can be ensured by a relation between the two coefficients of the 2nd and 4th feedback loop. As a result, management progress seeks to

avoid an excessive response of financial sensitivity.

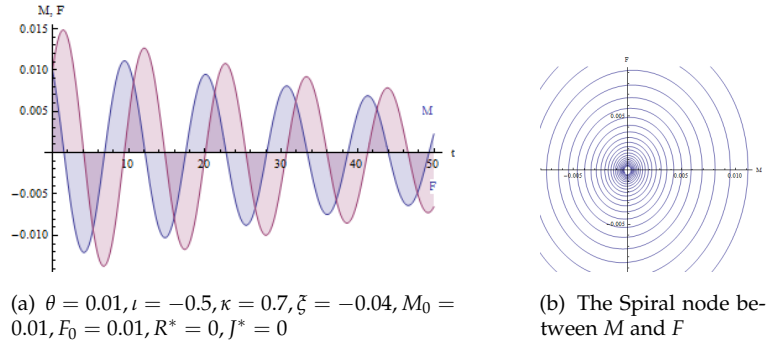


FIGURE 4.4: Stabilizing Process in Management-led Regime

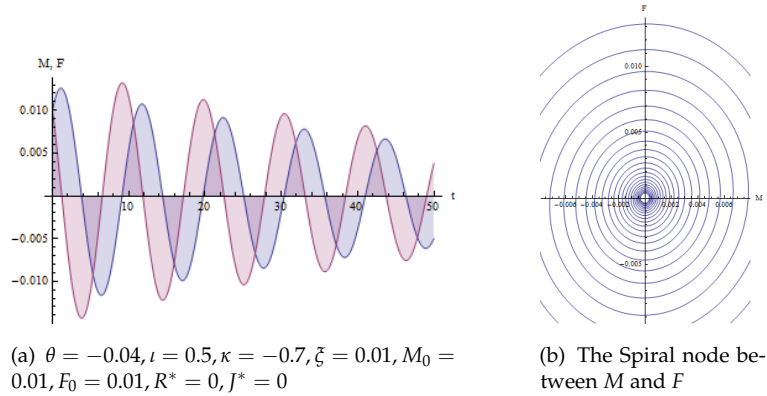


FIGURE 4.5: Stabilizing Process in Finance-led Regime

Finance-led Regime. As above, finance plays a crucial role to generate cyclical movements in this regime. Thus, management progress mainly depends on financial sensitivity, that is, the 3rd feedback mechanism has a positive sign, and 1st feedback mechanism of finance has a goal seeking loop with a time delay. The other mechanisms are same as the management-led regime. Contrary to the management-led regime, however, finance is afraid of a drastic growth of the management sector because it refers to greater autonomy of managers. Historically, as the autonomy was augmented, financial hegemony had ever been threatened.

La séparation de la propriété du capital et de la gestion, . . . , fut perçue comme un danger majeur. L'élément central était la conscience du

risque que la délégation des tâches de gestion faisait subir à la propriété capitaliste. Sorties, en quelque sorte, de la grande entreprise, les classes capitalistes s'exposaient à en perdre le contrôle. L'ouvrage le plus célèbre, aux États-Unis, sur ce thème est celui d'Adolf Berle et Gardiner Means, intitulé *La société moderne et la propriété privée* (1932) (Bidet and Duménil 2007: 75-76).

This is the reason why finance becomes the fickle lover for management as we mentioned above. By the way, if management entirely relies on finance, that is, the 4th feedback takes a negative form, the system will oscillate when the 3rd mechanism takes a positive feedback form. In the next section, the effects of these relationships on macro stability and business cycles will be presented.

4.4.2 The MSMM with a Periodic Relationship between Management Progress and Financial Sensitivity

Figure 4.6 shows an entire structure of the MSMM with the relation between management progress and financial sensitivity. And this structure can be illustrated by the following system of differential equations.

$$\begin{aligned}\dot{u} &= -M(u - \bar{u}) - \frac{1}{\varrho M}(s - \bar{s}) \\ \dot{s} &= u - au - bm \\ \dot{m} &= (F(u - \bar{u}) - \frac{1}{\zeta}(u - \bar{u}))m \\ \dot{M} &= \theta(M - M^*) + \iota(F - F^*) \\ \dot{F} &= \kappa(M - M^*) + \xi(F - F^*)\end{aligned}$$

These five deterministic equations will be used to represent irregular cycles in an economy. In the first equation in the above system, the time delays in the MSMM are transformed into the variables that represent management progress. First, the time delay to adjust discrepancies of the capacity utilization rates is

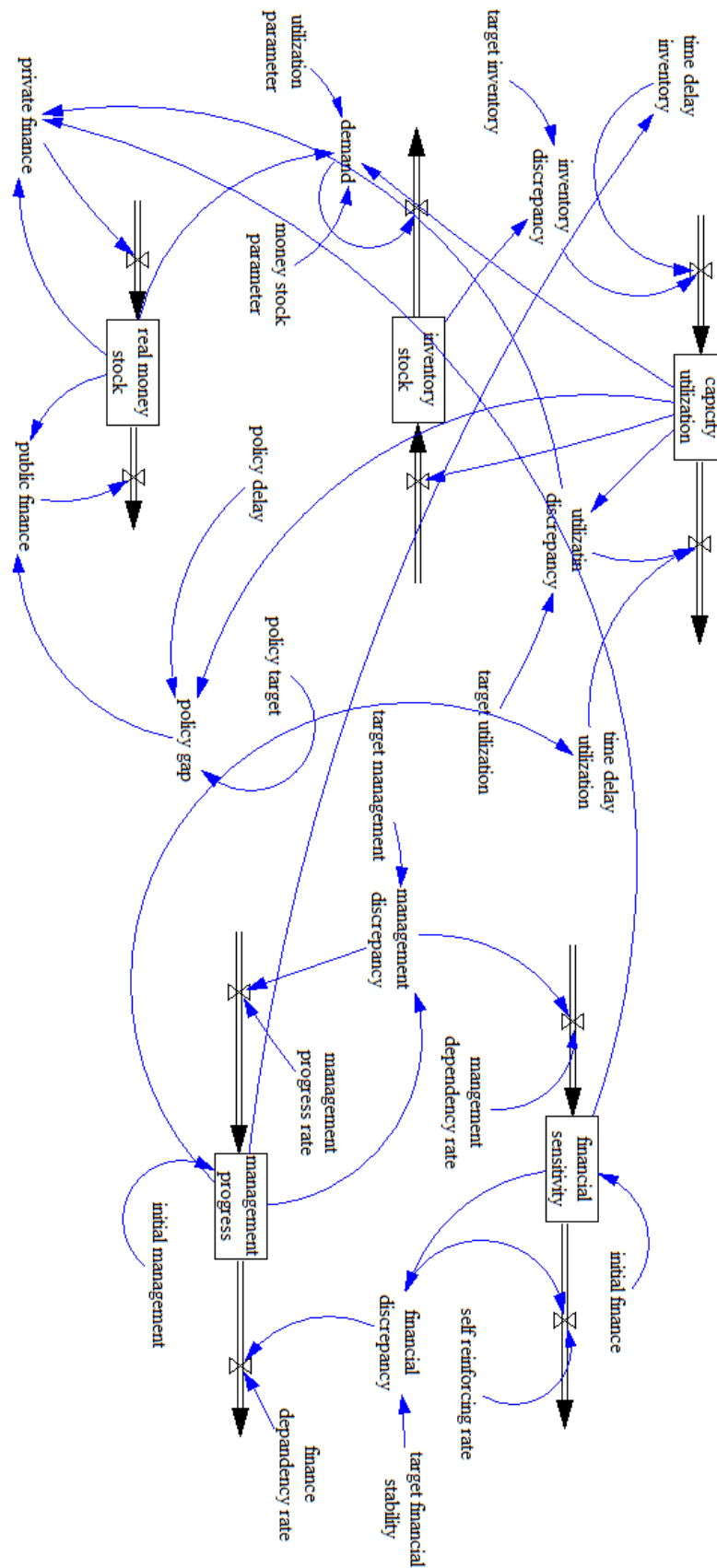


FIGURE 4.6: The MSMM with Management Progress and Financial Sensitivity

proportional to the management progress. Second, as the control methods of management are developed, the time delay to adjust inventory discrepancies is lengthened. It is represented by the operator, q , which is a converter of management progress. That is, inventory management can be loosened or smoothen if it is easy to be reached at a target production level. However, when firms are faced with business difficulty, such as a financial constraint in bad economic situations, they have no choice but to be tightened to manage their inventory level. Second, the coefficient of finance to adapt to additional requirements of household and firms, which refers to the financial sensitivity, is substituted for the new variable, F . It means that an adjustment speed of the financial sector can be increased or decreased according to economic circumstances.

To facilitate the stability analysis, we simplify the above equation system into a system with three differential equations. We suppose the periodic relationship between management progress and financial sensitivity, so to speak, an oscillation process, $\theta = \zeta$ with the opposite sign.

$$\dot{u} = -M[t](u - \bar{u}) - \frac{1}{qM[t]}(s - \bar{s}) \quad (4.5)$$

$$\dot{s} = u - au - bm \quad (4.6)$$

$$\dot{m} = (F[t](u - \bar{u}) - \frac{1}{\zeta}(u - \tilde{u}))m \quad (4.7)$$

where $M[t] = -c_1\iota \cos \sqrt{\det(A)}t - c_2\iota \sin \sqrt{\det(A)}t + M^*$ and $F[t] = c_1(\theta \cos \sqrt{\det(A)}t + \sqrt{\det(A)} \sin \sqrt{\det(A)}t) + c_2(\theta \sin \sqrt{\det(A)}t - \sqrt{\det(A)} \cos \sqrt{\det(A)}t) + F^*$. $\det(A)$ is the determinant of the coefficient matrix of Equation (3.2) and (3.3), that is, $\det(A) = \theta^2 - \iota\kappa$ if $\theta = \zeta$. And both of c_1 and c_2 are constants. Furthermore, we suppose $\bar{u} = \tilde{u}$ contrary to the original simulation process in Chapter 2.

4.4.3 Simulation

This section aims to represent the severe economic recessions in Figure 3.1. That is, to represent *the Crises* is the final goal in this section. To do so, we assume that

the system retains the local stability over the entire period as we studied in Chapter 3. The relationship between management progress and financial sensitivity should thus oscillate around a fixed point of the MSMM system. That is, it has to keep the local stability or to display a damped oscillation process. However, this process is complicated by a reciprocal relationship between management progress and finance sensitivity. This process allows the MSMM to approach more realistic patterns of business cycles. Now we represent the movements of the capacity utilization by numerical simulations using the system dynamics approach.¹

Management-led Regime. First of all, we take account of the management-led regime presented in the above sections. Here we assume that a situation that the growth rate of management progress is positive and financial sensitivity has a negative feedback loop. That is to say, the finance sensitivity could be increased when there is a gap in management progress. Figure 4.7 illustrates the local stabil-

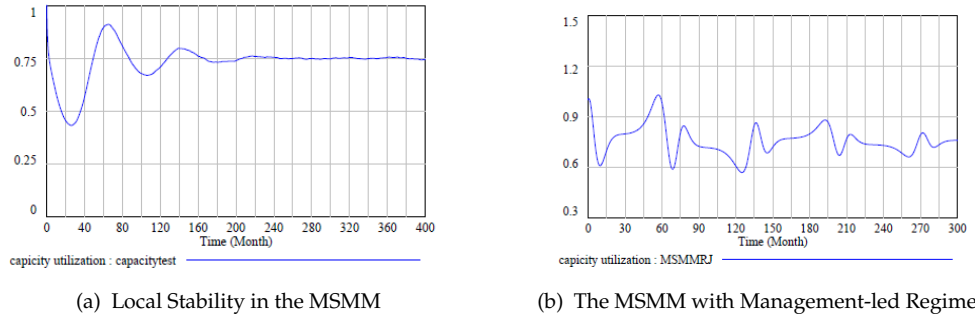


FIGURE 4.7: Local Stability in MSMM and Management-led Regime

ity of the MSMM system (Figure 4.7a) and the MSMM with the management-led regime (Figure 4.7b). The coefficient values of Figure 4.7a are $\epsilon = 0.8, \nu = 5.8, \zeta = 1.95, a = 0.7, b = 0.5, \bar{u} = \bar{u} = 0.75, \bar{s} = 0.6, u_0 = 1, s_0 = 0.3, m_0 = 0.5$; whereas, in Figure 4.7b, $\theta_T = 12, \iota_T = -8.4, \kappa_T = 7.5, \xi_T = -12, \varrho = 5, M_0 = 0.8, F_0 = 0.3$. Figure 4.7a shows the local stability around \bar{u} , and the damped oscillation process of this system. However, we can explore an irregular cycle (Figure 3.7b) departing from the local stability, which is one of many cyclic patterns that could

¹For the consistency in the modeling process, the coefficients $\theta, \iota, \kappa, \xi$ are transformed into the form of the time delays, that is, $1/\theta_T, 1/\iota_T, 1/\kappa_T, 1/\xi_T$, respectively. The subscript, T , refers to time delays.

be generated in the MSMM with the management-led regime. This system has long-term stability: mid-term movements along with an interrelation between management progress and financial sensitivity; and quantity adjustments in the short term; whereas short-term-noises are abstracted. Figure 4.8 illustrates a trajectory between u and s .

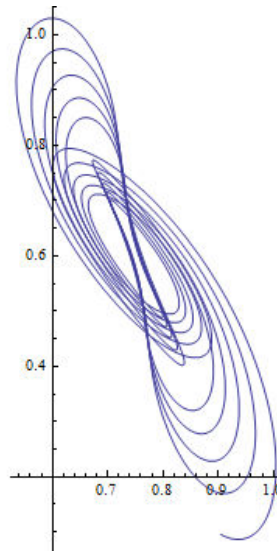


FIGURE 4.8: The Phase Space between u and s in the Management-led Regime

As shown in Figure 4.9, the irregular business cycles stem from an intersection between management progress and financial sensitivity. Certainly, the cyclical movements shown in the intersection have an influence on the entire pattern of the movements of the capacity utilization rate, but the sharp reduction in the rate is not coincident with the periodicity of each variable because of their different time delays.

In the management-led regime, the movements of the financial sensitivity depend on the management progress. As finance strongly responds to funding requests from firms and households, the general level of activity of economy steadily increases. However, the simultaneous deterioration of the managerial and financial conditions leads to a *sudden* collapse of economic activity rather than a smooth stabilizing process. From 80 to 120 period in Figure 4.8 and 4.9 or 210 and 250 period in Figure 4.9, particularly, there is a gradual downward trend owing to the untimely periodic contraction of the management

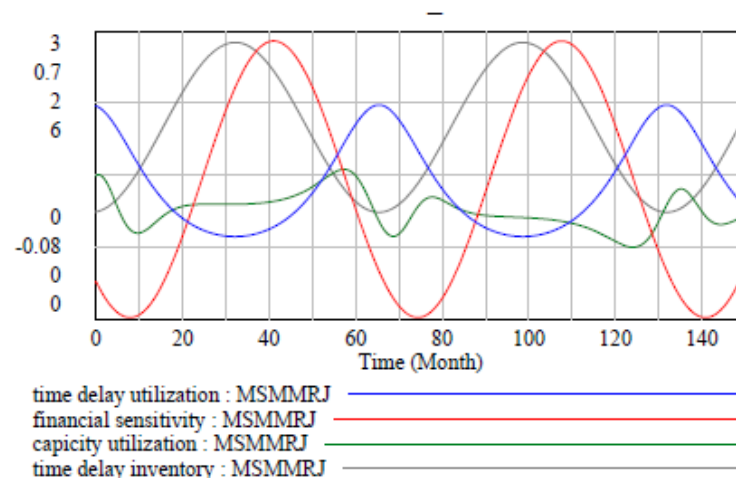


FIGURE 4.9: Time delays, Financial Sensitivity, and Capacity utilization rate in the MSMM with the Management-led Regime

progress and excessive financial activities for an economic recovery: management progress $\searrow \rightarrow$ time delay of utilization \nearrow , time delay of inventory $\searrow \rightarrow$ financial sensitivity \searrow , private finance $\searrow \rightarrow$ sudden collapse of economic activity. As the speed of management progress is slowed down, finance sensitivity trends downward and the provision of private finance is reduced. Thus, this situation is forced into a strict management, that is, a tight inventory management.

Figure 4.10 shows a role of the monetary control in the system. The path of

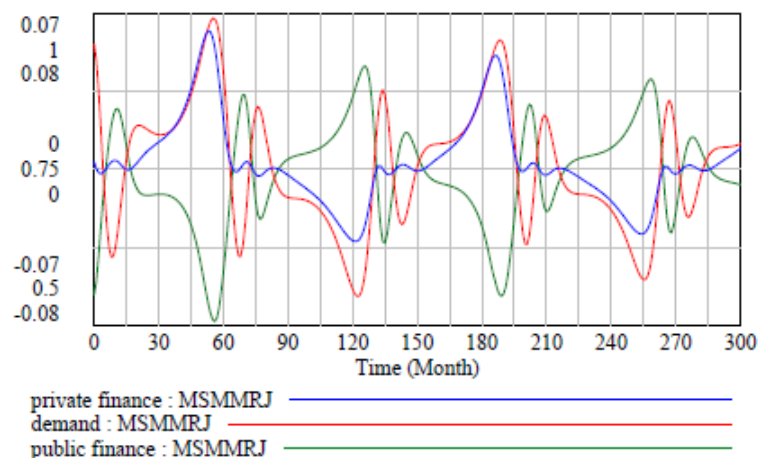


FIGURE 4.10: The Monetary Control (Public Finance), Private Finance and Demand

demand goes along with the private finance, but the sudden contraction of economic activity does not lead to a persistent economic depression due to the

countercyclical monetary control. That is, the monetary control variable, a goal-seeking mechanism of central authorities is one of the most important factors to prevent a breakdown of the system. Nevertheless, the monetary control would have a limit to make the system stable due to its time delays. As mentioned

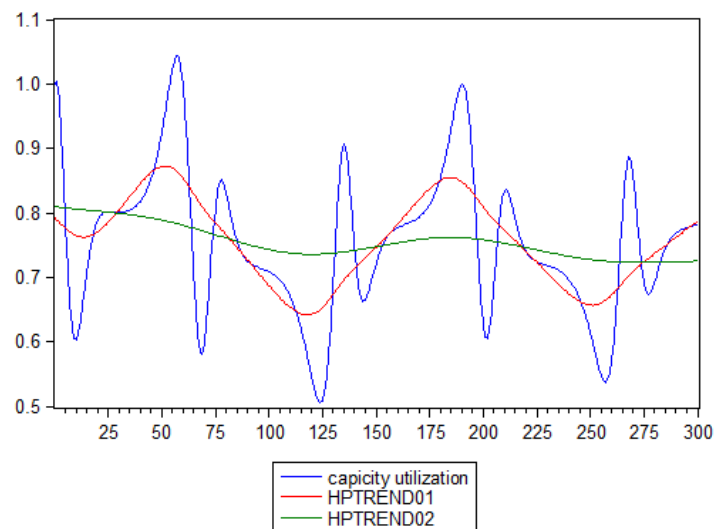


FIGURE 4.11: A Temporal Configuration of the MSMM: Hptrend01 14400; Hptrend 1440000

above, the short-term noises are abstracted from the entire time series. Thus, we can pick out three time-trends in Figure 4.11. Firstly, there is a long-run trend over the cyclic movements, which must be deeply related to the target value, 0.75 (the green line). Secondly, with a more fluctuated pattern and expanded amplitude, there is a mid-term trend influenced by the financial movements in Figure 4.11. Finally, there is a short-term quantity adjustment process with a much shorter frequency than any other trajectories. In this short-term flows, a characteristic feature is the sudden collapse of the economic activity resulting from *a dangerous intersection for economic activity* between the variables concerning management progress and financial sensitivity. This is a typical business cycle movement with the long-term stability. Policy makers in the public institutions or private firms should agonize over how the short-term and mid-term trends in business cycles can be stabilized.

Financial-led Regime. Financial-led Regime refers to a regime that management progress heavily relies on financial conditions in the entire economy. Since, for instance, a sufficient funding to the economy would make a positive expectation of firms and households, the firms' burden of inventory management could be relieved during that condition: it could be much looser than that in the previous periods. Moreover, the firms could easily find their needed resources, such as materials and labor forces, so they could hold production capacities enough to adapt to new orders quickly. However, it is the most important thing that management cannot develop beyond the average level of the management progress without the help of finance, $\theta < 0$. Figure 4.12a shows the movements of the capacity utilization rate in the finance-led regime; Figure 4.12b illustrates the relation between u and s . In Figure 4.12b, $\theta_T = -12$, $\iota_T = 9.6$, $\kappa_T = -8.5$, $\xi_T = 12$, $\varrho = 5$, $M_0 = 0.6$, $F_0 = 0.35$.

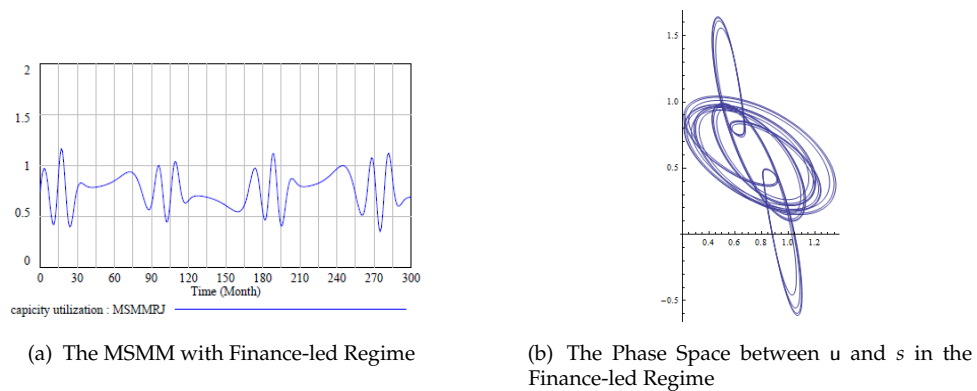


FIGURE 4.12: The MSMM with Finance-led Regime

Figure 4.13 shows how the movements of the capacity utilization rate are made. As in Figure 4.9, there are the bad intersections by the time delays of each related variable that make severe sudden economic collapses. Contrary to Figure 4.9, the bad intersection occurs when financial sensitivity comes to a recovery—however, it is worth noting that the intersection point may change little by little in accordance with the time delays and sensitivity: financial sensitivity $\searrow \rightarrow$ private finance and time delay of utilization \searrow , time delay of inventory $\nearrow \rightarrow$ sudden collapse of economic activity because finance is the fickle lover, who 'begins to find Romeo[management] progress strangely attractive when he gets discouraged and back off' (Strogatz, 1994a: 138) As the time delay of management

dependency of financial sensitivity is getting longer at the moment for certain reasons, the macroeconomic volatility will be amplified. This is the reason why more severe situation than any previous periods occurs, and therefore more strong public monetary controls are needed.

Figure 4.14 illustrates a relationship between the monetary control, private

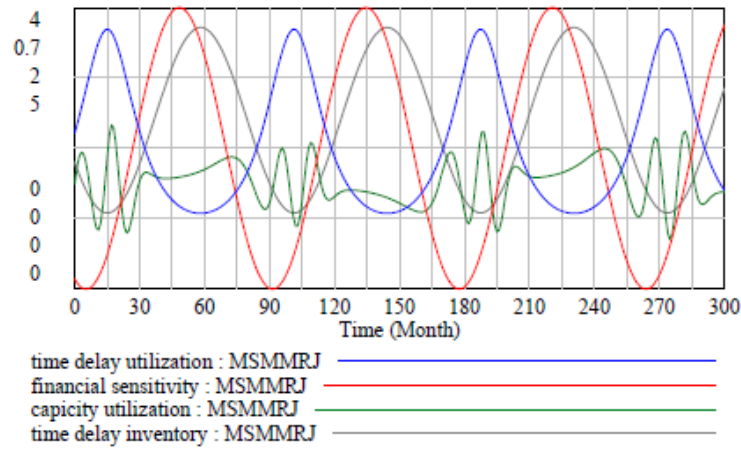


FIGURE 4.13: Time delays, Financial Sensitivity, and Capacity utilization rate in the MSMM with the Finance-led Regime

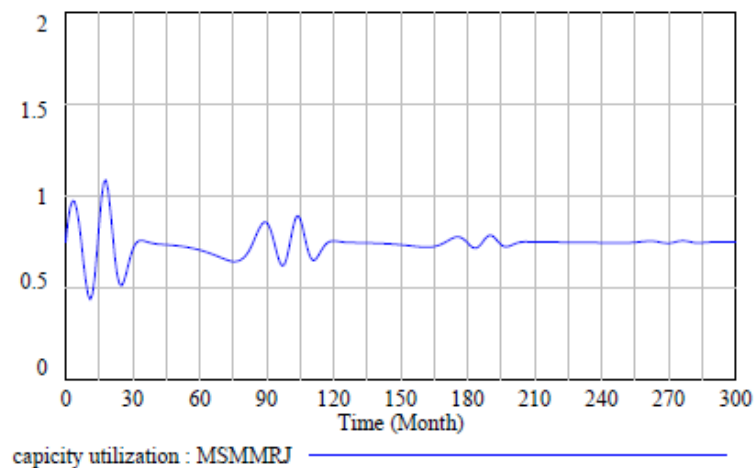


FIGURE 4.14: Enhancing stability, $\xi = 2.25$

finance, and the capacity utilization rate. The monetary control by central authorities is a supplement to successive changes of private finance. Nonetheless, the public action cannot perfectly defeat the volatility in the economy because the action is too sensitive to fluctuations as can be seen from the figure. If the

sensitivity was reduced—that is, the time delay of the monetary control lengthens, it would be possible to relieve the volatility. This is not to say that it is the best policy to shorten the time delay of policy, because an excessive response of central authorities to economic circumstances may worsen the situations. In Figure 4.15, we can see the movements of the central control over macroeconomy with its time delay, ζ , over time in this model. In Section 3.4.4 is devoted to the discussion relating to these aspects of policies, specifically.

Not surprisingly, it is hard to distinguish a finance-led regime from a management-led regime through the seeming patterns of movements of the capacity utilization rate. Nonetheless, a good or bad intersection of functional capabilities of management and finance is the most likely cause of the severe economic recessions or unexpected economic booms. Furthermore, a certain level of a central intervention may lead to economic stability. However, these results have to be recognized as a zero-possibility that simple macro policies like the monetary policies could have. That is, the stabilization policies may lose their way in *the labyrinth of the complexity* because this system holds the extreme sensitivity of initial values and parameter changes.

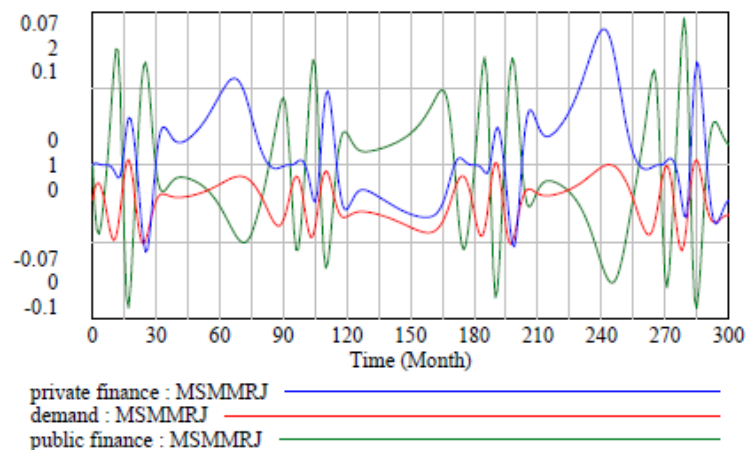


FIGURE 4.15: The Monetary Control(Public Finance), Private Finance and Demand in the MSMM with the Finance-led Regime

4.4.4 Impossibility and Necessity of the Central Intervention: Keynes vs. Hayek

We cannot imagine a macro system without an intervention of central authorities because the economy entirely loses its activity if there is no central action or the authorities disregard the discrepancies, that is, their actions have long time delays (Figure 4.16). However, the economy will suffer from an amplified volatility if the macro policies make an excessive response to discrepancies between the actual and target capacity utilization rate. These circumstances conditions a difficulty to perform the stabilization policy. Although these negative monetary feedbacks of the public authorities are necessary so that the system maintains a local stability, a disproportionate action of the agencies may make it worse. Alan Blinder, the former vice-chairman of the US Federal Reserve, has ever described concerning this as follows.

Lags in monetary policy ... tend to be trivialized or ignored in academia ... But they pose a huge practical problem for policymakers. Failure to take proper account of lags is, I believe, one of the main sources of central bank error.

One reason is simple ... All central bankers understand that there are long lags in monetary policy. But when policy is being either tightened or eased, policy makers typically have no usable quantitative estimate of what are often called "pipeline effects", that is the lagged effects of previous monetary policy actions that have not yet shown through in the data.

The second problem with lags runs much deeper and is, at least in part, psychological. Put plainly, a human being has a hard time doing what *homo economicus* does so easily: waiting patiently for the lagged effects of past action to be felt. I have often illustrated this problem with the parable of the thermostat ([Stermann, 2000](#): 786).

The example of the thermostat that he mentioned is very similar to the perspective of system thinking we already mentioned. It is the case for system dynamics to stress the negative feedback mechanism with time delays ([Morecroft 2010](#):

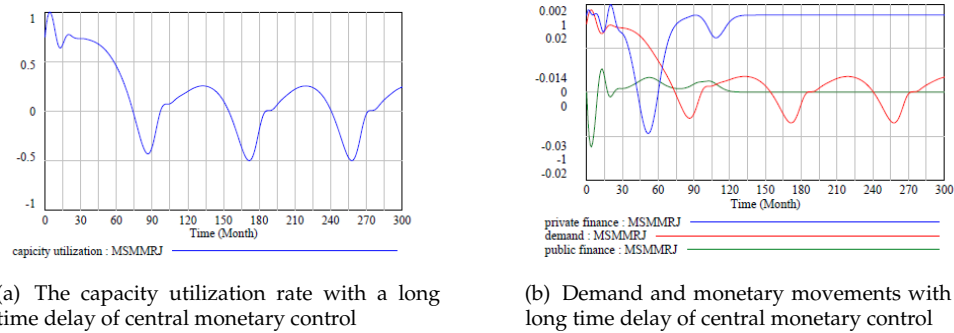


FIGURE 4.16: The long time delay of a monetary action in Finance-led Regime, $\xi = 9.375$

33-38). Let us suppose a thermostat. To achieve the desired temperature we have to adjust the flow of hot and cold water appropriately. However, too excessive response to discrepancies of the authority would lead to an over-reaction to the discrepancy. On the contrary, too passive action will cause an unrecoverable state of economic activity. If the relationship between management progress and financial sensitivity has not the closed-orbit with the exact extent which depends on the initial values and fixed point, but, with irregular movements, it is hard for policymakers to set an appropriate time delay or intensity of the policy. It may be just *by chance* to achieve stability with small oscillations. This is the reason why there are still persistent business cycles with the evolution of sophisticated macro policies.

These observations concerning the necessity and impossibility of macro policies hark back to the famous debates between John Maynard Keynes and Friedrich August Hayek. First, it is very well-known that Keynes argued an imperfection of market mechanism would ask for a government intervention.

Given the weak equilibrating powers of the market mechanism in these circumstances the implication of Keynes's analysis was that fiscal and monetary policy could correct the aggregate instability exhibited by market economies and help stabilize the economy at full employment (Snowdon and R.Vane, 1997: 5).

In this Keynesian point of view, an intervention by central mechanisms with a goal seeking feedback loop is *necessary* to stabilize macroeconomic activity.

Likewise, in our MSMM model, the feedback loop performs the role of the important stabilizing factor. Without the behavior of the agency, the model is destabilized in the intersection of the private initiatives between management and finance as it can be seen from the above simulation process. At the same time, however, this policy action has impossibility because it is hard for policymakers to recognize the complexity of the entire system. Hayek has ever said as follows.

Most defects and inefficiencies of such spontaneous orders result from attempting to interfere with or to prevent their mechanisms from operating, or to improve the details of their results. Such attempts to intervene in spontaneous order rarely result in anything closely corresponding to men's wishes, since these orders are determined by more particular facts than any such intervening agency can know (Hayek, 1988: 84).

As we can see from the above quotation, Hayek highlights the aspect of the *impossibility* of the public goal-seeking actions. This statement is consistent with our observations through which the existence of the persistent business cycle with the sudden collapse in the real world and our artificial world can be seen, and so the public actions have not yet fully been satisfied. Also, excessive or passive response to the discrepancy may give rise to what the policy makers did not wish to happen. Unlike our simple modeling, in the real world, there may be much more numbers of dynamics or exogenous shocks that we don't have included in the model.

Faced with the overwhelming complexity of the real world, time pressure, and limited cognitive capabilities, we are forced to fall back on rote procedures, habits, rules of thumb, and simple mental models to make decisions. Though we sometimes strive to make the best decisions we can, bounded rationality means we often systematically fall short, limiting our ability to learn from experience (Sterman, 2000: 26).

Consequently, Keynes and Hayek had argued two contradictory aspects—two sides of the same coin— of the macro policies rather than struggled with each other within their different camps. However, the impossibility that Hayek said doesn't mean all the attempts to stabilize economy are impossible, in my opinion. He put emphasis on an institution to make a new design to manage a stable growth for society.

Le Pouvoir, au sens large, est nécessairement le produit d'un dessein intellectuel. Si nous pouvons lui donner une forme telle qu'il procure un cadre favorable à la libre croissance de la société, sans donner à quiconque mission de diriger cette croissance dans le détail, sans doute pouvons-nous espérer voir se poursuivre le développement de la civilisation (Hayek, 1983: 182) .

4.4.5 Enhancing Stability: Exits of the Labyrinth

Severe economic recessions in our model stem from the *bad intersection* between the response of management and finance to the economic circumstances. This is a force inherent in the market process that destabilizes an economy. Therefore, the stabilization policy of the central authorities is necessary. As a result, the economy is not always unstable, and thus has the local stability but largely shaken sometimes, and requires the intervention of the central authorities holding the capacity to be able to ensure the stability of the bad economic situation. However, the management and financial progress may lead to these strong responses to business situations. It is the excess response of the private sectors including the nonfinancial and financial firms to destabilize the economy, but it is very hard to avoid that because such activities come from underlying motives to act them within the markets—maximize their profits. In these observations, the tendency towards increasing instability pursuant to the progress of management and finance can be seen.

To avoid the significant fluctuations of the macro activity, it is necessary to control the excessive response of the management and finance besides the interventions of the central authorities. In particular, the behavior of the private finance is not

a goal seeking feedback mechanism but a positive feedback mechanism leading to overheating and recessions. Moreover, finance itself imposes a strict rule to maximize its profits on the management stimulating the excessive response of the firm-management. If the private finance also had a goal-seeking feedback loop, it made it easier to stabilize the economy.

Nevertheless, the periodic movements between management and finance that we suggested are not a rule but an analogy that we borrowed from the mathematical description called *the Love affair model*. Thus, it is imperative to establish the relation between them more theoretically.

Chapter 5

The MSMM with Capital Accumulation

5.1 Introduction

The MSMM model in the previous chapters included the quantity adjustment process in the short-term and the mid-term evolutionary change in the financial and production behavior with the local stability in the long run. In this chapter, an investment behavior by an internal fund and financial assistance of financial institutions will be included in the model. It is necessary to take account of several additional factors to do this: distributional relationship (nominal wages, profit, and the rate of profit), investment function, and behaviors of the pricing decision. This modeling can illustrate a capital accumulation process, but we still suppose a constant technical condition in this chapter.

The parameter effects on stability in the previous MSMM are held in the model with capital accumulation. However, demand in the model will be subdivided into two other sectors: households and firms. That is, consumption demand is composed of workers' income, a portion of entrepreneurs' income, and household loans by the banking sector. Because the part of their earnings is divided into their consumption and investment, another portion of capitalists' income,

namely, saving of capitalists or firms and financial provision by banks are invested. This division of loans into consumption and investment reflects another important aspect of the banking sector. It would accompany a behavioral shift in the financial institution; For example, there is a significant difference in financial behaviors between before and after the 1997 Asian Crisis in Korea. The restructuring adjustment in the Korean economy has resulted in a big swing of financial loans from the business sector to households. This shift led to the dramatic increase in the household debt and diminution of their saving rate while the debt of the business sector in the country has remarkably reduced. This transformation gave rise to the stagnation of net investment, but the general level of activity in the country still fluctuates around their target.

In this chapter, we discuss these effects in *the MSMM with capital accumulation under a permanent technical condition* and whether it is consistent with the Korean case. Section 5.2 discusses whether the local stability in the previous sections is held in the new model. Section 5.3 contributes to what effect a financial shift like the Korean case has on a growth path of output or capital, that is, a financial parametric effect on the growth paths.

5.2 Capital Accumulation under a Constant Technical Condition

In this chapter, we study an expanded version of the MSMM in the last chapters and Appendix D. The models in the previous chapters were an abstract form for highlighting the movement of capacity utilization rate. Thus, the MSMM is expanded to a growth regime that represents changes in the levels and income distribution under a constant technical condition. However, the model in this section remains on the same time horizon with the previous models in a sense.

5.2.1 The MSMM with Capital Accumulation

Production is determined by firms, which have the two negative feedback mechanisms like the previous models as follows.

$$\dot{u} = -\frac{u - \bar{u}}{\epsilon} - \frac{s - \bar{s}}{\nu} \quad (5.1)$$

where u and s are the capacity utilization rate and the ratio of inventory to the productive capacity, Kb where K refers to the stock of capital. Two time delays, ϵ and ν are involved in this production process. Therefore, the level of production, Y , and inventory, S , are as follows.

$$Y = Kbu, S = Kbs$$

where the parameter, b is the output level 'obtained with one unit of fixed capital for $u = 1$ ' (Duménil and Lévy 1996: 377). If $b = 1$, $u = Y/K$. The changes in inventory are the same as production minus demand as follows.

$$\dot{S} = Y - D \quad (5.2)$$

Demand is composed of consumption and investment. We suppose that workers consume their all incomes, total wages, and entrepreneurs consume just a certain portion of their incomes, profits. Thus, the rest of the consumed profits are invested. Thus, demand and gross investment can be defined in this section as follows.

$$D = W + (1 - \alpha)\Pi + L_c + I$$

$$I = \dot{K} + \delta K$$

where W, Π are total wages and profits, respectively. The parameter, α and δ , is entrepreneurs' saving rate, and the depreciation rate of capital, respectively. L_c refers to the consumer loan from commercial banks. By the above relationship, we can be defined the growth of capital stock.

$$\dot{K} = I - \delta K = \alpha r K + L_p - \delta K \quad (5.3)$$

where L_p is productive loans. Thus, variables related to distribution should be defined. Our assumption related to income distribution is a constant share of wages. Furthermore, these variables are measured at the current prices. Therefore,

$$W = \omega pY, \Pi = pY - W$$

where p is the level of price and the parameter, ω , is the share of wages. According to this definition concerning distribution, the rate of profit is defined as $r = (\Pi - \delta K)/pK$. And then we assume that the loans to producers and consumers are determined by behaviors of both of the commercial banks and monetary authorities.

$$\dot{m} = \rho(u - \bar{u}) - \frac{j}{\zeta} \quad (5.4)$$

The change in real money stock is realized by the issue of loans by the commercial banks and a negative feedback effect by the monetary authorities. Thus, the variable, j is inflation rate and, the authorities have a time delay to adjust to their target, ζ . The inflation rate, j , reflects two discrepancies with time delays.

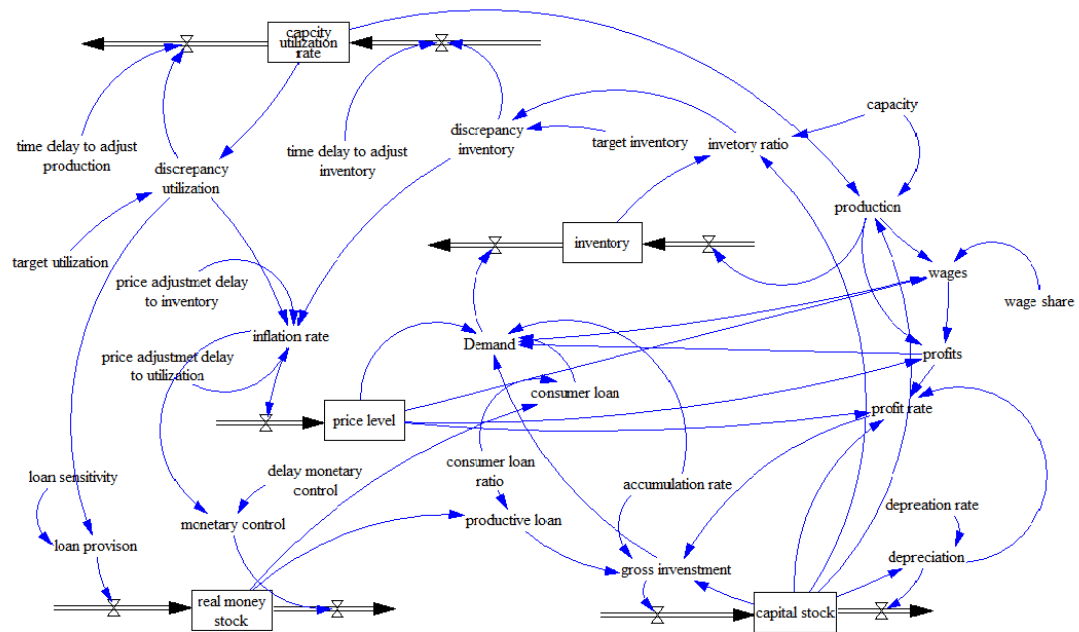
$$j = \frac{u - \bar{u}}{\chi} - \frac{s - \bar{s}}{\tau}$$

That is, the inflation rate responds to the discrepancy in the capacity utilization rates and inventory. Like other behavioral equations in this study, there are the two parameters of time delays, χ , and τ , which refer to the time delays to achieve the target, in the equation. Indeed, this equation represents the behaviors of monetary authorities as well as firms because it includes the behavior of firms' price adjustment. Furthermore, the general level of economic activity beyond the target also has a positive relationship with the inflation rate.

Consequently, this system is composed by four differential equations, (5.1),

(5.2), (5.3), (5.4) and variables are endogenously correlated by the additional definitions in this chapter. Thus, this system is closed. By this modeling with capital accumulation process, the growth pattern of each level of variables, such as production, inventory, the stock of capital, and price or inflation rate could be studied with system dynamics approach.

FIGURE 5.1: The MSMM with Capital Accumulation



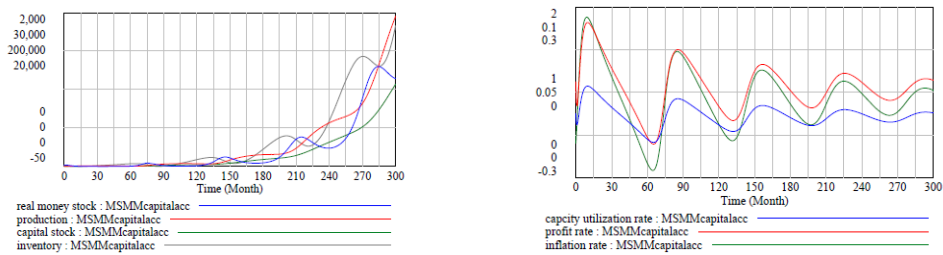
5.2.2 Feedback Structures and Damped oscillations in the Model

It is worth noting that the additional two feedback mechanisms in investment and finance are included to represent a growth regime. First, investment has a positive response to profitability and the productive loan from finance. We will call this a financial acceleration effect on capital accumulation. If a firm can invest more than their level of profitability, this is attributable to the acceleration effect by the financial sector. We assume that the productive loan depends on the behaviors of the banking sector, such as the loan sensitivity and the ratio of the consumer loan to productive loan. The changes in these parameters could result from a shift of the financial operations as well as regulation. Furthermore, the

monetary authorities constantly intervene in the economy in order to maintain an appropriate level of economic activity. This is the second feedback mechanism. Unlike the simple structure where the authorities just cope with the discrepancy between the actual and target level of the capacity utilization rate in the previous section, in this section, they take into account not only the level of activity, namely, the capacity utilization rate but a gap of demand and supply reflected in inventory discrepancy. Thus, two parameters related to price decision to adjust prices are included in the model.

Figure 5.1 shows the relationship between variables and parameters of the

FIGURE 5.2: The MSMM with Capital Accumulation



(a) The growth of each variable

(b) Oscillations in the MSMM with Capital Accumulation

model. The equations in this system can be seen in Appendix D. Figure 5.2a shows the growth paths of the levels of each variable in the model, such as production, the stock of capital and real money, and inventory, of which the paths fluctuate around an exponential growth trend. Thus, certain variables may present an oscillation process. Figure 5.2b illustrates the oscillating process of the capacity utilization rate, the rate of inflation and profit. Thus, this system with a certain set of parameters has local stability (See Appendix D).

In the previous chapters, we paid attention to the change in the loan sensitivity. However, we should take account of another factor of finance, the ratio of the consumer loan to total loans; For example, following the East Asian Crisis in 1997, the Korean economy suffered from a sharp decline in the rate of growth in both net investment and output, but the capacity utilization rate is maintained around the target or average value. This is the next theme of study. Our hypothesis is that the behavioral shift of the financial institution in Korea, which means the

change in the ratio of the consumer loan, makes a difference from the former growth regime before the Crisis in 1997.

5.3 Financial Shift and a Growth Path: the Korean case

In this section, we try to apply the MSMM with capital accumulation to an empirical case. Because the model can represent a growth regime according to the parameter setting, the parametric change can lead to a regime change. Above all, we take account of the Korean case after the East Asian Crisis in 1997. The country experienced a substantial transformation of the economy in both of financial and management aspects. In particular, the nonfinancial firms in the country began to decrease their debt ratio and to depend on their internal capital to fund for investment, and the financial firms focused on the loan operations for consumers rather than the business loans for expansion of the productive capacity in order to avoid risks associated with the business ones.

The results on macroeconomy of this shift have well known: a slower growth of output and net capital stock; greater volatility of economic fluctuation. Thus, the aim of this section is to represent the transformation of a growth regime in the MSMM with capital accumulation by the parametric changes, such as the financial reorientation to the consumer loans in the Korean economy. Because, in particular, this shift stemmed from not a natural evolution but an organizational transition by the government policies and a recommendation of the international institutions, such as IMF¹, this transformation should be illustrated not as a quantitative change but as a parametric change.

¹The Korea-IMF Stand-By Arrangement and the Letter of Intent to the IMF contained several measurements of financial sector reforms.'(Kown 2004: 85)

5.3.1 An Interrelation between Financial and Management Shift in Korea

Notwithstanding the radical turn of the Korean economy to the liberalization in the early 1980s, the shock of the East Asian Crisis in 1997 gave rise to an unprecedented structural change of the economy: From the 'government-business risk partnership' (Lim and Hahm 2006: 84) concerning investment in 1960s-1970s to the onset of the financial crisis in 1997, it has dramatically been changed into the market-oriented pattern of finance after the crisis, despite a gradual transition period from the 1980s to 1990s. Figure 7.14 in Chapter 7 illustrates the results of the radical shift. After the crisis, the ratio of the consumer loans to total loans sharply increased and reached to almost 50 percent in 2006.

The strengthened supervision of authorities allowed banks in the country to avoid the provision of the risky loans to the business sector. Compared to the corporate sector, the loan provision for consumers was not only a safety zone but a profitable field for banks in the country (KDI 2007: 177-180). Table 5.1 shows the profile of the ratio of the consumer loans to the business loans in the wake of the crisis in 1997. As the high-interest rates of the consumer loans before 1997 decreased below those of business loans, the accessibility to the loans of household became more expanded. Furthermore, the traditional low rate of the delinquency of the consumer loans was very attractive for the banks. This comparative advantage of the consumer loans for the banks gave rise to the transfer of debt from the business sector to household sector.

This radical shift of financial behavior after the 1997 crisis and its effect on macro-performance in the country are inseparable with a management shift of firms. As we mentioned, a target of the financial sector in the country reoriented for needs of consumers rather than firms' growth of capital stock. In this circumstance, the capacity utilization rate could be maintained around their target because a proportion of investment in the aggregate demand is displaced by consumption. Meanwhile, this country's annual growth rates of GDP fell 50 percent lower than 1980s-1990s and, in the case of its accumulation rates, the results were harsher (See Chapter 7 and 8). Although the independency of firms to decide on investment has been amplified more than before, this shift has not led to a

TABLE 5.1: Average Interests and Delinquency rates: Deposit Banks in Korea(percent, annual), 1997-2005, ^a

year	interest rate		delinquency rate	
	household loan	business loan	household loan	business loan
1997	12.30	11.75	3.3	7.3
1998	15.21	15.20	7.1	8.9
1999	10.85	8.91	3.2	4.4
2000	9.88	8.18	2.4	3.4
2001	8.20	7.49	1.3	2.1
2002	6.92	6.50	1.5	2.0
2003	6.50	6.17	1.8	2.1
2004	5.88	5.92	1.8	2.1
2005	5.64	5.75	1.4	1.9

^asource: [KDI 2007](#): 173

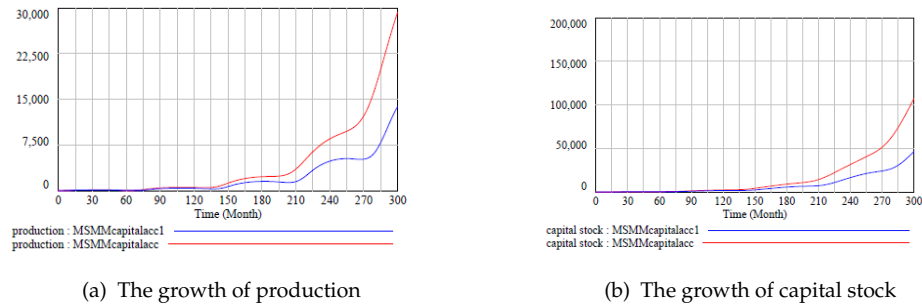
substantial growth of the country. If it had been a result of the entrance into a group of the advanced countries of the country as the traditional Solow model is suggested, it would not have taken a form of the sudden collapse. If it cannot be applied to a essential evolution process of the case of the Solow model, what model is helpful to explain this situation? Therefore, we need a macroeconomic model with capital accumulation including a financial relationship like the MSMM with capital accumulation in the previous sections.

5.3.2 A Parametric Change of the MSMM with Capital Accumulation

The consumer loan, L_c , and the productive loan to firms, L_p , were included as components of demand. These variables are determined by the monetary sector presented in Equation 5.4 in a positive and negative feedback responding to levels of macroeconomic activity. Thus, new loans, $L_c + L_p = m$, and thus, $L_c = \mu m$, $L_p = (1 - \mu)m$ where μ is the ratio of consumer loans to total loans. A change in the financial environment like the Korean case before and after the 1997 crisis could be reflected in this ratio. As mentioned above, however, there is no direct impact on the aggregate demand but only a change in its component.

Figure 5.3 shows the different growth paths of production and capital stock

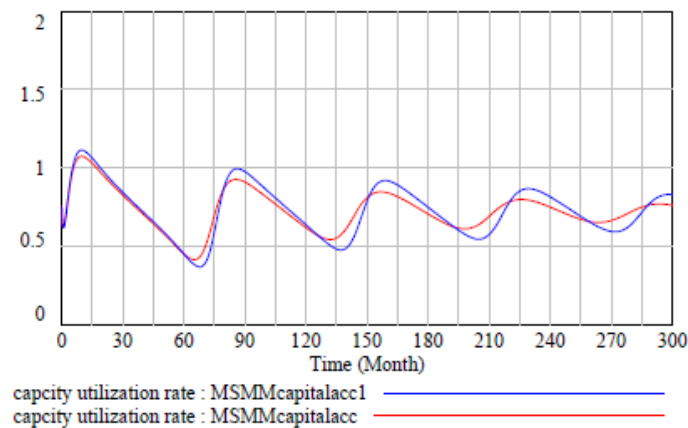
FIGURE 5.3: The MSMM and a Financial Shift



corresponding to the change in the parameter, μ . The red and blue lines represent each path with $\mu = 0.3$ and 0.55 , respectively, if other conditions are constant. Evidently, the growth path with the higher ratio is slower than the other path with the lower. Unsurprisingly, this result is exactly coincident with the Korean case. Furthermore, we can also see a movement of the capacity utilization by the simulation of the MSMM in Figure 5.4. In this figure, the red and blue have the same meaning in Figure 5.3. As shown in Figure 5.4, the effect of the financial shift from business loan to consumer loan leads to fluctuations at a higher amplitude. That is, even though it has a damped oscillation system, it goes through lots of difficulties to arrive at its fixed point.

Table 5.2 shows the annual growth rates of GDP and capital stock, and standard

FIGURE 5.4: The Capacity Utilization Rate and a Financial Shift



deviation of the capacity utilization rate in the successive two periods, 1980-1997

and 1998-2012 in the Korean economy. As shown in Figure 7.14, the financial shift is one of the reasons that make an important difference before and after the crisis. The results are evident in Table 5.2. Besides the impact on the growth of GDP and capital stock, in particular, the volatility of the capacity utilization rate can be measured by the standard deviation of that rate. If we take it into account, the rate fluctuated larger than the previous period. This is another important aspect that should not be overlooked. That is, *the financial shift could affect the production and inventory determination without the change in their parameters related to the determination* because the amplitude is expanded. Although the parameters, such as the time delays and targets, were not changed, and the model still has a damped oscillation process, the amplitude has increased. All these observations can be seen in the MSMM with capital accumulation as above.

TABLE 5.2: Average Growth rates of GDP and Net Capital Stock, and Standard Deviation of the Capacity Utilization Rate, 1980-2014

	1980-1997	1998-2012
Annual Growth rate of GDP	0.082	0.04
Annual Growth rate of net capital stock	0.17	0.08
S.D. of the capacity utilization rate	3.22 ^a	4.14

^aWe excluded 1980-1982 when the rates were extremely evaluated in the related statistics

Therefore, this model can illustrate the result of the financial shift by using the parametric change. Although this shift increases the volume of consumer loans, the effect of the reduction in the productive loans on demand has a more substantial impact on the macro-performance of the model. Chapter 7 presents a further study under technological progress in the very long run with *Financial Acceleration Effect* by an empirical study on the Korean economy.

5.4 Concluding Remarks

In this chapter, we introduce a macrodynamic model based on the MSMM with various feedback mechanisms: including the production determination by firms,

the demand formation by household incomes and loan provision by the financial sectors, and the stabilization policies by the central authorities. In particular, both consumers and producers in the economy could benefit from the loan provision by the financial sectors. That is, the loans have an effect stimulating demand of the economy regarding consumption as well as investment. The loan propensity of the financial sector has been reflected in the parameter, μ through which we describe an institutional shift in that sector.

In general, the pace of capital accumulation in an economy depends on firms' profits after payments of taxes, dividends, and interests, namely the retained profits that we call capitalists' saving according to the classical economists' terminology in this study. However, a financial effect on capital accumulation is another important factor in funding for investing in new capital. It could allow a faster pace of capital accumulation.

In particular, the rapid growth of capital compared to the lower retained profits in the Korean economy was ascribed to the external funding through the government-banks-Chaebol complex in that country. We can see this aspect in the rupture of that after the 1997 crisis. On this account, there was an institutional change reducing the proportion of the productive loans for capital accumulation in the complex of the country, which eventually led to an expansion of consumer loans.

This behavioral change of the financial sector is reflected in the change in the parameter, μ . This change resulted in the slower pace of capital accumulation as well. However, the more important thing that we could find in the model is the larger fluctuations of economic activity after the change, regarding the capacity utilization rate. Consequently, the parametric change relating to the behavioral transition of the financial sector in the model has led to not only the slow growth of capital accumulation but the large amplitude of business fluctuations. These findings are very coincident with the facts after the 1997 crisis in the Korean economy. f

Chapter 6

Capital Accumulation and Stochastic Technical Change

In the previous chapters, we studied capital accumulation with a constant technical change and distribution and presented its local stability in the long-run. Thus, in Chapter 5, we presented a model of capital accumulation but pay attention to a financial effect with constant technology and distribution. Therefore, the models that we studied so far should be appreciated as the reproduction models including a financial effect, rather than capital accumulation models in Marx's classification.

In models of reproduction, we abstract from the changes in the structure and organization of production that accompany real accumulation and assume that the parameters of the capitalist production process remain constant despite changes in scale. . . . *Accumulation models*, on the other hand, reflect the full impact of accumulation on all aspects of capitalist production and allow for changes in the underlying parameters (Foley, 1986b: 64).

In the very long run, production technology and distribution may change over time, and a trajectory of profitability with the technical and distributional change determines a pace of capital accumulation, which is transformed into output

under a given technical condition. Moreover, new techniques are *endogenously* introduced according to a profitability criterion.

In this process, technological progress is the engine of economic growth. In traditional theory of economic growth—The Solow-Swan model—, it has a growth effect while the saving rate has only a level effect at the steady state. The endogenous growth theory or so-called New Growth Theory, such as Romer (1990), Aghion and Howitt (1992), and Grossman and Helpman (1991), was the very efforts that tried to explain the endogeneity as part of economic activities. First, we examine the status of technological progress within the traditional theory of economic growth more detail; the structure and limitation of the New Growth theory, and, secondly, introduce the stochastic model of technical change that Duménil and Lévy have developed as an alternative to the prior approaches. Lastly, we apply their stochastic model to an example of the Korean economy.

6.1 Economic Growth and Technical Changes

Economic growth is determined by an increase in inputs such as capital and labor or technical progress. In economics, various types of models to explain this process have been developed. In Section 6.1.1, we introduce some limitations from the Solow-Swan model to the endogenous models, particularly concerning the technological change. Section 6.1.2 contributes to showing the technological trajectories in S. Korea and analyzing their specific characters out. In Section 6.1.3, the model of induced technical change à la Kennedy, which represents the *endogenous direction of technical change* (Julius 2005: 101), rather than the *endogenous technological progress* of the mainstream endogenous growth model, is explored.

6.1.1 Previous Models of Technical Changes

Economic growth is determined by how much factors are injected in production and how efficiently they are used. In the Solow-Swan model, technological progress has a persistent growth effect on output per capita at a steady state.

Although the model with the technological progress is incorporated into the neoclassical production function, it still takes an exogenous form. That is, the technological progress is taken into account outside the economic sphere.

For this reason, the endogenous growth theory has tried to endogenize the growth effect of technology; For example, the first generation of endogenous growth theory (Romer, 1986, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 1991) suggested a R&D or idea-based model 'in which growth is driven by technological change that results from the research and development efforts of profit-maximizing agents' (Jones, 1995: 759). In these models, 'R&D spending creates new technological knowledge improving product quality or expanding product variety and generating persistent per-capita growth (Greiner, 1996: 105).'

We suggest here a simple model with two sectors: the production sector and research sector.

$$Y = K^\alpha A L_Y^{1-\alpha} \quad (6.1)$$

$$\dot{A} = \eta L_A A \quad (6.2)$$

Equation 6.1 represents the traditional Cobb-Douglas production function with technology. Capital, K , Labor devoted to final output production, L_Y , and technology, A , are involved in production. Technology can be improved by the efforts of researchers, L_A , with research intensity, η . Therefore, total labor, L , is $L_A + L_Y$, which can be expressed by the share of labor devoted to research, ϵ ; for example, $L_A = \epsilon L$. This is the simple structure of the endogenous growth. If we take the logarithms of both sides in Equation 6.1 and differentiate with respect to time, t ,

$$g_y = \alpha g_k + (1 - \alpha) g_A \quad (6.3)$$

where y and k respectively refer to output per capita and capital per capita, and $g_A = \dot{A}/A$. In the same manner, g_y and g_k refer to their growth rates of y and k . Since $g_k = g_y$ on a balanced growth path, $g_y = g_A$. Therefore, $g_y = \eta \epsilon L$. In other words, the growth rate of output per capita depends on the growth rate of

technology at the steady-state.

$$g_{P_K} = (\alpha - 1)g_k + (1 - \alpha)g_A \quad (6.4)$$

where P_K refers to the productivity of capital. Similarly, $g_{P_K}=0$ under the condition of the balanced growth path. This means that the productivity of capital is constant regardless of the scale of capital. Therefore, the growth rate of output per capita depends on the level of labor devoted to research activities and the intensity of research. Furthermore, like the AK model, if we defined capital as a broad concept, the rate of saving could affect the growth rate of output per capita without an assumption of exogenous technological progress unlike the Solow-Swan growth model.

To sum up, technological progress has an endogenous long-run effect on a sustained economic growth and this can be stimulated by an increase in saving or the strong devotion in R & D activities. If, however, the research sector has a particular character like Jones' arguments (Jones, 1995; 1999) or the production function of final output take a different form with the AK model, the long-run effect in the endogenous growth model can be eliminated.

From now on, we assume that Equation 6.2 doesn't have the linear form like the above anymore.

$$\dot{A} = \eta L_A A^\theta \quad (6.5)$$

where θ refers a possible nonlinearity in the research sector. According to this, g_A becomes $n/(1 - \theta)$ where n is the growth rate of population. If $n > 0$, and $\theta = 1$ like the above endogenous growth model, the growth rate of this sector is explosive. Thus, it is hard to imagine this linearity assumption concerning knowledge production in the real economy. 'The discretionary choice, ..., is indeed an additional level of "ad hoc-ness", superposing itself onto ... knife-edge growth path indispensable to balanced growth, linear technology in the accumulation of knowledge' (Herrera, 2011: 33-34). Furthermore, Robert M. Solow said that it is a very hard problem to deal with research activities in economics.

[T]here is probably an irreducibly exogenous element in the research

and development process, at least exogenous to the economy. ... A second difficulty, no doubt related to the first, is the large uncertainty surrounding many research projects (Solow, 1994: 51-52).

Because of this excessive sensitivity, we will not suppose a special or *a priori* form of research activities or final output production. In particular, a particular or *biased* assumption related to the *emergence* of technology will have to be excluded. Instead, it is described as a stochastic process with a probability distribution where entrepreneurs can select a technique according to their criterion, that is a profitability criterion. For example, the entrepreneurs in an economy select a series of techniques that can increase their profitability and a trajectory of technical changes will be formed by the activities. In this framework, a pair of g_{P_K} and g_{P_L} where P_L refers to labor productivity defines the technique of production. In the next section, we will identify each trajectory of g_{P_K} and g_{P_L} in a country's historical case, which is the case of S. Korea here.

6.1.2 A Historical Example: the Korean Case

As is well known, the Korean economy has been ranked one of the advanced countries very fast.¹ The development of the manufacturing sector in that country has largely contributed to its economic growth and it still has a significant proportion of many economic activities in the country. Thus, the performance of that sector could be a representative one of the country's technical progress.

Before seeing historical trajectories of this country, we need to define a relationship between economic variables. If assuming the utility function as log felicity, $\ln C_t$ and there is no depreciation concerning capital accumulation for the sake

¹Double-digit export growth in volume terms during the past 20 years has made Korea the seventh largest exporter and 15th-largest economy in the world. By 2011, Korea's per capita income reached 62% of that in the United States (OECD 2014: 10).

of simplicity, one can set a dynamic optimization problem as follows.

$$\begin{aligned} \max \quad & \int_0^\infty e^{-\rho t} \ln C_t dt \\ \text{s.t.} \quad & \dot{K}_t = Y_t - C_t \\ & K_t \geq 0 \\ & K_0 \quad \text{given} \end{aligned}$$

where $\rho > 0$ is the subjective rate of discount. C_t , Y_t , and K_t refer to consumption, output, and capital stock, respectively. From this setting, the Euler equation is derived.

$$\frac{\dot{c}}{c} = r - \rho$$

where $r = MP_L = \partial Y / \partial K$. Here r is the rate of profit, Π / K where P_i is total profit, which is defined as follow. If we assume $Y = K^\alpha L^{1-\alpha}$ as the Cobb-Douglas form,

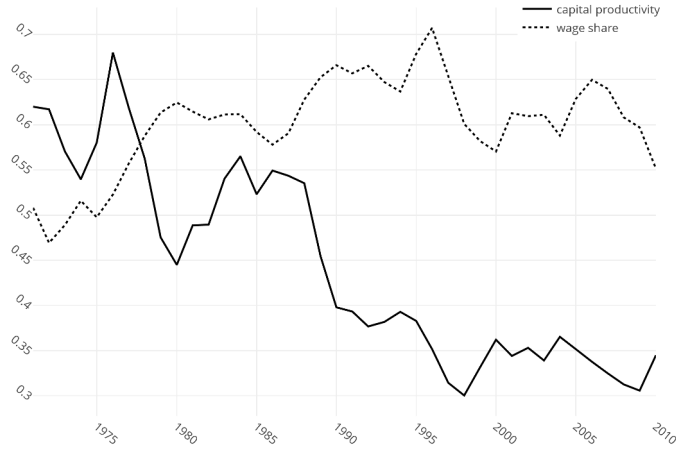
$$r = \frac{\partial Y}{\partial K} = \alpha k^{\alpha-1} = (1 - \omega) P_K \quad (6.6)$$

where ω refers to the wage share, namely, the ratio of total wages to output. As is well known, the exponents of the Cobb-Douglas form are income shares of each input and $k^{\alpha-1} = K^\alpha L^{1-\alpha} / K = Y / K = P_K$. Furthermore, $\dot{K} = I = arK$ where a is the rate of capital accumulation and we assume wages are all consumed and a certain proportion of profits, arK is invested in new capital. If P_K changes, the pace of the long-run growth will be changed. It affects dynamics of not only capital accumulation but consumption.

Now, let us turn back to the S. Korean case. As described above, the rate of profit is a proxy variable representing technology and distribution. In Equation 6.6, $(1 - \omega)$ and P_K represent distribution and technology, respectively. Thus, the rate of profit is very useful variable to analyze the evolution of distributional and technical patterns over time. Let us see the trajectories of capital productivity and wage share of manufacturing sector in S. Korea relating to the profit rate from 1970 to 2010.

Figure 6.1 shows the technological and distributional profiles of the manufacturing sector in S. Korea. First, capital productivity of the manufacturing sector in

FIGURE 6.1: capital productivity, P_K and wage share, ω : manufacturing sector in S. Korea (1970-2010)



Source: *National Accounts and National Balance Sheets* in S. Korea. <http://ecos.bok.or.kr>, *Labor Force Survey and Economically Active Population Survey*, kosis.kr

this country has an overall downward trend. That is, it has the negative rates of growth despite the moderation of them after the last half of the 1990s. Secondly, the wage share is stabilized around 60 percent although it was largely fluctuated before the 1980s and in the 1990s. As a result, the profit rate would fall during the observation period (Figure 6.2).

We can translate capital productivity of the manufacturing sector observed in Figure 6.1 into the mathematical framework as follows.

$$\dot{P}_K = \frac{g_{P_K}}{t} P_K$$

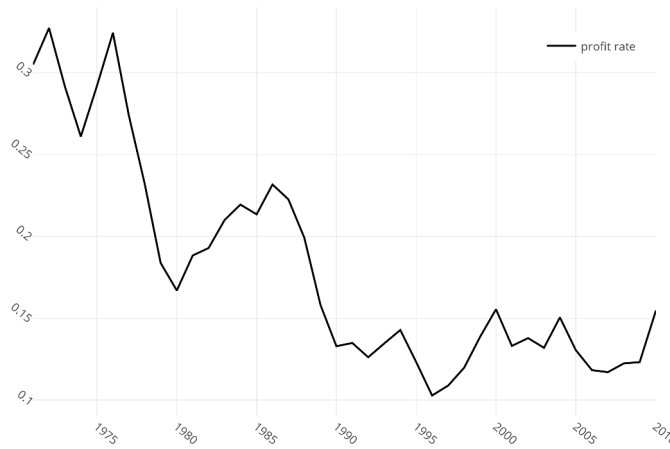
where $g_{P_K} < 0$. It means that the growth rate of capital productivity, g_{P_K} , slows down over time as shown in Figure 6.1. If we take the wage share into account,

$$\dot{\omega} = g_w - g_{P_L}$$

Since P_L refers to labor productivity, w is the wage rate or labor cost per working time. If assuming that the wage share is stabilized in the long run, there is a

ω^* for which $g_w = g_{P_L}$. From now on, we consider an endogenous direction of technical change, which is determined by a relationship between the selection of techniques and distribution. That is, the substitution between the production factors depends on each relative price of the factors. This is the model of induced technical change in the Kennedy-Weizsäcker line (Kennedy 1964: von Weizsäcker 1966).

FIGURE 6.2: Profit rate, r : manufacturing sector in S. Korea (1971-2010)



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

6.1.3 Induced Technical Change

Kennedy(1964) and Weizäcker(1966) developed the model of induced technical change, which was an attempt to explain John R. Hick's comment that a decrease in the relative price of capital to labor induces invention of labor-saving type techniques (Acemoglu 2003: 6). If inputs for production are capital and labor, and the economizing rate or improvement rate of each factor is defined as $g_{P_K} = a$ and $g_{P_L} = l$. The economizing rate of cost per unit, τ , is as follows.

$$\tau = (1 - \omega)a + \omega l \quad (6.7)$$

where $0 < \omega < 1$. The economizing rate of cost per unit depends on the weighted value of income shares and the improvement rate of each factor. We have to define the *innovation possibility frontier* or innovation possibility function, which means that the labor-saving technology has a trade-off relationship to the capital saving technology (Acemoglu 2001: 4).

$$l = f(a) \quad (6.8)$$

where f is a strictly concave function, $f' < 0, f'' < 0$. So we can set a maximizing problem as follows.

$$\begin{aligned} \max \quad & \tau = (1 - \omega)a + \omega l \\ \text{s.t.} \quad & l = f(a) \end{aligned}$$

The first order condition of this problem is $-(1 - \omega)/\omega = f'(a)$ where $f'(a) = \partial f / \partial a$. If the wage share, ω falls, l and a must increase and decrease, respectively. This relationship can be expressed as follows.

$$a = a(\omega), \quad a' < 0 \quad (6.9)$$

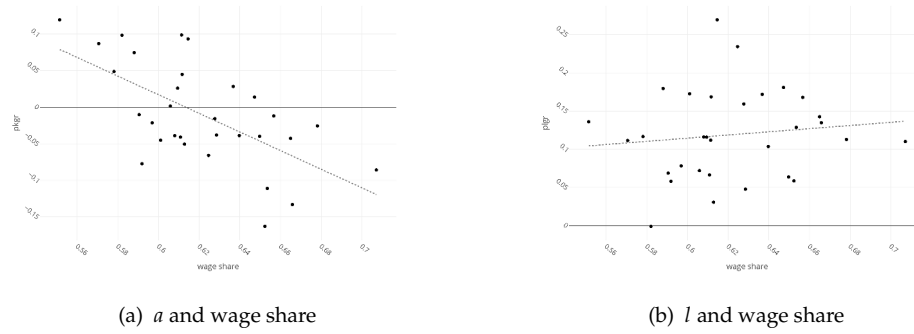
$$l = l(\omega), \quad l' > 0 \quad (6.10)$$

where a' and l' refer to $\partial a / \partial \omega$ and $\partial l / \partial \omega$, respectively.

Figure 6.3 shows a relationship between l , a , and the wage share of the manufacturing sector from 1980 to 2010 in the Korean economy. The relationships that are shown in Subfigure (a) and (b) represent Equation 6.11 and 6.12, respectively. We capture the trajectories of l and a in S. Korea for the past 30 years (1980-2010).

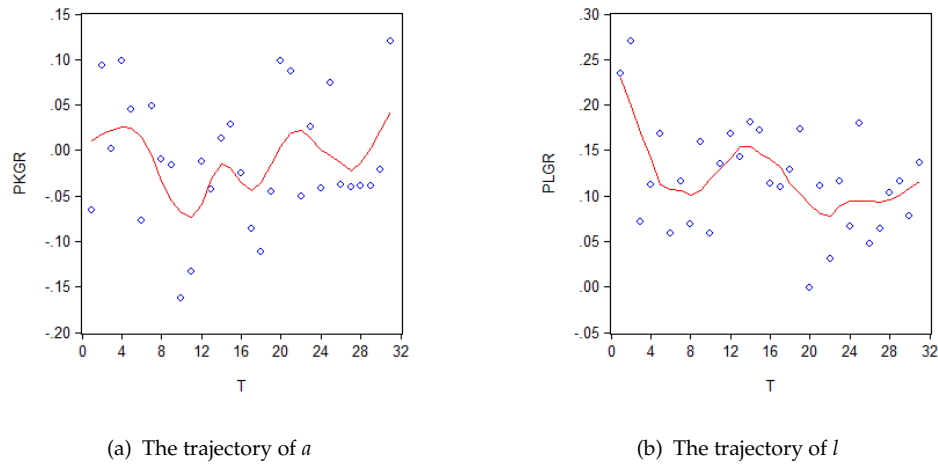
Subfigures (a) and (b) in Figure 6.4 show the trajectories of a and l from 1980 to 2010 in the Korean economy. These results can be translated into the mathematical form like the previous section. Besides the exceptional periods when they had positive values, in particular, in the early 1980s and the late 2000s, the growth rate of capital productivity of the manufacturing sector was negative. On the contrary, that of labor productivity was consistently positive during the

FIGURE 6.3: The Relationship between $a = PKGR$, $l = PLGR$, and wage share, ω : manufacturing in S. Korea, 1980-2010



Source: *National Accounts and National Balance Sheets* in S. Korea. <http://ecos.bok.or.kr>, *Labor Force Survey and Economically Active Population Survey*, kosis.kr

FIGURE 6.4: The Trajectories of $a = PKGR$, $l = PLGR$: manufacturing in S. Korea, 1980-2010(LOESS Fit: Degree=1, span=0.3, iters=4)



Source: *National Accounts and National Balance Sheets* in S. Korea. <http://ecos.bok.or.kr>, *Labor Force Survey and Economically Active Population Survey*, kosis.kr

observation period. Therefore, a and l can be defined as follows.

$$\dot{P}_K = \frac{a(\omega)}{t} P_K \quad (6.11)$$

$$\dot{P}_L = \frac{l(\omega)}{t} P_L \quad (6.12)$$

where $a < 0$ and $l > 0$. Furthermore, the growth rates of each productivity were slowed down over time as $a(\omega)/t$ and $l(\omega)/t$. To sum up, a and l depending on the change in the wage share fluctuated around a tendency over time. Above all, the average pattern of technical change, $a < 0, l > 0$ in the manufacturing sector is noticeable, which is called the Biased-Technical change. These observations so far are as follows: 1) we can see that the idea of induced technical change can be applied to the historical example in S. Korea at least between 1980 and 2010. 2) The endogenous direction of technical change has the average pattern of a biased technical change, $a < 0$ and $l > 0$. In this framework, however, there is no discussion about where the techniques originated from as mentioned above. According to the discussion in Section 6.1.1, the assumptions with regard to research activities or production techniques such as a formal equation for describing the research sector or even production function supposing a degree of a factor substitution should be avoided in this study.

6.2 A Stochastic Model of Technical Change

In this section, we introduce a stochastic model of technical change developed by Duménil and Lévy (1995; 1996: 223-231) for studying the biased technological trajectories in S. Korea. As mentioned, the results from the endogenous growth model are too sensitive to how we establish the research equation. Furthermore, there are many exogenous elements and uncertainties in the R&D process according to Solow's arguments. Second, there exists a relationship between the substitution of production factors and distribution in the South Korean historical example (1970-2010). This allows the process of technical change to be 'decomposed into two steps: 1) The *emergence* of techniques, i.e., the outcome of R&D, called innovation, and 2) A *selection* process among available innovations' (Duménil and Lévy 1995: 214). In Section 6.2.1, the structure of this kind of technical change model will be explained; Section 6.2.2 is devoted to simulating the model for the reconstruction of *endogenous* trajectories in the Korean economy.

6.2.1 The Structure of the Stochastic Model of Technical Change

In order to avoid the *a priori* assumptions that the previous models hold and to include the uncertainties in R&D process, the emergence of a and l available for production is a stochastic process. From now on, therefore, $\{a_t\}_{t \in \tau}$ and $\{l_t\}_{t \in \tau}$ where $\tau = \{1, 2, 3, \dots, n\}$ are the families of random variables, a and l . Although it is impossible to know means and variances of this sequences in advance, the occurrence of new technology is not global but local. That is, there exist a maximum value and a minimum value of the set of available technologies. Thus, we can assume that they are random variables with a uniform probability distribution, $unif(max, min)$.

Firms adopt a new technique if the larger profit can be made by introducing it. Therefore, the criterion to choose is their profitability. This profitability criterion is crucial in the selection process. In order to describe this process, we have to begin with the definition of the rate of profit $r = (1 - \omega)P_K$. It can be differentiated with respect to time, t , as follows.

$$\frac{dr}{dt} = \frac{dP_K}{dt} - \frac{d\omega P_K}{dt} = (1 - \omega) \frac{dP_K}{dt} + \omega \frac{dP_L/dt}{P_L} P_K$$

where $\omega = w/P_L$ and w is wage rate. Since $(dP_K/dt)/P_K = g_{P_K} = a$ and $(dP_L/dt)/P_L = g_{P_L} = l$, $(dr/dt)/r$ can be arranged as follows.

$$\frac{dr/dt}{r} = \frac{\omega l}{1 - \omega} + a \quad (6.13)$$

The criterion for the selection of new techniques is $r^e > r$ where $r^e = r(1 + \dot{r})$ with $\dot{r} = (dr/dt)/r$. That is, the techniques on the region, $r^e > 0$ will be selected by firms. Otherwise, firms must maintain an existing technique. We can derive an *innovation selection frontier* from the above, which is $r = r^e$, that is, $\dot{r} = 0$. Thus, it is as follows.

$$l = -\mu a, \quad \text{with} \quad \mu = \frac{1 - \omega}{\omega} \quad (6.14)$$

Theorem 6.1 If $\omega = 0$, then $\mu = \infty$. And if $\omega = 1$, then $\mu = 0$. Therefore, the slope of the innovation selection frontier, μ , turns in a counter-clockwise direction if wage share, ω , increases.

This is evident from Equation 6.16. Theorem 6.2 can be derived from Equation 6.15.

Theorem 6.2 In a set of new techniques selected according to the profitability criterion, $a(\omega^*)$ and $l(\omega^*)$ cannot be negative at the same time if ω^* is given.

Theorem 6.3 If, therefore, we can define the space of the selected techniques according to the profitability criterion as Π , which is a subset of the innovation set with the uniform distribution, $unif(max, min)$, there exists a pair of average values of a and l , $(\bar{a}(\omega^*), \bar{l}(\omega^*))$ in Π where \bar{a} and \bar{l} refer to the average values of each variable respectively.

6.2.2 Simulating the Stochastic Model

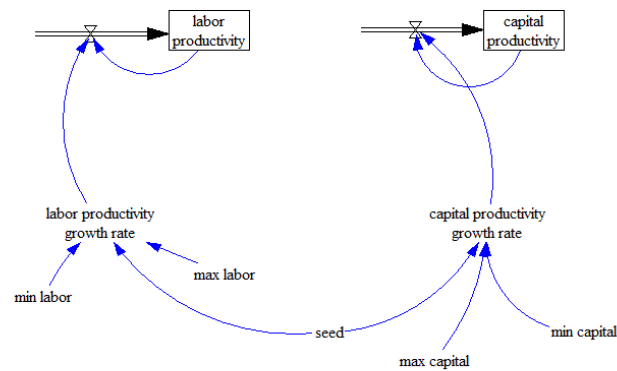
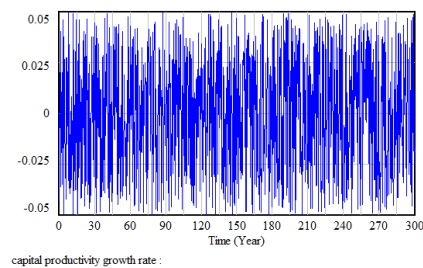
In this section, trajectories of technical change are represented by transforming the structure in Section 6.2.1 into the equations of VENSIM, which is one of the packages representing the system dynamics approach. First, the productivity of labor and capital are defined as follows.

$$P_L = P_{L0}(1 + l)^t, \quad P_K = P_{K0}(1 + a)^t \quad (6.15)$$

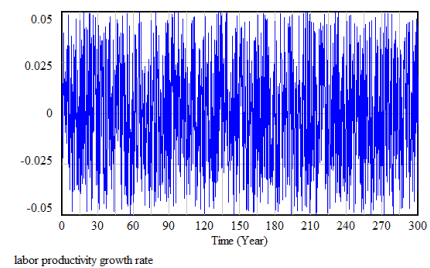
where P_{L0} and P_{K0} refer to the initial values of each productivity, respectively. In this simulation process, they are the values in 1971 of the manufacturing sector estimated in the previous sections, Section 6.1.2 and 6.1.3. According to the discussion in Section 6.2.1, a and l are the stochastic random variables with the uniform distribution, $unif(min, max)$. The generation of a random variable is performed by RANDOM UNIFORM(min, max, seed), which is one of the functions in the VENSIM.

As shown in Figure 6.5, we can see two positive (reinforcing) loops concerning the productivities with the innovation set constituted by random variables over time. As mentioned, it is impossible to know means and variances of the innovation set in advance. Thus, arbitrary values are given as the minimum and maximum in this process.

FIGURE 6.5: The Structure of innovation set and the growth of productivities

FIGURE 6.6: The appearance of the rates of productivity growth (min: -0.05, max: 0.05, seed: 0), $t=[0, 300]$ 

(a) the growth rate of capital productivity



(b) the growth rate of labor productivity

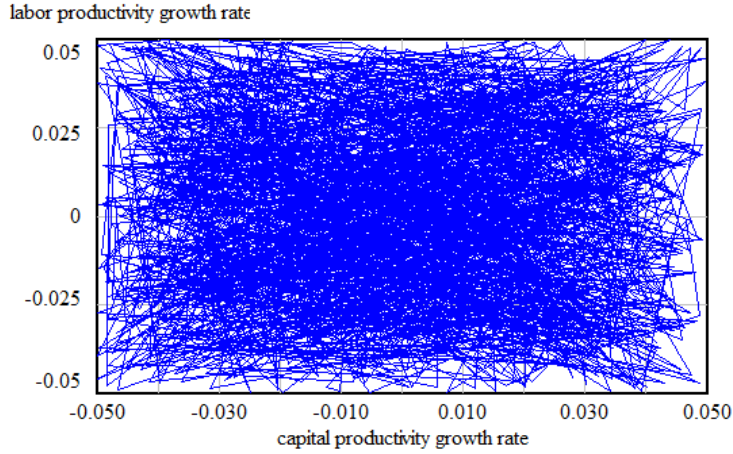
FIGURE 6.7: The innovation set: $t=[0, 300]$ 

Figure 6.6 and Figure 6.7 show each random process of the productivities or the set of innovation, (a, l) . In order to establish the profitability criterion, we have to establish an assumption of income distribution. It is assumed that the wage share is stable in the long run.

$$\dot{w} = \dot{w} - l, \quad 0 = \dot{w} - l \quad (6.16)$$

where w is wage rate. In other words, the growth rate of labor productivity and the wage rate have same in the long run. As mentioned, the profitability criterion is to select techniques that yield larger profit rate as follows.

$$r^e(a_N, l_N) \quad \text{if} \quad r^e > r(a^*, l^*) \quad (6.17)$$

$$r \quad \text{if} \quad r^e \leq r \quad (6.18)$$

where a_N and l_N is available new techniques which are random stochastic variables. If the expected rate of profit is smaller than the rate of profit with the existing techniques, (a^*, l^*) , firms maintain their existing ones. Therefore, Equation 6.16 is the selection frontier and techniques within the region, Π could be selected. Under the condition that is given by Equation 6.19 and 6.20, the criterions of the productivities in the simulation are as follows.

$$IFTHENELSE(l_N > criterionvalue(pl), l_N, 0) \quad (6.19)$$

$$IFTHENELSE(a_N > criterionvalue(pk), a_N, 0) \quad (6.20)$$

where *IF THEN ELSE* is the function provided by VENSIM package. In Equation 6.21, if l_N is more than a value the criterion pl , which can be calculated on the selection frontier, $l = -\mu a$, then l_N is selected. Otherwise, labor productivity is maintained at the existing level, which means $l = 0$. The same is true in the selection between $a_N = 0$ and $a = 0$.

FIGURE 6.8: The structure of simulation of the stochastic technical change

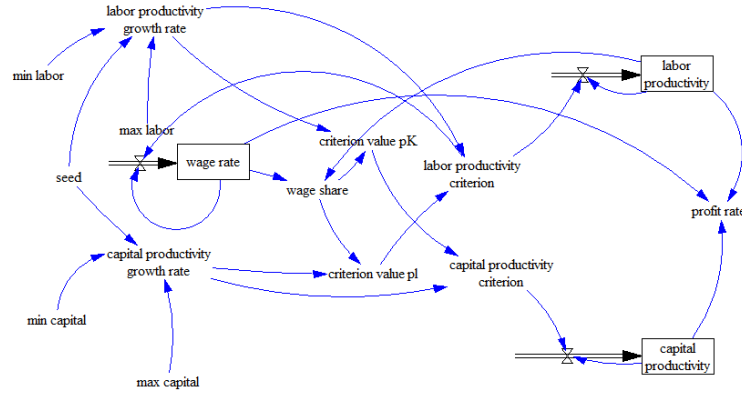


Figure 6.8 shows the structure of simulation process including the emergence of production techniques with a probability distribution, the stable wage share in the long run, and the profitability criterion. According to this structure, we can build a trajectory of the profit rate with $unif_{cap}(-0.65, 0.4)$, $unif_{lab}(-0.05, 0.488)$ where $unif_{cap}$ and $unif_{lab}$ respectively refer to the uniform distributions of capital and labor productivity with at seed 0, by which the innovation set is formed.

FIGURE 6.9: A trajectory of the profit rate from the simulation

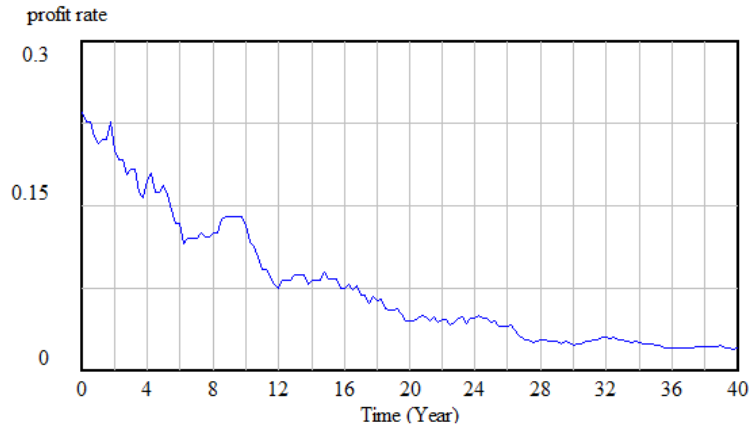


Figure 6.9 shows an example of a trajectory of the profit rate reconstructed by the above method with the biased technical change, $\bar{a} < 0$, $\bar{l} < 0$. However, our next goal is to reconstruct the trends of actual data series, especially of the manufacturing sector in the Korean economy since the 1970s.

6.3 Reconstructing the trends in the Korean Economy

In this section, we apply the stochastic model of technical change to the Korean case (1970-2010). The model can represent the trajectories of the profit rate, labor productivity, capital productivity, wage share, and so on; these major trends reconstructed by the model is compared with the actual trends of them of the manufacturing sector. Despite the stochastic character of technical change in the model, an underlying assumption about income distribution is needed. First, the growth rate of labor cost is exactly proportional to the growth rate of labor productivity: a constant wage share. Second, the growth rate of labor cost is constant, but the wage share changes over time along with the change of the growth rate of labor productivity. In Section 6.3.1, we reconstruct the major trends under the first assumption of a constant wage share and, in Section 6.3.2, represent them under the second assumption: a constant growth rate of labor cost.

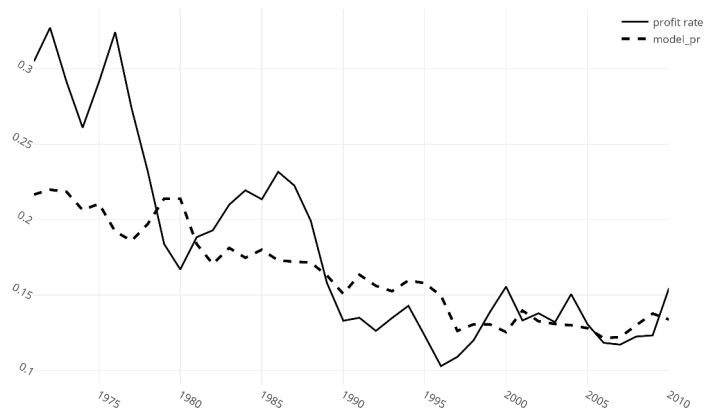
6.3.1 The Major Trends at a Constant Wage Share

Duménil and Lévy reconstructed the trends of distribution and technology in the US economy since the Civil War ([Duménil and Lévy 1995](#)). In this section we show that this stochastic model can be applied to those in the Korean economy since the 1970s.

By the estimation of the rate of profit, r , each productivity of factors, namely labor productivity, P_L , the productivity of capital, P_K , and the wage rate (labor cost), w , of the manufacturing sector, we reconstruct their trend using the stochastic model of technical change. Finally, this could allow us to represent the trajectory of capital accumulation in that sector.

Figure 6.10 shows the actual trajectory of the profit rate of the manufacturing sector and its trend reconstructed by the model. For the 1970s, there is a big difference between the actual data series and the reconstructed trend. This result stems from our assumption relating to the initial value setting. For simplicity

FIGURE 6.10: The rate of profit (profit rate)* and its trend reconstructed by the model (model-pr) : manufacturing sector, 1971-2010



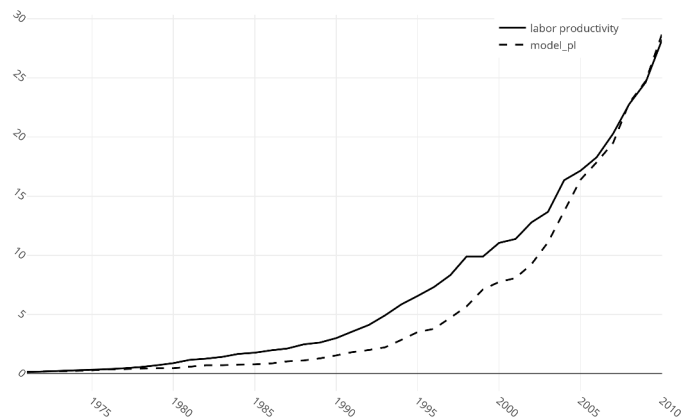
*Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

and ensuring the stability of the wage share, we assume the initial value of the wage rate as 0.08—The actual value of the data series is 0.06947 in 1971. Therefore, the wage share is stabilized at 0.615385 (about 61 percent) over the entire period. However, the wage share was constantly increasing in the 1970s from the lower level than 1980s (See Figure 6.1).

Likewise, the actual labor productivity and wage rate grew faster than the trends but converged with the trend reconstructed by model since the late of the 2000s (See Figure 6.11). As mentioned above, the wage share defined by the model maintains at the constant, but the actual wage share fluctuated (See Figure 6.1 and Figure 6.12) If we could establish a more specific model concerning the wage share, more fitted data series could be obtained. However, the long-run equilibrium between the growth rates of wage rate and labor productivity couldn't be appreciated as an unreasonable sense both theoretically and empirically. As shown in Figure 6.12, it fluctuates around the reconstructed trend.

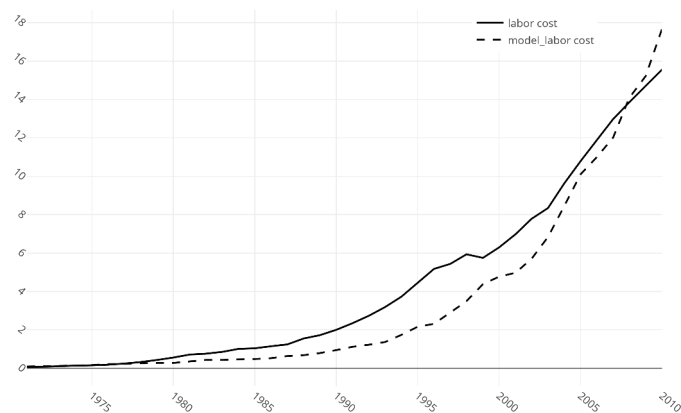
Figure 6.13 shows the actual productivity of capital of the manufacturing sector and its trends. Compared to Figure 6.10, there is no structural gap between the actual series and the reconstructed trend, in particular, in the 1970s. These facts show that the model represents the technological trajectories very coincidentally.

FIGURE 6.11: labor productivity* and its trends reconstructed by the model:
manufacturing sector, 1971-2010



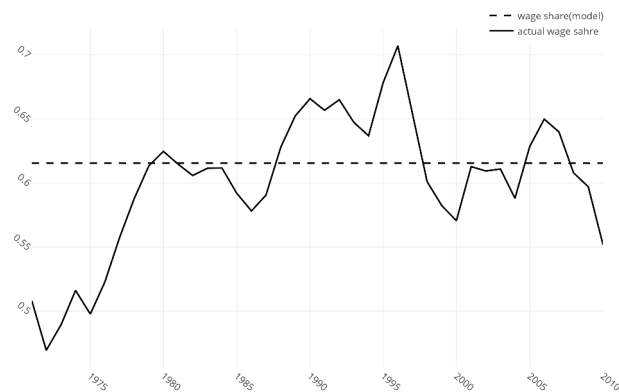
*Source: National Accounts <http://ecos.bok.or.kr>, Labor Force Survey and Economically Active Population Survey, kosis.kr

FIGURE 6.12: wage rate(labor cost)* and its trends reconstructed by the model :
the manufacturing sector, 1971-2010



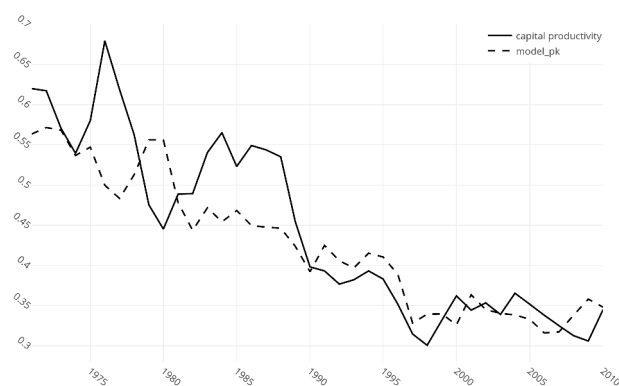
*Source: National Accounts <http://ecos.bok.or.kr>, Labor Force Survey and Economically Active Population Survey, kosis.kr

FIGURE 6.13: The actual wage share in S. Korea* and values given by the model



*Source: *National Accounts* <http://ecos.bok.or.kr>

FIGURE 6.14: the productivity of capital* and its trend reconstructed by the model : the manufacturing sector, 1971-2010

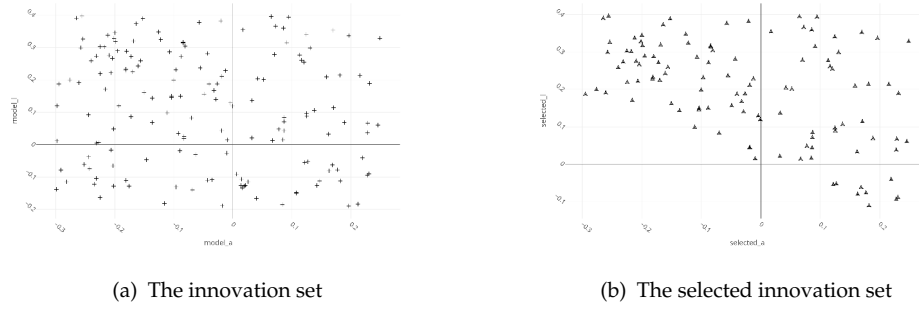


*Source: *National Accounts* and *National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

However, the fluctuations of distribution should be taken into account for the reconstruction of the profit rate.

Figure 6.14 shows the innovation set for reconstructing the trend in the Korean economy and the selected techniques according to the selection frontier,

FIGURE 6.15: The innovation set for the reconstruction and the selected innovation set: $unif_{cap}(-0.3, 0.25)$, $unif_{lab}(-0.2, 0.4)$



that is the region II. Within the region, the growth rates of capital and labor productivities that allow yielding larger profits are selected under the assumption, $\omega^* = 0.615385$. Those average growth rates are $\bar{a}(\omega^*) = 0.01398$ and $\bar{l}(\omega^*) = 0.134938^2$, respectively. This is the type of the biased technical change, which is consistent with the observation in Section 6.1.2 and 6.1.3.

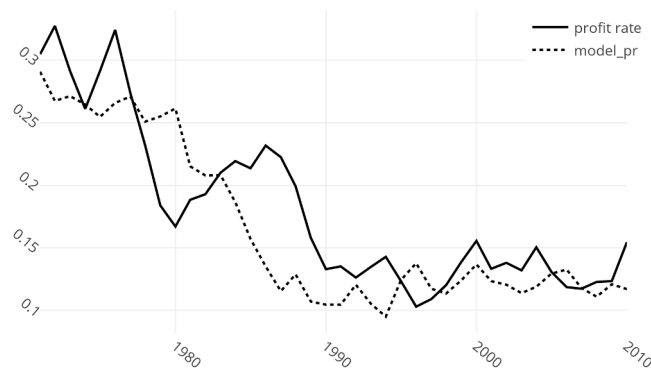
6.3.2 The Major trends at a Constant Growth Rate of Labor Cost

In Figure 6.10, there is a quite big gap between the trajectories of the model-profit rate and actual profit rate. This result stems from the difference between the actual wage share and the constant wage share that is our assumption in Section 6.3.1 (See Figure 6.12). In this section, we introduce a constant growth rate of labor cost as a new assumption, and therefore the wage share reconstructed by the model may change over time.

Figure 6.16 shows the actual profit rate and its trend reconstructed by the model. The gap in Figure 6.10 disappears in Figure 6.16 because the share of wages can fluctuate at the constant growth rate of labor cost according to the change rate of labor productivity in the model (See Figure 6.19). This is the more positive result than that of the model with the assumption of the constant wage share.

²These average values contain all the selected values even including when the average value is zero

FIGURE 6.16: The rate of profit (profit rate)* and its trend reconstructed by the model (model-pr) : manufacturing sector, 1971-2010



*Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

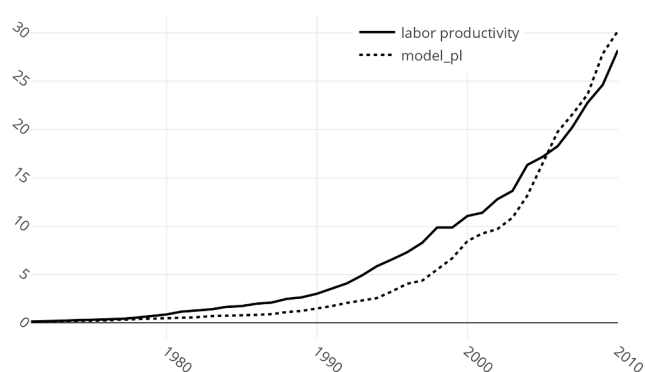
That is, the extraordinary levels of the profit rate in the 1970s resulted from the relatively low levels of the wage share compared with that after the 1970s.

Figure 6.17 and 6.18 illustrate the trajectories of the labor productivity and the labor cost. In particular, the trend of the labor cost reconstructed by the assumption can be seen in Figure 6.18. The movements of the two variables lead to the fluctuations of the wage share in Figure 6.19. Through this process, they are reconstructed more close to the movement of the actual wage share. Understandably, the trajectory of the capital accumulation built by the model corresponds to the actual one approximately (Figure 6.20).

6.3.3 The Profit Rate and Capital Accumulation

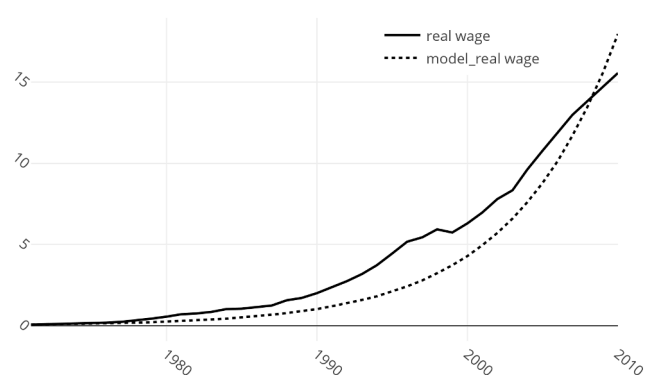
For the next chapter, a study on the relationship between the profit rate and capital accumulation is needed. As shown in Figure 6.20, the relationship can be represented by the profit rate reconstructed by the model. However, the accumulation rate, which is a rate that refers to a portion of invested profit in

FIGURE 6.17: labor productivity* and its trends reconstructed by the model:
manufacturing sector, 1971-2010



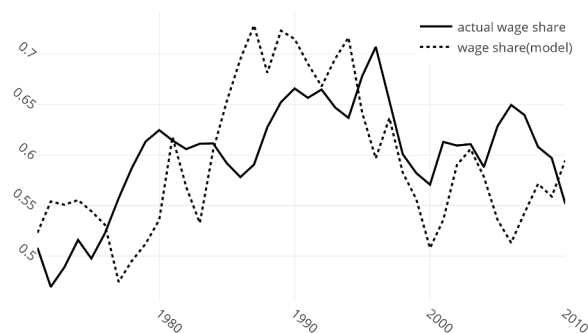
*Source: National Accounts <http://ecos.bok.or.kr>, Labor Force Survey and Economically Active Population Survey, kosis.kr

FIGURE 6.18: wage rate(labor cost)* and its trends reconstructed by the model :
manufacturing sector, 1971-2010



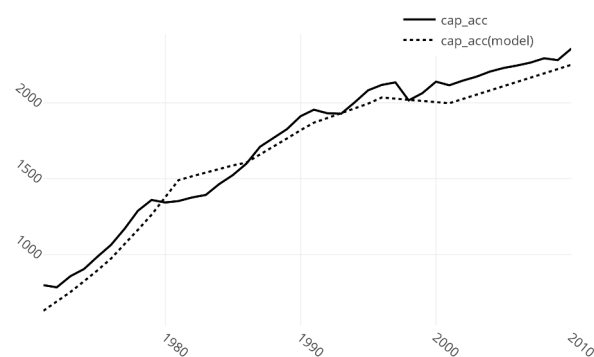
*Source: National Accounts <http://ecos.bok.or.kr>, Labor Force Survey and Economically Active Population Survey, kosis.kr

FIGURE 6.19: The actual wage share in S. Korea* and values given by the model



*Source: *National Accounts* <http://ecos.bok.or.kr>

FIGURE 6.20: The actual capital accumulation and its trend reconstructed by the model : manufacturing sector, 1971-2010



*Source: *National Accounts* and *National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

new capital, is set up to reflect various effects on the profit rate such as the payments of interest and dividends in the model. That is, although the profit rate is the primary variable that could affect the pace of capital accumulation, taking account of the other effects on the profit rate is indispensable for analyzing the relationship between the profit rate and capital accumulation.

FIGURE 6.21: The relationship between the profit rate and capital accumulation

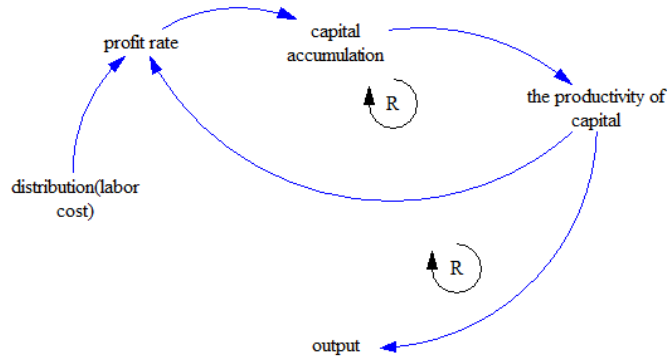


Figure 6.21 describes the relationship relating to capital accumulation. A greater profit rate allows for a higher capital accumulation; this relationship has a positive feedback loop. Capital accumulated by this process converts to production according to the level of the productivity of capital. Thus, the profit rate in the next period is determined by the levels of labor cost and capital productivity. This kind of relationship can be translated into a mathematical form as follows.

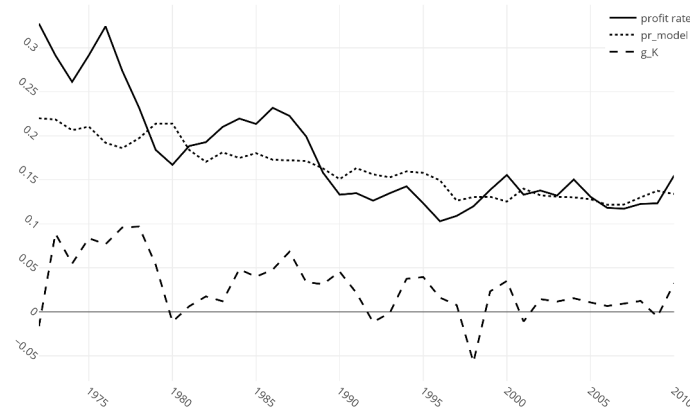
$$\dot{K} = \alpha(1 - \omega)P_K K$$

where $(1 - \omega)P_K$ refers to the profit rate, r , as shown in Equation 6.6, and α is the rate of capitalization. Because firms should pay part of their profits to the interests and dividends, $0 < \alpha < 1$. In other words, there is a gap between the profile of the profit rate and the growth rate of capital accumulation in general. Empirically, we can see this kind of difference between them in the trajectories of the manufacturing sector in the Korean economy. The growth rate of capital accumulation, g_K , is as follows.

$$g_K = \frac{\dot{K}}{K} = \frac{TFF_t - TFF_{t-1}}{NFC_{t-1}} \quad (6.21)$$

where TFF is total fixed capital formation in the *National Account* and NFC is net fixed capital stock.

FIGURE 6.22: The actual profit rate, the profit rate reconstructed by the model ($model_{pr}$), and the growth rate of capital accumulation (g_K): manufacturing sector in S. Korea(1972-2010)



*Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

Figure 6.22 illustrates three trajectories of the manufacturing sector, the profit rate, the profit rate reconstructed by our model, and the growth rate of capital accumulation in S. Korea. As mentioned above, there is a big gap between the profit rates and the growth rate of capital accumulation, which refers to the existence of the rate, α . This is one of the important aspects of the study of the profit rate. Although the historical profile of the profit rate represents the trajectories of technology and distribution, the impact of corporate governance and state policy on the profit rate, such as the payment of interest and dividends or taxation, should be taken into account.

6.4 Concluding Remarks

In the stochastic model of technical change, there are not any *a priori* assumptions concerning the trajectories of technological change. Instead, they are formed by the entrepreneurs' choice of techniques according to the profitability criterion

under a stochastic emergence of techniques and a given set of income distribution. Thus, the adjustment of the probability conditions of the techniques allows us to reconstruct the historical data of the related variables such as the profit rate under the assumption of the distribution, which is the only assumption in this reconstructing process.

This chapter was devoted to fitting the model to the S. Korean historical data such as the productivity of capital, labor productivity, and profit rates (1970-2010) under the two assumptions of income distribution: a constant wage share and constant growth rate of labor cost. Under the first income distribution assumption, the trends of the productivity of capital and labor productivity are represented close to the real trends, whereas there is a quite big gap between the model-trend and actual trend. The fitting process under the second assumption narrows the profit rates gap made under the former. This means that the levels of the profit rates of the manufacturing sector in the 1970s can be explained by the extraordinarily low levels of wage share (See Figure 6.13 and 6.19).

However, the importance of the profit rate in an economy relates to its effect on capital accumulation. If effects of not only the corporate governance, taxation on the profit rate but loan provision of financial institutions have to be taken into account, we can more efficiently estimate the relationship between the profit rate and capital accumulation in the real economy, in particular, the Korean economy.

Chapter 7

Profit Rates, Capital Accumulation, and Income Distribution in the Korean Economy

7.1 Introduction

The neoliberal transformation of the South Korean economy (Korean economy) took place for almost 20 years, from the late 1970s through 1997. In the late 1970s, the Comprehensive Economic Stabilization Policy provided its starting point, and neoliberalism settled in as the country's normal economic system following the 1997 crisis. In particular, the country achieved higher rates of economic growth and an investment boom from the late 1980s through the mid-1990s, and it introduced this as a successful case of the neoliberal reform to other countries, especially emerging economies such as China. However, this growth had a complex aspect that cannot be explained as an achievement of the neoliberal reform. In this chapter, the historical transition of the Korean economy is illustrated in the relationship between the rates of profit and capital accumulation in the country. An evanescent financial effect on capital accumulation during the neoliberal turn of the country, which was a fundamental basis for the investment boom in the mid-1990s, can be observed. After 1997, the country suffered from

the investment stagnation, which is a common feature of neoliberalism in other countries. This paper, however, reviews the slowing pace of capital accumulation in the Korean economy in the context of globalization. In considering income distribution in the Korean economy during the neoliberal transition period, the top income groups made remarkable achievements similar to those in other countries, especially the U.S. As of 2014, the income share of the top 1% group accounted for 13% of the total household income, and that of the top 10% group accounted for 48%, while those values in the 1970s were, on average, 8% and 28%, respectively. In terms of stable growth, however, it is worth noting a historical profile of the income share of 90-99 or 90-95 income group. While the top 1% group had suffered from the relatively large fluctuation of their income share during the transition period between the 1980s and the 1990s, the income share of the groups just below them such as the 90-99 group had steadily increased in spite of the convulsion of their economic system. Section 2 is devoted to the computation of profit rates, and a particular bias in their distributional profile is removed by scrutinizing classifications in the country's national accounting. Additionally, the profit rates in several sectors are computed, and then their impacts on the country's economy is examined not only in terms of capital accumulation but also in terms of business fluctuations. In Section 3, radical changes in capital accumulation during the neoliberal turn of the Korean economy are illustrated from a historical perspective, which suggests that a more specific study on the distributional profile of and social class configuration in the country may be appropriate.

7.2 Profit Rates in the Korean Economy

The profit rate is a prominent variable in studying long-term technological and distributional changes in a country. Furthermore, it is also involved in capital accumulation, in the shadow of taxation policy and corporate governance. In Section 2.1, the profit rate for the economy as a whole adjusted for a distributional profile in the self-employed sector is computed and compared with other sectors, such as the nonfinancial and manufacturing sector. Section 2.2 contributes to the

exploration of possible consequences of profit rates on the economy in terms of both business cycles and capital accumulation.

7.2.1 Profit Rate à la Marx in the Korean economy

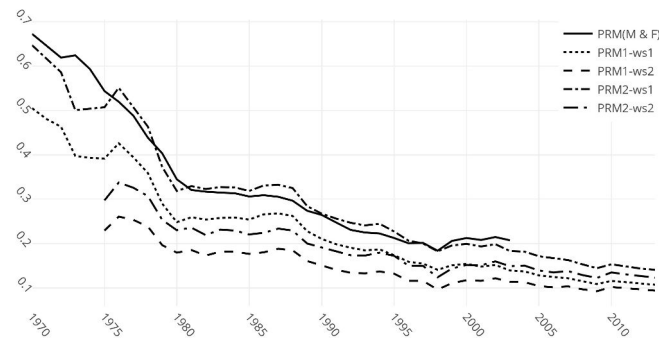
In Marxian economics, the profit rate is a prominent variable that explains many economic phenomena; for example, competition, the stability of the macroeconomy, and historical tendencies of the capitalist economy such as technology and distribution (Duménil and Lévy, 1993b, pp. 3-18). The profit rate defined by Marxian economists (Profit Rate à la Marx: PRM) is as follows.

$$PRM = \frac{NNI - LC}{K} = P_K * (1 - ws)$$

where NNI refers to Net Domestic Income that is GDP minus the consumption of fixed capital in National Accounts. LC and K respectively refer to labor compensation and net capital stock. P_K is the productivity of capital, and ws is the wage share. Therefore, Marxist economists have suggested the PRM as a measure that can follow tracks of technology, P_K , and distribution, ws , in an economy. Figure 7.1 shows the trends of PRMs as defined as above between 1970 and 2013 in all industries of the Korean economy. $PRM1$ and $PRM2$ refer to the ratio of profits to net capital stock and nonresidential capital stock, respectively, and $PRM (M-F)$ refers to the profit rates in the Expanded Penn world Tables version 4.0 as estimated by Duncan Foley and Adalmar Marquetti (M-F). The meaning of $ws1$ and $ws2$ can be seen in Figure 7.2. Because *National Accounts* in Korea considers all incomes of the noncorporate sector to constitute an operating surplus, an additional assumption with regard to the income distribution profile in the noncorporate sector is needed. $ws1$ is the labor share that does not adjust income distribution in the self-employed sector and has an upward trend. However, $ws2$ is supposed to have almost the same distributional profile in other sectors¹.

¹The income share of the self-employed sector is abstracted from Net Value-added.

FIGURE 7.1: PRMs: S. Korea(1970-2013, yearly)



Source: <https://sites.google.com/a/newschool.edu/duncan-foley-homepage/home/EPWT>

Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

FIGURE 7.2: The productivity of capital and wage shares: S. Korea (1970-2013)

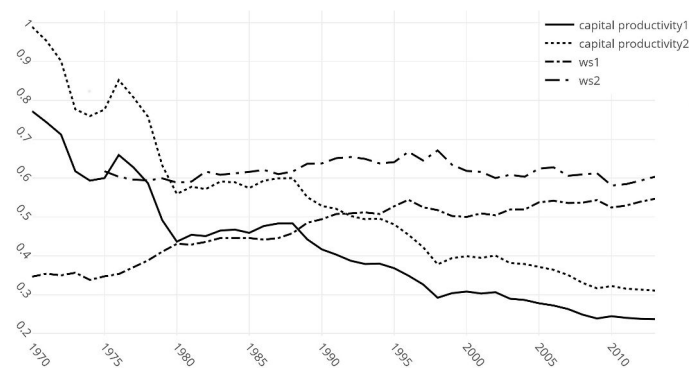
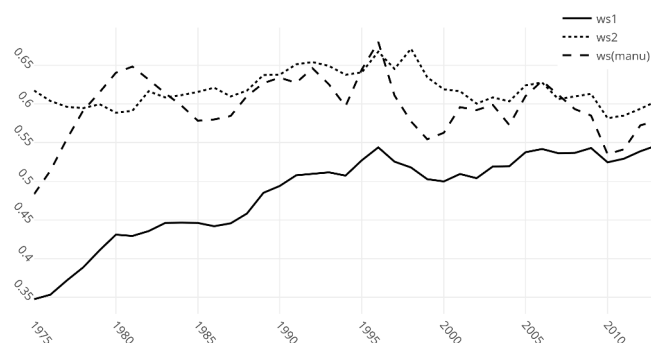


FIGURE 7.3: Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

FIGURE 7.4: The wage shares : S. Korea (1975-2013, yearly)

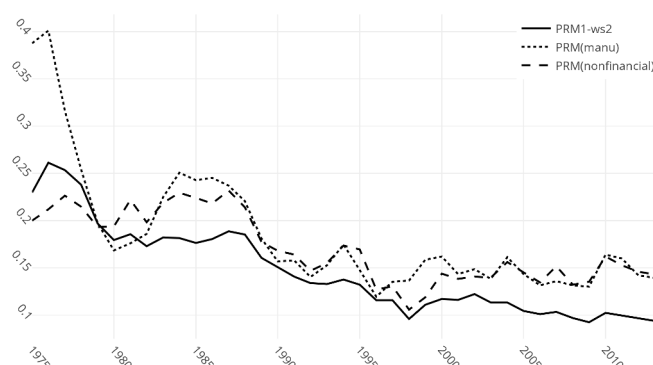


Source: National Accounts and National Balance Sheets in S. Korea.
<http://ecos.bok.or.kr>

For the 1970s, due to differences in the definitions of their profit rates, there are significant gaps between the PRMs that nonetheless grow smaller with the passage of time. *PRM (M-F)* has almost the same profile with *PRM2-ws1*. The measure of capital for its computation is the non-residential capital stock in all industries; for labor compensation, however, income distribution in the self-employed sector is excluded as mentioned above. As a result, they were extraordinary high—almost 70%—in 1970. The cause of the differences, as mentioned above, is seen in Figure 7.2. The gaps between *ws1* and *ws2* become narrower towards the end while the differences between *capital productivity1*, which includes residential stocks, and *capital productivity2*, which excludes them, are nearly constant.

ws (manu) in Figure 7.3 is the wage share in the manufacturing sector of the country. There is a significant gap between *ws1* and other estimates, particularly between the 1970s and the 1990s. Therefore, it is hard to regard *ws1* as an average variable that represents the income distribution profile in the country. Therefore, *PRM1-ws1* as well as *PRM (F-M)* and *PRM2-ws1* could not be regarded as a variable that appropriately represents both the technological and distributional trend in the Korean economy. Let us compare the profit rate in all industries with that in other sectors, such as the nonfinancial sectors. There are cyclical gaps prior to 1997 between the PRM of all industries and that of other sectors,

FIGURE 7.5: PRMs measured by net capital stock including residential : S. Korea (1970-2013, yearly)

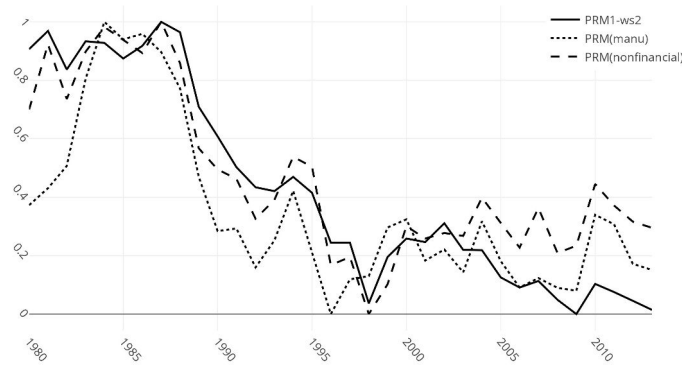


Source: National Accounts and National Balance Sheets in S. Korea.
<http://ecos.bok.or.kr>

such as the nonfinancial sector, *PRM (nonfinancial)*, and the manufacturing sector, *PRM (manu)*, as shown in Figure 7.4. These rates, particularly *PRM (nonfinancial)* and *PRM(manu)*, move in tandem except the late 1970s. In the late 1970s, when a policy of promoting the heavy chemical industry was implemented, as well as during the export boom of the late 1980s, the PRM of the manufacturing sector was distinguished from that of other sectors; however, it converged from the 1980s towards the PRM in the nonfinancial sector. Above all else, it is worth noting the widening gap after the late 1990s between the PRM of all-industries and the PRMs in other sectors as compared with those during all other periods.

In Figure 7.5, each PRM in Figure 7.4 is normalized between 0 (min) and 1 (max). A prominent recovery in the PRM of nonfinancial corporations is explicitly identified in Figure 7.5. While the recovery ratio of the average value of the all-industries PRM after 1997 to that between 1990 and 1997 is only approximately 0.79, that of the nonfinancial PRM and the manufacturing PRM are approximately 0.90 and 0.98, respectively. This prolonged consolidation of the profitability disparity would correspond to a productivity gap if we consider nearly similar pattern of the wage shares in each sector (See Figure 7.3), and it refers to a *deepening heterogeneity* of the economy, which was, before the 1997

FIGURE 7.6: Each variable in Figure 7.3 is normalized between 0 (min) and 1 (max) (1980-2013). Those of the 1970s are excluded because of the relatively high values of the manufacturing PRM



crisis, just a cyclical phenomenon stemming from the export boom in the 1980s and the investment boom in the 1990s.

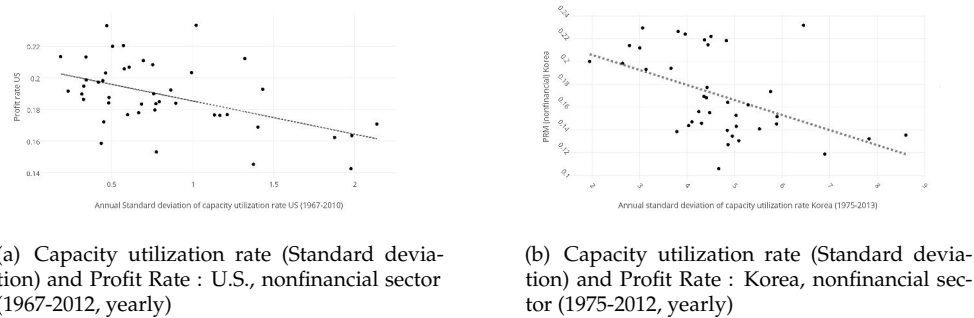
7.2.2 Impacts of the Profit Rates on Korean Economy

This section investigates two impacts of profit rates on the Korean Economy. Section 7.2.1 devotes an empirical study to the relationship between macroeconomic stability and profit rates. The former can be estimated by the standard deviation of fluctuations such as the capacity utilization rate that represents business situations. Section 7.2.2 presents the dynamics of capital in the Korean economy and examines what their main determinant is in the country.

7.2.2.1 Business Fluctuations and Profit Rates

The well-known approach to the relationship between business fluctuations and profit rates was suggested by Weiskopff (1979). Regular declines in the profit rate had spurred severe economic recessions in the postwar U.S. economy. However, it is quite difficult to regard the cyclical declines in the profit rate as the ultimate cause of these crises in general, because they often appear as the

FIGURE 7.7: Business volatility and profit rates



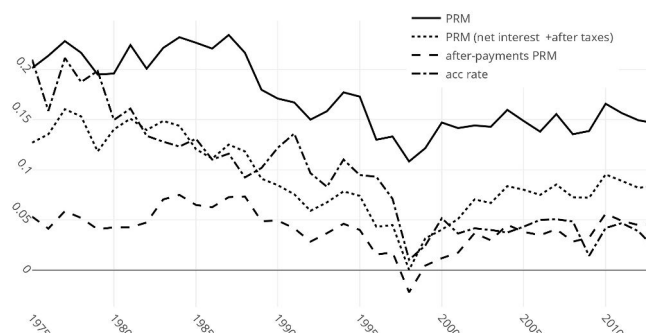
source : The BOK database www.bok.or.kr, The BEA database www.bea.gov.

effects of business fluctuations (Izquierdo, 2013). Instead, Duménil and Lévy (1993a) linked profitability to a stability analysis and suggested that declines in the profit rate have a destabilizing effect on the macroeconomy by modifying firm behavior (Duménil and Lévy, 1993a, p. 28). Their findings can be translated into a relationship between macroeconomic volatility and profit rates because macroeconomic instability leads to an amplification of deviations from normal or average levels of activity.

Figure 7.6 shows a statistical relationship between the profit rate (nonfinancial corporations) and the volatility of business fluctuations in the U.S. (Figure 8.7a) and the Korean (Figure 7.6b) economy. In both countries, a decline in the profit rate compromises the stability of the economy, while higher levels of the profit rate allow each country to ensure stability. Therefore, the increasing trend of instability in the Korean economy over the past 20 years could be accounted for by lower levels of the profit rate in the country. This trend is the first reason why we should pay attention to historical profiles of the rate of profit.

According to a long-term perspective, however, the rate of profit provides historical tendencies of technology and distribution in an economy. Furthermore, the effects of government policy—representations of taxation—and the corporate governance as interest payments and dividends on profitability should also be considered in this study.

FIGURE 7.8: Profit rates and capital accumulation : Korea, nonfinancial corporations (1975-2013, yearly)



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

7.2.2.2 Capital Accumulation and Profit Rates

The basic relationship between the profit rate and capital accumulation can be represented as follows.

$$\frac{K_{t+1} - K_t}{K_t} = \frac{I}{K} = \alpha r = \alpha \frac{\Pi}{K}$$

where r refers to the rate of profit, I is net investment, and $\alpha = I/\Pi$, with Π referring to profits, the capitalization rate, which can be translated into the dividend and interest payment rate, and the profit rate taking account of this rate refers to the after-payments profit rate. In practice, however, credit flows should be taken into account because firms can be provided capital from the banking sector that is available for investment. Therefore, the capitalization rate would be greater than 1 (See Section for details).

Figure 7.7 illustrates the pace of capital accumulation, i.e., the *acc rate*, the profiles of *PRM*, *PRM* that includes firms' property incomes such as interest and dividends after payments of taxes and interest (*PRM (net interest+after taxes)*), and

PRM that includes firms' property incomes after-payments of interest and dividends PRM, *after-payments PRM*). There is a significant gap between *PRM* and *after-payments PRM* during the observation period; the pace of capital accumulation trends downward for a period of time but converged towards *after-payments PRM* following the 1997 crisis.

Before the 1997 crisis, the pace of capital accumulation corresponded with the trend of *PRM (net interest+after taxes)*. In other words, the payment of dividends was not taken into account in nonfinancial firms' investment decision-making. The rate of capital accumulation often surpassed the level of any after-payments PRMs, which was possible because they strongly depended on external funds from the public and private financial sector. However, the propensity for investment radically changed because of the change in corporate governance after the 1997 crisis. The pace of capital accumulation moved in tandem with *after-payments PRM*, such that payment of dividends was now taken into account in nonfinancial firms' investment decision-making.

7.3 Korean Economy in Historical Perspective

From the mid-1970s to the late 1970s, the Heavy Chemical Development Plan (HCDP), led by military dictator Park, constituted the climax of Korea's old developmental strategy : financial repression by the state, policy finance for selected industries, export-led growth, and so on. However, external factors—the global recessions, and the oil price shocks in the 1970s—and internal factors, i.e. real estate speculation², which resulted in a distortion of the credit allocation and increased pressure on real wages following the high inflation rates of the 1970s, cried out for a wholesale change to the Korean economic strategy.

The "American trained neo-classical economists", such as Kim, Jae Ik ([Pirie, 2008: 78](#)), suggested a new plan for the Korean economy that included financial and

²Chaebol speculation in real estate, ..., became the eve of a political storm, as the price of real estate skyrocketed in the inflationary spiral of the late 1970s, which was caused by the monetization of foreign borrowing and vast liquidity flows from the Middle East. ..., a substantial portion of the chaebol's fixed assets was in holding of real estate unrelated to business operation ([Woo, 1991: 173-174](#)).

trade liberalization. This was the onset of the neo-liberal turn of the country's economy. However, it took a quite long time for the country to completely embody this neoliberal transformation; indeed, there were two shocks and one reprieve in the historical process.

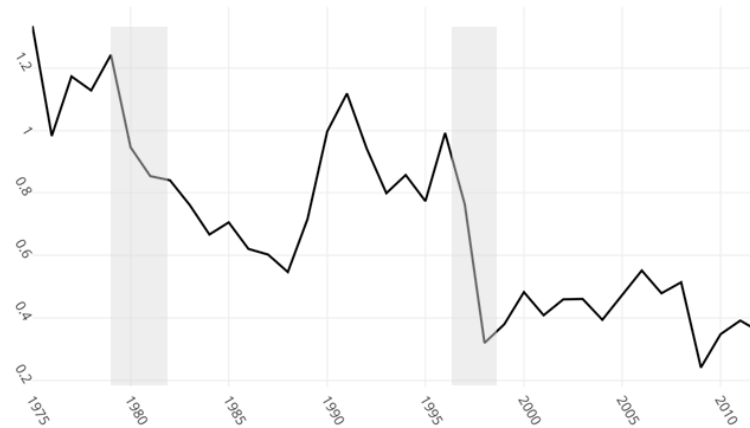
In this paper, *neoliberalism* refers to a disintegration of previous national development strategies that included financial repression, credit allocations for selected industries or corporation, and so on. The Korean economy has been transformed into a more market-friendly one, but this transformation has been accomplished by way of a hybridization process that encompassed previous developmental strategies, such as the export-oriented industrialization led by *Chaebol* and the establishment of a state strategy by highly qualified public and private managers. Thus, the export-oriented industry concentrated in the manufacturing sector has an important position in the economy, and, at the same time, the income and wealth of the *Chaebol* and competent personnel have not damaged by the neoliberal turn of the country at all.

7.3.1 The Neoliberal Turn in the Korean Economy : Two Shocks and One Reprieve

The 1979 crisis did not stem from a structural problem in the Korean economy. As shown in Figure 7.7, a dramatic increase in the financial burdens on corporations is not observed during the period as compared with the 1997 crisis. However, this crisis is sufficient to constitute the first shock that led to the neoliberal turn in terms of policy reform. The Comprehensive Economic Stabilization Policy (CESP) of 1979 emphasized three principles: stabilization, autonomy, and open economy. It aimed to relieve growing pressure on the cost side due to the high inflation rate and change the course of funds crowding into the real estate market pursuant to expected inflation. Strengthening the market mechanism to achieve those goals led to financial and trade liberalization (Cho, 2013).

Figure 7.8 gives information about the capitalization rate, which has been stated in Section 2.2.2 concerning the Korean economy between the years of 1975 and 2013. Two shaded areas in Figure 7.8 refer to the two shocks that led

FIGURE 7.9: The historical profile of the capitalization rate, α : S. Korea, nonfinancial corporations (1975-2013, yearly)



to the neoliberal policy reform. There is an overall downward trend of the capitalization rate during this nearly 40-year period. In both 1979 and 1997— an interval of approximately 20 years—, a sharp break in the capitalization rate is observed. Compared to Figure 7.7, these breaks correspond to radical changes in the pace of capital accumulation. After the first shock, the pace converged towards the profit rate after payment of taxes and interest and then coincides with the after-payments profit rate following the 1997 crisis.

Notwithstanding this event, there were two peaks of investment between the two shocks. The investment boom of these two peaks, which ran from the late 1980s to the mid-1990s, stemmed from two economic situations in the country : the export boom and financial liberalization. The former, which began in the late 1980s, allowed to record a trade surplus for the first time after the civil war. In particular, this boom created a favorable environment in which the export-oriented the Chaebol could expand their own scale economically and politically. However, it must be noted that this boom could not have been achieved without the HCDP that the neoliberal technocrats had deemed a miserable failure in terms of the state intervention.

The Second Peak, which occurred just before the 1997, was reached through a complex state of affairs whereby financial liberalization was combined with the remaining propensity of investment as shown in Figure 7.7 and Figure 7.8. In other words, financial liberalization and the entrance into the OECD facilitated

firms such as the chaebol to locate sources to expand their scale (Haggard and Mo, 2000, pp. 200-208). After the 1997 crisis, investment propensity could not be tolerated by the radical change in corporate governance and financial globalization. This was a *reprieve* between the two shocks.

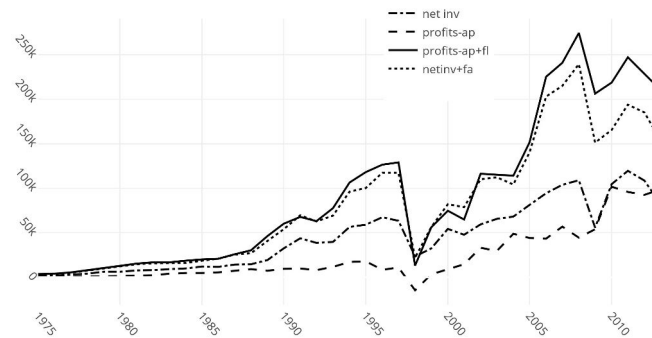
7.3.2 The Acceleration of Globalization and its Results

It is worth mentioning that liability levels have continuously increased in spite of dramatic reduction in the propensity of investment. In Figure 7.9, *fa* and *fl* refer to an increment in financial assets and liabilities, respectively, and *profits-ap* is the after-payments profits. Overall, excess levels of net investment, *net inv*, of nonfinancial corporations relative to *profits-ap* can be seen in Figure 7.9a, but the ratio of *net inv* to *profit-ap+fl* is sharply reduced. In other words, a significant portion of financial sources were used to expand their financial assets and the debt-equity ratio of the corporations was thereby improved after the 1997 crisis.

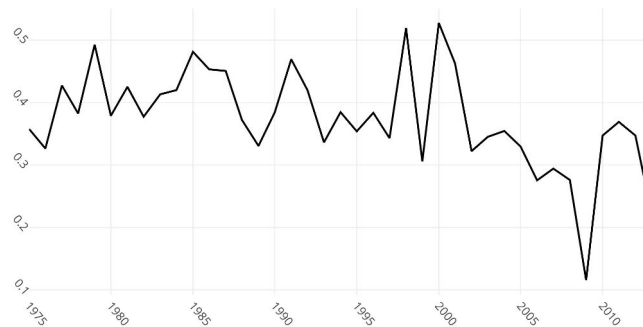
In addition, a widening gap between financial sources and uses after 2005 is shown in Figure 7.9a. This is one of the crucial elements in explaining the current economic state of the country. It refers to the net capital outflow of nonfinancial firms. Figure 7.10 shows FDI and other overseas investment excluding portfolio investment and financial derivatives of the country and the gap from Figure 7.9a. The capital outflow of nonfinancial firms in Korea accounts for a significant portion of FDI and overseas investment in the country, especially after 2005. This fact means that despite stagnation in domestic investment, foreign investment of the nonfinancial corporation has steadily increased.

Figure 7.11 shows long-term trends of the components of demand in the Korean economy between 1970 and 2015. The reprieve of neoliberalism through the investment boom in the mid 1990s is noticeable, but diametrical trends are also prominent after 2000; an enormous rise in both exports and imports can be observed and is coincident with a dramatic increase in outward investment and the stagnation of domestic investment in the country. However, for the last 3 or 4 years, both exports and imports sharply reduced, while the trade surplus has barely remained positive due to a more rapid decrease in import. As already

FIGURE 7.10: Total financial sources and net investment: S. Korea, nonfinancial corporations (1975-2014, yearly)



(a) Financial sources and uses

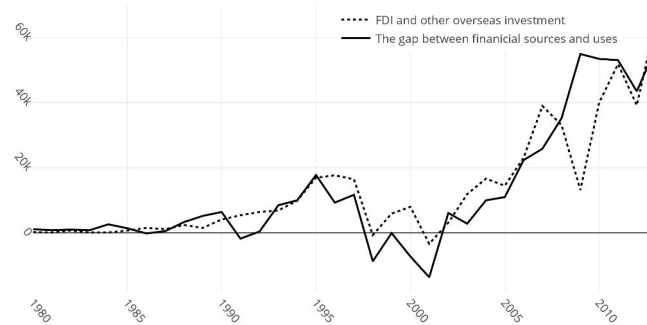


(b) The ratio of net investment to total financial sources

Source: *National Accounts and Flow of Funds* in S. Korea. <http://ecos.bok.or.kr>

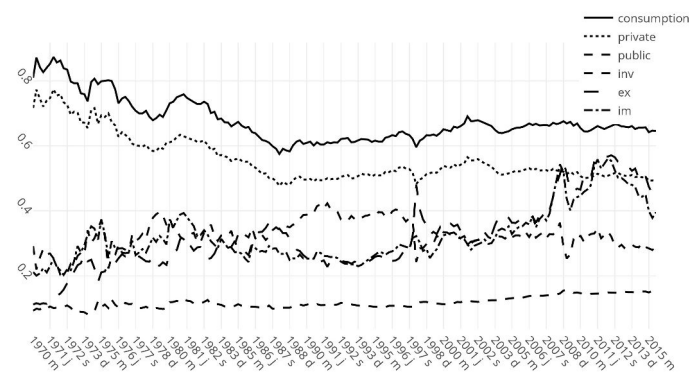
mentioned in the former sections, the widening gap in profitability between the manufacturing or nonfinancial sectors and all industries after the 1997 crisis pertains to the deepening heterogeneity, which has been a buffer rather than an economic obstacle. In the short term, however, it will disintegrate pursuant to the deteriorating state of the international trade. Consequently, if the propensities of other components of demand, such as government expenditures, do not change, this economy will be faced with a cul-de-sac in the near future.

FIGURE 7.11: The Gap between financial sources and uses of nonfinancial corporations, and FDI and other overseas investment: S. Korea (1975-2013, yearly)



Source: *Flow of Funds* and Balance of Payments in S. Korea. <http://ecos.bok.or.kr>

FIGURE 7.12: Demands to GDP : S. Korea(1970-2015, monthly)



Private and public refer to those consumption expenditures. Source: *National Accounts* in S. Korea

FIGURE 7.13: Shares of wages in total income: S. Korea , the corporate sector (1975-2013, yearly)



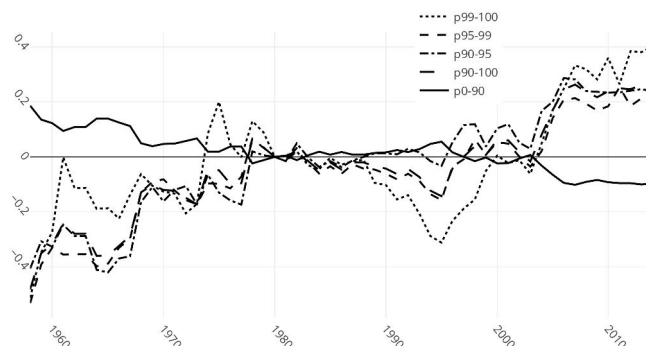
Source: National Accounts in S. Korea and Hong (2015b)
<https://sites.google.com/site/hminki00/>

7.3.3 Neoliberal Income Trends in the Korean Economy

Figure 7.12 shows the wage shares in the Korean corporate sector. *wsa* and *wsb* refer to the ratio of labor compensation, and the ratio of wages and salaries to the total income of the corporate sector, respectively. *wsa* vacillated by approximately 60 % despite an upward trend between 1997, while *wsb* clearly trended downward after the 1997 crisis. This trending is due to a gap between the two variables that corresponds with an increase in employers' social contributions. On the other hand, two peaks on a plateau in the mid-1990s can be observed in Figure 7.8, which roughly correspond with the investment boom.

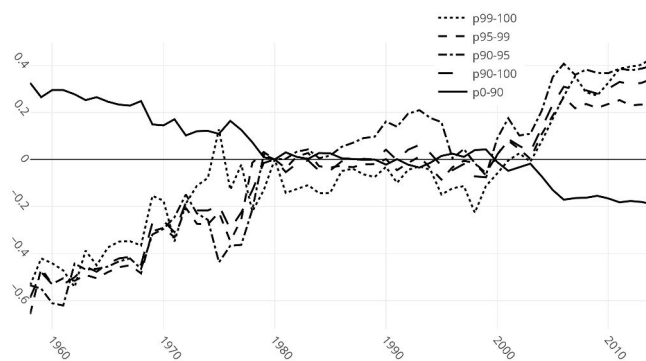
The differences between *wsb* and *p0-99* (0-99 income fractile) and *p0-90* (0-90 income fractile) refer to the top 1% share and the top 10% share in total wages, respectively. There is a significantly upward trend after the 1997 in both of these fractiles, which is consistent with other studies concerning the neoliberal income trends (Duménil and Lévy, 2011, pp. 49-50). However, as mentioned above, a slight increasing trend of the lower income fractiles in the mid-1990s corresponds to our analysis concerning the *reprieve* in the mid-1990s, as detailed in the foregoing section. In other words, the dramatical of the top 10% income

FIGURE 7.14: Shares of wages in total household income: S. Korea (1958-2014, yearly)



Source: Hong (?) <https://sites.google.com/site/hminki00/>. All series have been normalized to 0 in 1980.

FIGURE 7.15: Income shares including capital and business income in total household income received by each fractile: S. Korea (1958-2014, yearly)

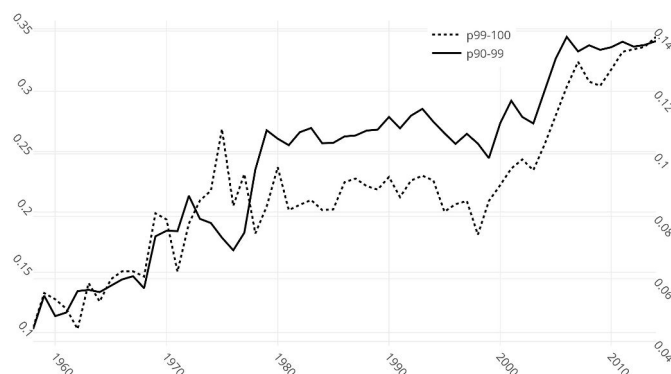


Source: Hong (2015a) <https://sites.google.com/site/hminki00/>. All series have been normalized to 0 in 1980.

share, and even the top 1%, which constitutes one of the striking features in neoliberal income trends, appeared after the 1997 crisis.

Figure 7.13 shows the shares of wages in total household income received by various fractiles between 1958 and 2014 in the Korean economy. The top 10% share of wages has an overall upward trend but the speed of increase was

FIGURE 7.16: The wage shares received by the 90-99 (Left axis) and the 99-100 fractiles (Right Axis): S. Korea (1958-2014, yearly).



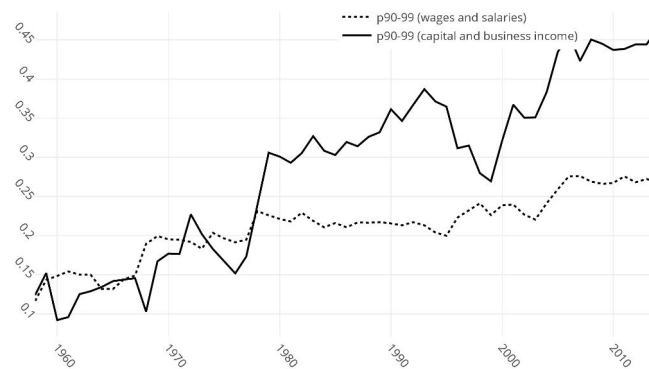
Source: Hong (2015a) <https://sites.google.com/site/hminki00/>

moderated between the 1980s and 1990s. The latter resulted from a decrease in the wage share of the 95-100 fractile, most particularly in the wage share of the 99-100 fractile; i.e., the top 1% wage share, from the late 1970s to the mid-1990s.

Figure 7.14 illustrates profiles of the income shares, including capital and business income, that were received by each fractile. In particular, from the 1980s to the mid-1990s, the income share of the 90-95 fractile steadily increased. If taking into account the increasing share of income of the 90-95 fractile given that the 90-95 and 95-99 fractile account for the the top income share trend, a relatively upward trend of the income share of the 90-99 fractile compared with that of the top 1% can be observed overall (See Figure 7.15). This finding is due to the complex effect of several different impacts on each income fractile between the 1980s and the 1990s: the stabilization policy and restructuring of the early 1980s, the great workers' struggle in 1987 and the wave of labor union establishment in the late 1980s, and the investment boom of the mid-1990s.

First, the moderation of income inequality in the 1980s and the 1990s shown in Figures 7.13 and 7.14, stemmed from a wage stabilization policy in the early 1980s (Cho, 2013, p. 70). Second, the growth of the active labor movement was a starting point for the slightly decreasing trends of the top income groups—that

FIGURE 7.17: The wage share, and capital and business income share of the 90-99 fractile: S. Korea (1958-2014, yearly)



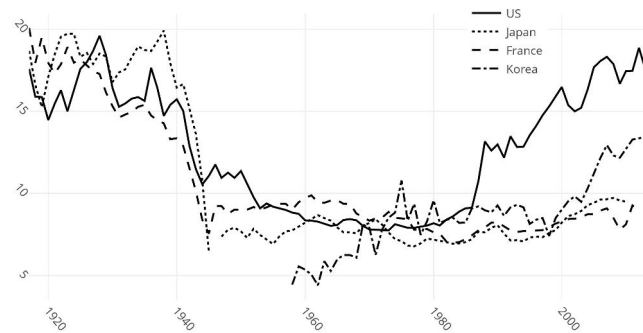
Source: Hong (2015a) <https://sites.google.com/site/hminki00/>

is to say, the 95-99, 99-100 group—, although the wage share of the 90-95 group was little affected by it. Instead, as shown in Figure 7.14, the latter's total income share constantly increased as compared with other income groups.

Figure 7.16 shows the wage share and the capital and business income share of the 90-99 group. In 1979 and 1980, there was a remarkable divergence between the two variables that had previously moved in tandem. Therefore, it seems that a rise in the capital and business income of the 90-99 group has contributed to the near constant upward trend at least between the 1980s and the 1990s. After the 1997 crisis, the performance of the income shares of the two top income groups was as prominent as that of the top 1% income group.

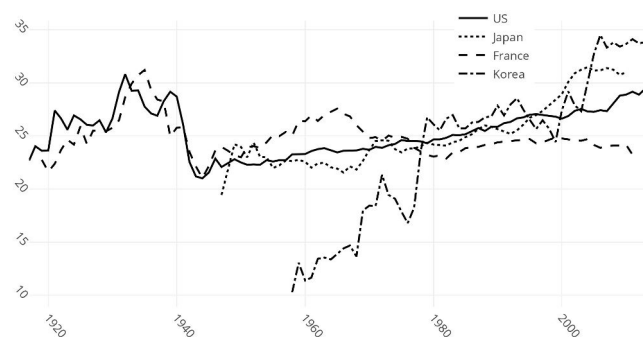
From an international point of view, the achievement of the top income groups in the Korean economy is more prominent. Figure 7.17 shows the top 1% income share of four countries. Compared to France and Japan, the pace of increase in the top 1% income share after the 1997 crisis was remarkable, and it could be compared with that of the US economy. However, the 90-99 group was ranked highest among all other countries in terms of performance. Additionally, after the neoliberal turn in approximately 1980, the income share of the two income groups converged towards that of the same groups in the other countries' which

FIGURE 7.18: Top 1% income share : the U.S., Japan, France, and S. Korea



Source: World Income Database www.wid.world, Hong (2015a)
<https://sites.google.com/site/hminki00/>

FIGURE 7.19: p_{90-99} income share : the U.S., Japan, France, and S. Korea



Source: World Income Database www.wid.world, Hong (2015a)
<https://sites.google.com/site/hminki00/>

made the performance of the 90-99 income group particularly dramatic (See Figure 7.18).

In sum, inequality in income distribution in the Korean economy has constantly increased since the 1960s, when the economic development of the country was on track. It seemingly moderated itself between the 1980s and the mid-1990s, but it must be considered pursuant to the political and economic environments of the country at that time. Above all, a note must be made of the achievement of

the 90-99 income group that, although it was composed of top public and private managers and professionals, particularly those in the law, health, and finance fields, it was *less* dependent on capital and business income compared with the top 1% group as mentioned above. Therefore, it seems that this group—rather than the top of the top income classes, such as the top 1% group, which were relatively *more* dependent on capital and business income—was the class that constantly benefited from the neoliberal turn.

7.4 Concluding Remarks

Thus far, profit rates, capital accumulation and income distribution in the Korean economy have been examined from a historical perspective. The profit rate is a variable used to represent technological and distributional patterns in an economy, and we assume that it has a close relationship with business fluctuations in the short term and capital accumulation in the long term. It would therefore affect the crucial stability condition in an economy and determine the pace of capital accumulation in providing larger funds available to invest in new capital. The impact of this observation on these two relationships in the Korean economy is as follows.

1) The profit rates in the Korean economy give information about the technology in and distribution of the country in the long term. First, the wage share of the country stabilized approximately 60% despite the recent slight downward trend after 1997. Second, in terms of long-term technological trends, secondly, there is a consolidated technological heterogeneity between the nonfinancial or manufacturing sector and all industries because of the overall stabilized distribution that was mentioned above. In other words, as of 2013, manufacturing and nonfinancial PRM had recovered approximately 90% of their 1990s PRM as compared with all industries PRM.

2) In the short term, it is very hard to define a relationship between profit rate and business fluctuations. Like the U.S., a lower profit rate increases the volatility of business fluctuations in that Korean economy; however, this fact means that profit rate would be one of the major factors in macroeconomic stability.

3) By definition, the profit rate has a close relationship with the pace of capital accumulation. The relatively high performance of the Korean economy between the late 1970s and the mid-1990s, however, depended strongly on external funds from financial institutions pursuant to a developmental strategy for the country. After the 1997 crisis, this financial acceleration effect on capital accumulation disappeared, and the pace of capital accumulation converged towards the after-payments rate of profit.

4) However, it is worth noting that there is a financial acceleration effect on the overseas investment of nonfinancial corporations in the country. With their increased assets, the scale of liabilities of nonfinancial corporations in the Korean economy steadily increased. This event, however, led not to domestic investment but to dramatically increased overseas investment, such as FDI, after 2005.

Considering income distribution in the Korean economy, its historical profile is much more complex than that of the advanced countries, such the U.S., in terms of the common features of income distribution in neoliberalism. This profile is attributable to the previous developmental strategy that depended on a mobilization of the labor force for selected industries and repressed on workers' movements as well as the financial sector. In particular, it is necessary to account for the historical profile of the income share of the 90-95 group, which is the least dependent group on capital and business income among the top income groups. In the general context that we suggested, it can be summarized as follows.

5) Considering labor compensation, the share of wages in the Korean economy has fluctuated by approximately 60% due to an increase in employers' social contributions. However, after the 1997 crisis, there was a downward trend in the wage share that excludes the social contribution; during the same period, the wage share of the top 1% and 10% sharply increased.

6) The top income share in the Korean economy saw an overall upward trend since the late 1950s. Due to the slightly increasing trend of the 0-90 income group's income share, it stagnated between the 1980s and late 1990s. However, the share of the 90-95 group 90-95 in the 90-99 group, which is relatively independent from the contribution of capital and business incomes as compared with the top 1% group, suffered some minor damage during the same period.

Ironically, the capital and business income share of the 90-99 group rose significantly upon the neoliberal turn of the Korean economy. It made it possible to not only increase income share level but to maintain the relatively stable pace of growth of the group's income share compared with other top income groups, even during the neoliberal turn. This result may correspond to a crucial role played by those classes in the neoliberal transformation of the economy.

Chapter 8

Profit Rates and Capital Accumulation in the Korean Economy: 1970-2012

8.1 Introduction

A primary purpose of this paper is both to compute profit rates and to investigate their impact on capital accumulation in the South Korean economy (Korean Economy). The only detailed report available in English speaking countries for the estimation of the profit rates was Jeong's paper ([Jeong, 2007](#)), which calculated them in the tradition of Marxian economics. One of the reasons for this scarcity is, above all, the absence of a solid statistics data series. The authorities in charge of the construction of national statistics such as the Bank of Korea (BOK) or *Statistics Korea*, have never released the official data set with regard to capital stocks.¹ Thus, the related studies have been mostly based on individual researchers' efforts including Jeong's paper. However, it makes us hard to go further due to the inconsistency and indiscrimination that the data hold.

Meanwhile, the Bank of Korea, jointly with *Statistics Korea*, released a brand new

¹They have ever provided a periodical data set by the *Survey of National Wealth* for the estimation of the stocks once a decade since 1968

data series for a transition to new national accounting system, which is called the 2008 System of National Account.² This data set is constructed on the basis of the *OECD Manual for Measuring Capital* (OECD, 2009). Therefore, in this paper, the profit rates in the Korean economy are newly computed on the basis of the official data set, and they updated up to the recent years on the one hand. On the other hand, various types of the profit rates are suggested for further study of their effects on other economic relation, particularly on capital accumulation. This study examines several important characters of the Korean economy from a historical perspective. First, we can see the famous Marxian thesis of the tendency of the rate of profit to fall in the Korean economy. Nevertheless, it has different effects on different sectors of the economy. Apart from the economy as a whole, the profit rates of the manufacturing and the corporate sector in the country significantly recovered levels of the 1990s after the 1997 crisis. Second, it is necessary to take into account the effect of the state policy and corporate governance on the profit rates. The taxation policy of the state has no counter-effect on the decreasing rate of profit in the long term because a tax burden on firms in the country increased immediately after the crisis. This may stem from government policies in order to be compensated for the spending on the structural reform during the crisis. Third, we should take account of a financial effect on capital accumulation in S. Korea although capital accumulation in the country currently depends on their after-payment rate of profit, the numerator of which is after-tax profits minus interest and dividends. A rapid growth of capital accumulation of the county was prominent from the late 1970s through 1990s, which was strongly depended on external funds beyond the retained profits. In particular, the sudden dissolution of the financial effect was deeply related to the financial liberalization process of the country since the 1980s. Section 2 is contributed to the update of profit rates in the economy as a whole (all industries) as well as different sectors, such as the manufacturing and the corporate (nonfinancial and financial) sector. The taxation impacts on the rate of profit are analyzed in Section 3, where we illustrate its contribution to the long-run and short-run trend of the rate of profit. In Section 4, the relationship between profit rates and capital accumulation is examined by a time-series econometric method, and the financial acceleration effect on capital accumulation inherent

²See <http://www.bok.or.kr/broadcast.action?menuNavId=634> On May 14th, 2014

to the Korean economy. Thus, a new econometric model that takes the effect into account will be presented in Section 5. On the basis of these observations, we build two models to reconstruct possible paths with or without the financial effect in Section 6. Lastly, we discuss these results from a historical perspective in section 7.

8.2 Profitability trends in S. Korea

The profit rate *à la Marx* (PRM) refers the ratio of total income minus labor compensation to net capital stock (Duménil and Lévy 2011: 57-8), which is the most fundamental Marxian ratio—a large or broad concept of the profit rate (Duménil and Lévy 2002). Apart from Jeong’s estimation that we mentioned, we can also find the profit rate in the Korean economy as estimated by Marquetti and Foley’s data on EPWT (Expended Penn World Table), and their data series is sufficient to compare with our new computation due to its historical range. The PRM *à la Marx* is defined as follows.

$$PRM = \frac{Y - W}{K} \quad (8.1)$$

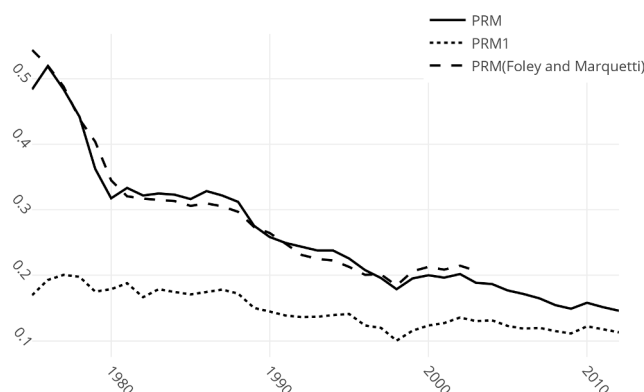
where Y and W refer to NNP (Net National Product) and labor compensation, respectively. The denominator, K , is net capital stock. This is decomposed into the productivity of capital, Y/K , and the profit share, Π/Y , as follows.

$$PRM = \frac{Y}{K} \frac{\Pi}{Y} \quad (8.2)$$

where Π refers to total profits and is identified with $NNP - W$. That is, the profit rate is a variable that represents an evolutionary process of technology and distribution in an economy.

Figure 8.1 shows the trends in three different measures of the profit rate in the Korean Economy: PRM (F-M: Foley and Marquetti), PRM , and $PRM1$, both of which

FIGURE 8.1: Two measures of the profit rate *à la Marx* (PRM): Korea (percent, yearly) Marquetti and Foley's PWT profit rate is brought from v , the gross profit rate in the Marquetti and Foley's table PRM from our calculation.



Source: <https://sites.google.com/a/newschool.edu/duncan-foley-homepage/home/EPWT>

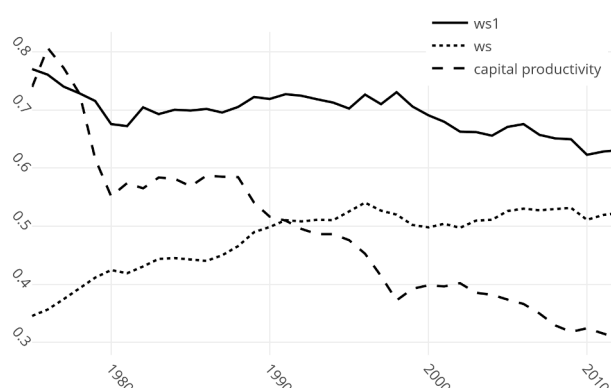
Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

are our computation of the rate of profit. For the computation of $PRM(F - M)$, the estimate of net capital stocks standardized in 2005 PPP is used, whereas our denominator is net fixed capital stock (non-residential) at the current price in billion Korean Won. $PRM(F - M)$ and PRM have a similar profile—an overall downward trend—in Figure 8.1, which may well recall the famous Marxian thesis, *the tendency of the rate of profit to fall*. However, the levels of two measures are extraordinarily high, especially almost 50% in the 1970s.³ $PRM1$ in Figure 8.1 refers to the rate of profit with an adjusted wage share. There is a significant gap between the $PRM1$ and other measures because total wages in the adjusted wage share are defined as the wages plus operating surplus of the self-employed persons in National Account of S. Korea.⁴ If we exclude the operating surplus of

³ Although PRM based on the new updated series of capital stock are fitted with the Marquetti-Foley data, both the $PRM(F - M)$ and PRM are much higher than in other countries; For example, the rates of profit of Japan in the 1970s in the Foley-Marquetti data series ranged from 40% to 20%.

⁴ National Account in S. Korea considers all incomes of the self-employed persons to constitute the operating surplus

FIGURE 8.2: Decomposition of PRM and PRM1: Capital Productivity and Wage Shares (Yearly, 1970-2012)



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

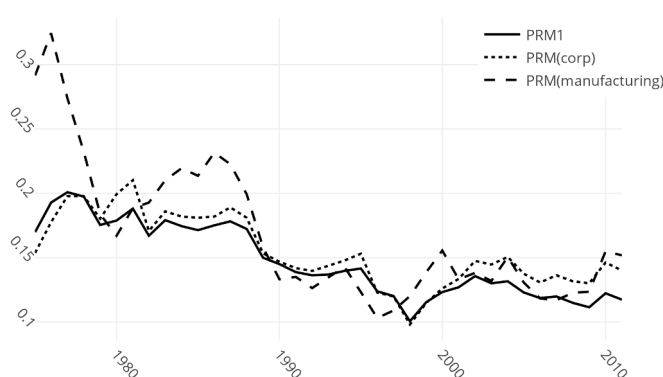
the self-employed persons from the estimate of the total wages, the wage share in the 1970s maintained an extraordinarily low level around 0.4 (*ws* in Figure 8.2)

Figure 8.2 describes the decomposition of *PRM* and *PRM1* in the Korean economy. Evidently, capital productivity has a long downward trend during the observation period, which pertains to a deterioration of technical conditions in the economy as a whole. However, the profiles of the wage shares have different patterns. The *ws* (non-adjusted wage share) of *PRM* had constantly risen from 1970 to 1997, and it, however, stabilized just below 0.5 (50 percent). Therefore, the constant downward trend of *PRM* stems from both the unrestored productivity trend and the upward trend of the wage share. It appears that the Marxian thesis is identified in the Korean economy once again. But *ws1* (the adjusted wage share) of *PRM1* is mostly stabilized around 0.7. Therefore, the overall downward trend of the *PRM1* results from the fall of the capital productivity, and its falling range is from 0.20 to 0.10. In addition, the last value of *PRM1* in the observation period is higher than that in 1997 unlike the level of *PRM(F - M)* and *PRM*. Consequently, a more delicate process dealing with an income distribution structure in the Korean economy will be needed in order to

completely grasp the trend of the rate of profit in the country.

Besides these problems, it is worth noting that PRM1 in Figure 8.1 is that of all industries in the country, including all of corporations, households and non-profit organizations, and government. Let us consider other PRMs such as

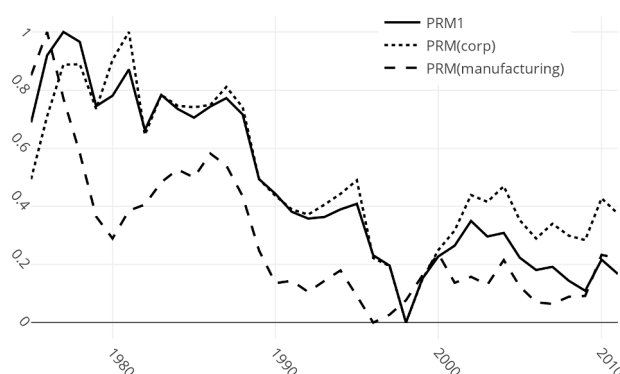
FIGURE 8.3: Three measures of the profit rate: Korea(yearly, 1975-2012). PRM (corp) and PRM (manufacturing) refers the profit rate *à la Marx* in the corporate and manufacturing sector, respectively



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

that of the corporate sector or the manufacturing sector. Figures 8.3 and 8.4 show *PRM1*, which is the same variable with the *PRM1* in Figure 8.1, *PRM (corporations)*, and *PRM (manufacturing)* in a different way. Unfortunately, net capital stock data in the corporate sector have released only between 2005 and 2012. Instead, we use another data series which refers to productive capital stock concerning capital stocks to compute the rates of profit in the institutional sector, that is, corporations. This dataset has been constructed on the basis of the age-efficient profiles at current prices. The profit rate computed using this data set of capital stock is overestimated in the early period, and the stock data make the profit rate underestimated in the last period in comparison to the net capital stock, because there is a gap between net capital stock and productive capital stock. In general, the latter grows faster than the former as time goes on (OECD, 2009: 60-2). Nevertheless, the growth rates of two data sets in the

FIGURE 8.4: Each variable in Figure 8.3 is normalized between 0(min) and 1(max).



manufacturing sector that we can come to hand both series of data have almost same in spite of a difference between the initial values in 1970. For these reasons, this rate would be an approximate estimator before the full data series is released. Although there are some measurement errors in this estimation, however, the reason we use them is because it allows us to compute other measures with regard to taxes, and interest and dividends consistent with Flow of Funds and National Accounts. In particular, a normalizing process between 0 (min) and 1 (max) in order to avoid the difficulty of the direct comparison of trends by the different levels in Figure 8.3 is applied in Figure 8.4. The declining trends of all the rates of profit are evident during the observation period. However, it is worth noting that there are quite upward trends of the rate of profit within the corporate and manufacturing sector following the East Asian crisis with which the country was faced in 1997.

In the profiles of these new measures, we can see a significant effect of the classification on the trends of the profit rates if we take account of the importance of those sectors in the country. Except the 1970s when the remarkable levels were scored, we need to distinguish successive levels for three periods, 1980-1989, 1990-1997, and after 1997, that is to say, 1998-2012 on the basis of serious economic recessions (1980, 1989, 1997, 2008) in the country.

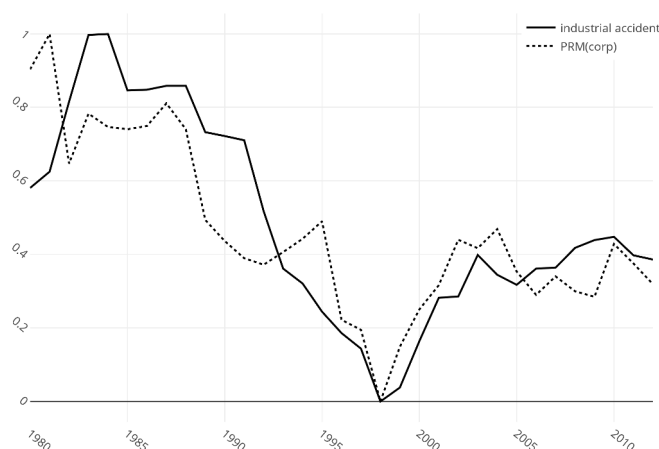
Table 8.1 shows the annual average profit rates in each successive period. PRMs

TABLE 8.1: The annual average rates of profit: PRM, PRM (corp), and PRM (manufacture)

Case	1980-1989	1990-1997	1998-2012
PRM1	0.17	0.13	0.12
PRM (corp)	0.18	0.14	0.13
PRM (manu)	0.20	0.12	0.13

($PRM1$, $PRM(corp)$ of corporations, and $PRM(manu)$ of the manufacturing sector) definitely declined during the observation period, but the level of the average $PRM1$ in 1998-2012 had recovered 90% ($0.12/0.13$) of that in the 1990s before the Asian crisis in spite of the impact of the well-known Subprime crisis in 2008. Likewise, $PRM(corp)$ had a similar pattern as $PRM1$, but its recovery ratio is 0.95 ($0.14/0.13$). Furthermore, it was restored to 72% ($0.13/0.18$) of the 1980s. In terms of the recovery, $PRM(manu)$ is outstanding, whose ratio is 1.07 ($0.13/0.12$).

It is worth mentioning another aspect of the recovery in profitability in the coun-

FIGURE 8.5: $PRM(corp)$ and the number of industrial accidents in Korea(1980-2012): normalized within the range 0 to 1.

Source: National Accounts, National Balance Sheets in S. Korea. <http://ecos.bok.or.kr>; Ministry of Employment and Labor in S. Korea, Year Book of Employment and Labor Statistics

try. Figure 8.5 shows almost the same profile between the PRM of corporations

and the number of industrial accidents, which may be the cost of the recovery in profitability in the country. This represented that the recent recovery was a paradigm of the destructive side of capitalism in the country.

In the next sections, we focus on a taxation and financial impact on the rates. Despite the importance of the manufacturing sector in the country, there is no consistent data to analyze the impacts on the sector. Therefore, the corporate sector or nonfinancial sector is our unit of analysis in the following sections because we can investigate various effects of state policy or corporate governance in the sectors.

8.3 Taxation Impacts on the Profit Rates

In the U.S. economy, taxation policy has a considerable countertendency effect on the decline of the profit rate. For example, Duménil and Lévy showed that a recovery ratio to the 1970s and restoration ratio to the 1950s and 1960s of the rate of profit for successive periods, 1952-1971, 1974-1983, and 1998-2007 are 1.29 and 1.06, respectively (Duménil and Lévy, 2011: 58-9).

In order to fully examine this effect, not only production taxes or indirect taxes, but also profit taxes paid by corporations should be taken into account. In general, net operating surplus in National Accounts refers to the portion subtracting indirect taxes from profits. Thus, We can estimate after-all taxes profit by deducting profit taxes from net operating surplus: a ratio of net operating surplus to capital stocks refers to after-production taxes profit rate; after-all taxes profit rate refers to a ratio of net operating surplus minus the profit taxes to capital stocks. According to Equation (8.1), each rate of profit is defined as follows.

$$PRM_{afterprotax} = \frac{Y - W - PT}{K} \quad (8.3)$$

$$PRM_{afteralltax} = \frac{Y - W - PT - PFT}{K} \quad (8.4)$$

where $PRM_{afterprotax}$ and $PRM_{afteralltax}$ refer to the after-production tax profit rate and the after-all taxes profit rate of corporations, respectively. Also, PT and

PFT are the production tax and profit tax paid by corporations.

Figure 8.6 shows $PRM(corp)$, after-production tax profit rate ($PRM_{afterprotax}$),

FIGURE 8.6: $PRM(corp)$, After-production rate of profit, After-all taxes rate of profit: corporate Secor, Korea (yearly, 1975-2012)



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

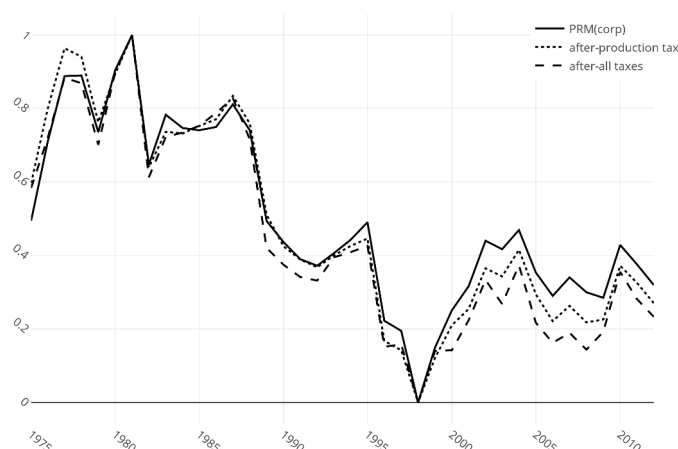
and after-all taxes profit rate ($PRM_{afteralltax}$) with different levels. Evidently, there is a gap between $PRM(corp)$ and other variables. Compared to Figure 8.3, it is difficult to compare with each other because of the significant difference between them. Therefore, they should be normalized between 0 (min) and 1 (max) in Figure 8.7.

TABLE 8.2: The annual average rates of profit: $PRM(corp)$, After-production taxes, and After-all taxes

Case	1980-1989	1990-1997	1998-2012
$PRM(corp)$	0.18	0.14	0.13
After-production taxes	0.14	0.10	0.09
After-all taxes	0.12	0.08	0.08 (0.077)

$PRM(corp)$ did not fully recover to the levels of the 1980s or even the 1990s, and the effect of both the after-production tax and after-all taxes profit rate on $PRM(corp)$ effect didn't have a countertendency *in the long run*. Overall, All

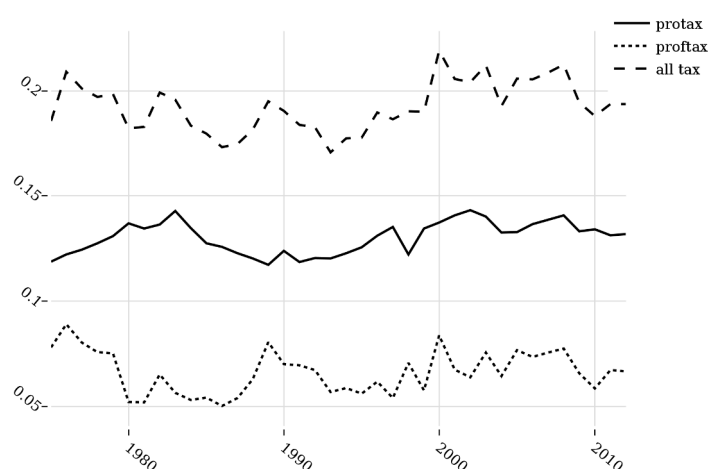
FIGURE 8.7: All the measures in Figure 8.6 are normalized between 0 (min) and 1 (max): corporate Sector, Korea (yearly, 1975-2012)



these profit rates have a downward trend over the entire period and are nearly consistent with the fluctuations of $PRM(corp)$. However, after-production tax rate of profit recovered approximately 92% ($0.09/0.10$) and the recovery ratio of after-all taxes profit rate is 89 percent ($0.077/0.08$). Nevertheless, both of the rates of profit that take the tax impact into account failed to be restored to the levels before the 1990s (1980-89). Interestingly, the gap between $PRM(corp)$ and after-taxes profit rate became narrower during the observed period, but the ratio of restoration in the after-all taxes profit rate (63 percent) is less than that of the after-production tax profit rate (68 percent). However, the restoration and recovery ratio of $PRM(corp)$ is slightly greater than other indexes considering the taxation impacts as 95 and 72 %, respectively (See Table 7.2).

In Figure 8.8, *protax* and *proftax* refer to the ratio of the production taxes and profit taxes to value-added of corporations in S. Korea, respectively. As seen from Figure 8.8, we can observe the absence of the long run countertendency effect on $PRM(corp)$ in two respects. First, there is no special trend of the share of taxes to value-added, but they fluctuate during the observed period. Second, however, we can observe the exceptional levels of those variables between 2000 and 2008, followed by a sharp reduction that may stem from a response to the impact of the Subprime crisis in 2008, resulting from a simultaneous increase in

FIGURE 8.8: The ratio of production tax (*protax*), profit tax (*proftax*) and all taxes (*all tax*) to value-added: corporate sector in Korea (yearly, 1975-2012)



Source: *National Accounts* in S. Korea. <http://ecos.bok.or.kr>

production taxes and profit taxes. In particular, the rise in the share of profit taxes in 2000 is noticeable—it increased by almost 40 percent in the year compared with ones in the previous year, the level of which records the highest one during the observation period except that in 1976.

TABLE 8.3: Augmented Dickey-Fuller test

variables	t-Statistics	probability
PRM_{corp}	-1.490178	0.5274
<i>protax</i>	-5.285225	0.1475
<i>proftax</i>	-3.591527	0.0108

However, we could not jump to the conclusion that the countertendency effect of taxation on the rate of profit does not hold in the Korean economy. Furthermore, we need to investigate a relationship between them more specifically. There are three series of data, PRM_{corp} , the ratios of production taxes (*protax*) and profit taxes (*proftax*) to value-added, and the null-hypothesis for the Augmented Dickey-Fuller test cannot be rejected in PRM_{corp} and *protax* at the significance 5% level, and they have a unit root. However, *proftax* is a stationary variable,

which has no unit root (See Table 8.3).

All variables are differentiated in the first order. We pay attention to if the change in PRM_{corp} affects the determination of the ratio of the profit taxes in the next period or not. A simple regression model could help to find the relationship. If it is established, a positive relation between the change in PRM_{corp} in period $t - 1$ and $proftax$ in period t means there is a countercyclical effect of taxation on the rate of profit at least *in the short term*.

TABLE 8.4: $DPROFTAX = C(1)*DPRM(-1) + C(2)*DPROTAX(-1)$: Ordinary Least Squares

	coefficient	probability
c(1)	0.271124	0.0279
c(2)	0.084887	0.7997
$adj.R^2$	0.12	

Because the Serial Correlation LM test, Breusch-Pagan-Godfrey Heteroskedasticity test, and the normality test do not reject the null hypothesis at the significance 5% level, respectively, the residuals have no serial correlation and heteroskedasticity (See Table F.1 and F.2 in Appendix F), and are normally distributed (Jacque-Bera: 0.35, probability: 0.83). Therefore, the OLS method can be applied to this test. Through this test, it is evident that the positive relationship that we suppose above is established. In the Wald test for the coefficients, the null hypothesis ($c(1)=0$) is rejected (Chi-square, $df(1)$: 5.278481, Probability : 0.0216). These results mean that the profit tax burden on corporations diminished in period t if the rate of profit in corporate sector became lower in period $t - 1$ compared with one in the previous period in the Korean economy (See Table 8.4).

8.4 Which of Profit Rates is most deeply involved in Capital Accumulation?

In general, many studies on the rate of profit suggested that it is deeply correlated with capital accumulation in a target country. Duménil and Lévy found a 'tight

relationship between the accumulation rate and the rate of retained profits' (Duménil and Lévy 2011: 152-153), in the U.S. and France. However, it is worth noting that the measure involved in the pace of capital accumulation is ROE (Return On Equity), which is the ratio of profits to net worth rather than net fixed capital (Duménil and Lévy 2004: 89-94). To compute this kind of rate of profit, financial assets and liabilities data in Flow of Funds should be used in this computation.

If the after-payment (interests and dividends) ROE is taken into account, the

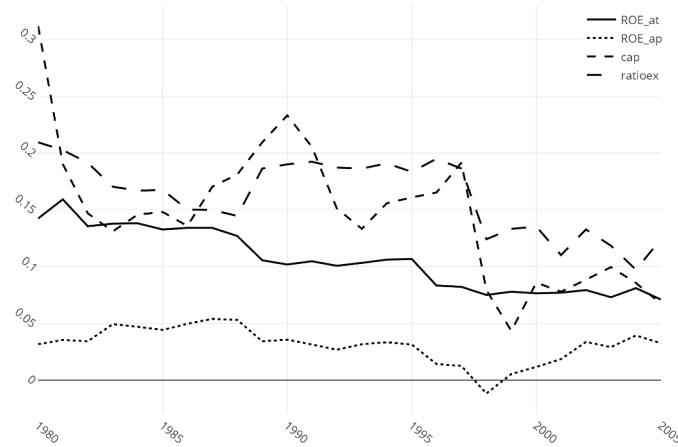
FIGURE 8.9: After-payment(interest and dividend) ROE of the nonfinancial corporations in S. Korea (1980-2005)



Source: *National Accounts, National Balance Sheets, and Flow of Funds* in S. Korea.
<http://ecos.bok.or.kr>

restoration effect is extremely outstanding as shown in Figure 8.9. Despite this effect, the rate of capital accumulation did not recover to the level between the 1980s and 1990s. So which of profit rates were concerned with capital accumulation in the Korean economy? For this analysis, each rate of profit (ROEs) is defined as follows.

FIGURE 8.10: ROEs, capital accumulation, and external financing ratio(1980-2005)



Source: *National Accounts, National Balance Sheets, and Flow of Funds* in S. Korea.
<http://ecos.bok.or.kr>

$$ROE_{at} = \frac{\Pi - AT}{TA - NL} \quad (8.5)$$

$$ROE_{ap} = \frac{\Pi - AT - AP}{TA - NL} \quad (8.6)$$

where ROE_{at} and ROE_{ap} refer to the after-all taxes ROE and after-payment (interest and dividends) ROE, respectively. The denominator is the net worth of nonfinancial corporations that refers to tangible assets TA , which is composed of net capital stocks and inventories, minus net liabilities NL , that is, assets minus liabilities deflated by the inflation index. Lastly, $\Pi = Y - W$.

Figure 8.10 shows the profile of capital accumulation—the rate of accumulation, in other words, the growth rate of capital stock—, ROE_{at} , and ROE_{ap} of nonfinancial corporations in S. Korea between 1980 and 2005. As shown in Figure 8.10, there is a big difference between them—the growth rate of capital stock has high levels in comparison to the other variables. It makes it hard to study a relationship among them unlike the case in the US. Furthermore, the telltale signs suggest that additional effects on capital accumulation should be taken

into account other than the connection with the rate of profit.

However, there may be another channel to fund for the growth of capital stock other than ROE_{ap} in S. Korea unlike the case of the US. This stems from the existence of a strong external financing in the country. We can call this *an acceleration effect of external financing on capital accumulation* corresponding to the impact of increasing ROE_{ap} . That is, the nonfinancial corporations in S. Korea have a strong sensitivity of investment to external financing channels, at least before 1997. The auto financing ratio of nonfinancial corporations (ARC) could be a proxy variable for this. We compute the ratio by National Account and *Flow of Funds* as follows.

$$ARC = \frac{SF}{SF + SFT}$$

where SF refers to Self-Financing that is the sum of net saving, net capital transfer, and consumption of fixed capital in National Account. The total resources available to invest in new assets of nonfinancial corporations are composed of this self-financing plus sources by the financial transaction (SFT) in Flow of Funds. Therefore, $1-ARC$ would mean the external ratio of financing. If they made a drastic investment decision or were easy to access any external funding channels, this external ratio could remain at high levels.

The variable, $RATIOEX$, refers to the external ratio of financing, whose trajectory is almost same with the profile of the growth rate of capital. Consequently, the high accessibility to external funding would accelerate the growth of capital stock along with an increase of ROE_{ap} . We can construct new VAR model including the effect of acceleration on investment.

Therefore, we introduce an econometrical method to overcome the difficulty of analysis. It begins with testing whether each variable has a unit root or not. According to the Phillips-Perron test, the null hypothesis that all variables have a unit root can be rejected at the significant 5% level (Table 8.5).

This test allows the VAR model (Sims 1980) to be applied to this study for an additional 'impulse response analysis', 'variance decomposition', and 'forecasting' on a baseline model. To do this, we should find appropriate time lags to build the VAR model. If we take into account the period 1980 to 2005, the six-lag

TABLE 8.5: Phillips-Perron unit root test

variables	t-Statistics	probability
CAP	-2.994902	0.0388
$DROE_{ap}$	-3.130964	0.0276
$DROE_{at}$	-4.318572	0.0007
$DRATIOEX$	-4.215322	0.0010

structure for this model (VAR(6)) is needed according to AIC (Akaike Information Criterion) and HQ (Hannan-Quinn Information Criterion)⁵. Furthermore, a dummy variable is introduced in order to see a structural break before and after the Asian crisis in 1997. The following target equation (TE1) in the VAR system is used for the estimation.

$$CAP_t = c_1 + DSTR + \sum_{j=1}^p c(1)_j CAP_{t-j} + \sum_{j=1}^p c(2)_j DRATIOEX_{t-j} + \sum_{j=1}^p c(3)_j DROE_{at,t-j} + \sum_{j=1}^p c(4)_j DROE_{ap,t-j}$$

where CAP , $DROE_{ap}$, ROE_{at} , and $DRATIOEX$ are the rate of capital accumulation, the first difference of ROE_{at} , ROE_{ap} , and $RATIOEX$, respectively. $RATIOEX$ refers to the ratio of the external financing ; c_p , $p = 1, 2, 3$, and $c(p)$, $p = 1, \dots, 9$ represent the intercepts and coefficients. $DSTR$ is a dummy variable which is defined as follows.

$$\begin{aligned} T < 1996, & \quad DSTR = 0 \\ \text{Otherwise,} & \quad DSTR = 1 \end{aligned}$$

Additionally, the Structural VAR (SVAR) method is used for a direct economic interpretation. The short run restriction for the SVAR is composed of the following four statement.

⁵For the estimation, the annual data series of each variable is transformed into quarterly data by the linear interpolation

- (a) ROE_{at} is a variable to take more time to be adjusted than other variables because taxation is determined by the state policy.
- (b) ROE_{ap} instantly affects the rate of capital accumulation.
- (c) $RATIOEX$ contemporaneously responses to the rate of capital accumulation.
- (d) CAP responses to all variables in the VAR system immediately.

TABLE 8.6: 1980-2005 SVAR capital accumulation model without the structural break ($DSTR = 0$)

variables	cap shock	ratioex shcok	ROE_{at} shcok	ROE_{ap} shock
CAP	[+]*	[+]*	[+]	[+]*
$DRATIOEX$	0	[+]*	0	0
$DROE_{at}$	[-]*	0	[+]*	0
$DROE_{ap}$	[+]***	0	[+]*	[+]*

*, **, *** indicate that the coefficients are significant at 1%, 5%, 10%, respectively

This SVAR model is just identified; the estimation results are given in Table 8.6. The relationship between the capital accumualtions and each structural shock is presented in the first row; all structural shocks have a positive impact on the rate of capital accumulation at significant 10 % except for the ROE_{at} shock.

Figure 8.12 shows the results of the structural impulse response analysis on the basis of the 1980-2005 SVAR model without a structural break; Shock1, Shock2, Shock3, and Shock 4 refers to cap shock, ratioex shock, and ROE_{at} and ROE_{ap} shocks, respectively. The response of capital accumulation to the structural shock of an unexpected increase in the ratio of external financing is more persistent and explicit than other profitability shocks (ROE_{at} , ROE_{ap}), which has a positive effect on capital accumulation.

Let us take account of the dummy variable, $DSTR$ referring to the structural break in 1997. This 1980-2005 SVAR with the 1997 structural break is just identified; the estimation result is almost the same but the effect of the structural $capshock$ on ROE_{ap} is not statistically significant at 10 % (Table 8.7).

Figure 8.12 shows the structural impulse response analysis of the 1980-2005 SVAR with the structural break. In this analysis, the persistence of the effect of

FIGURE 8.11: Structural impulse response: 1980-2005 SVAR without DSTR

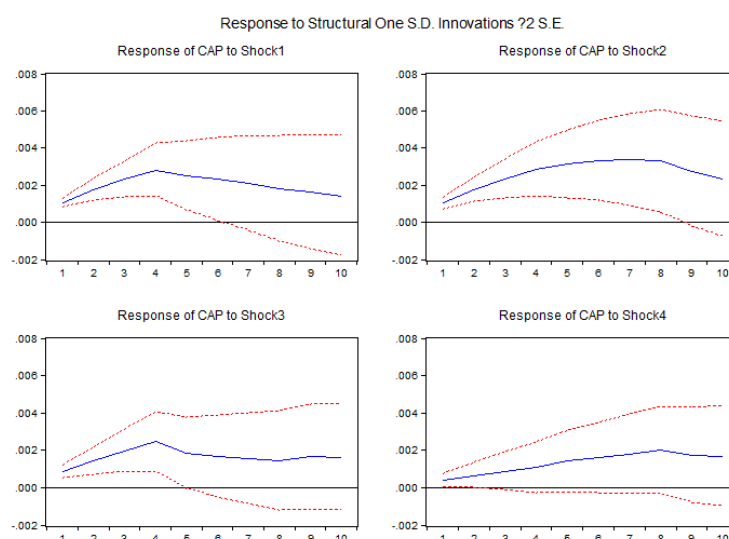


TABLE 8.7: 1980-2005 SVAR capital accumulation model with the structural break

variables	cap shock	ratioex shcok	ROE_{at} shcok	ROE_{ap} shock
CAP	[+]*	[+]*	[+]	[+]*
$DRATIOEX$	0	[+]*	0	0
$DROE_{at}$	[-]*	0	[+]*	0
$DROE_{ap}$	[+]	0	[+]*	[+]*

*, **, *** indicate that the coefficients are significant at 1%, 5%, 10%, respectively

the external funding on capital accumulation is reduced as compared with the above model.

The variance decomposition of 1980-2005 SVAR model with or without DSTR is shown in Figure 8.13 and 8.14. The contribution of the external funding to the capital accumulation is comparably reduced in Figure 8.14. This finding may pertain to a disappearance of a financial acceleration effect on capital accumulation in the Korean economy. Instead, the contribution of ROE_{at} (shock 3) to capital accumulation increased in the model with the structural break as shown in Figure 8.14.

Figure 8.15 illustrates the debt ratio of the manufacturing sector in S. Korea between 1970 and 2007. Over the past 40 years, it was reached at the extraordinary

FIGURE 8.12: Structural impulse response: 1980-2005 SVAR with DSTR

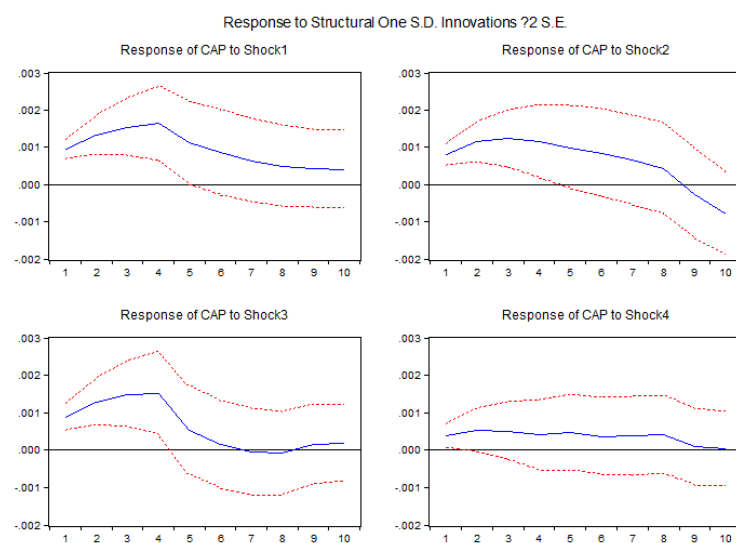


FIGURE 8.13: Variance decomposition of 1980-2005 SVAR without DSTR

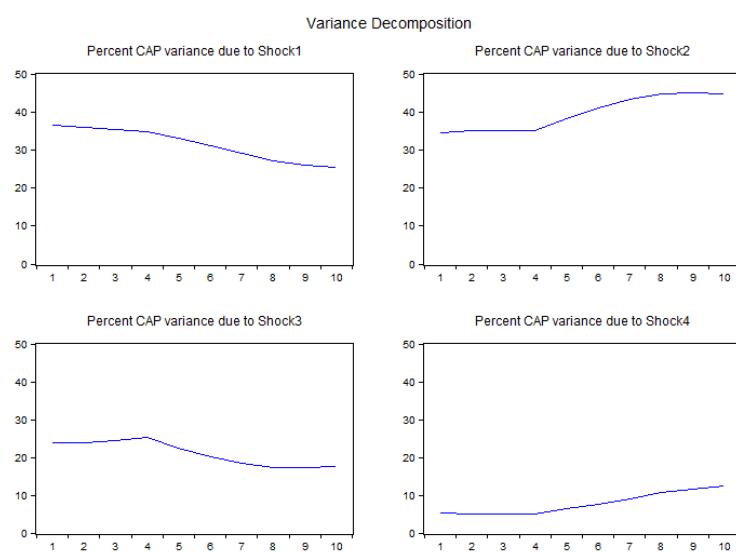
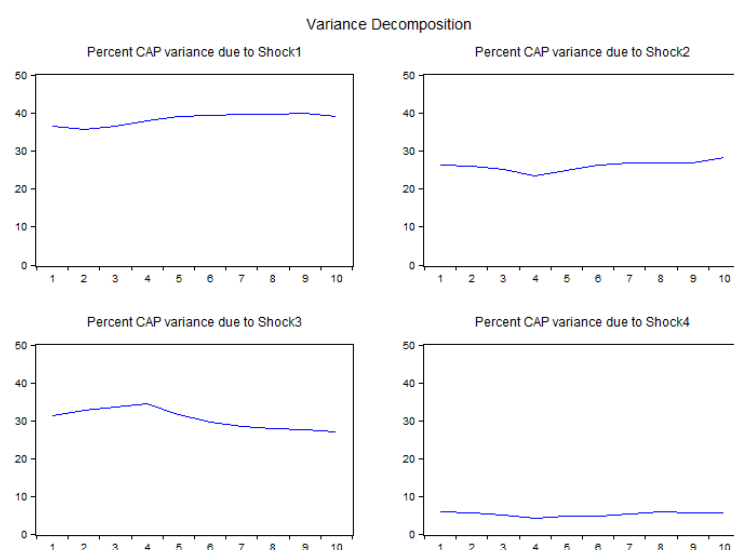


FIGURE 8.14: Variance decomposition of 1980-2005 SVAR with DSTR

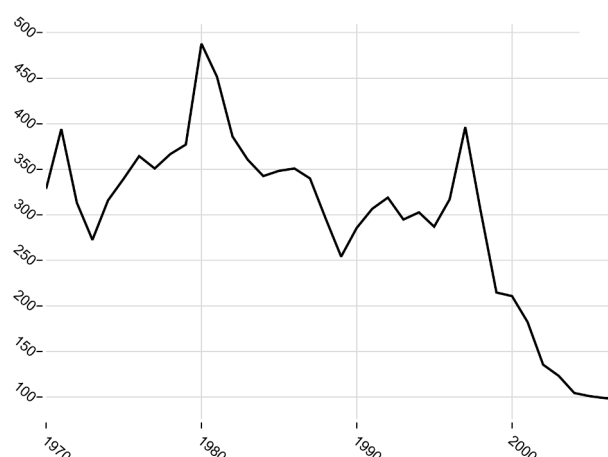


lowest level. However, this was not a smooth adjustment process but a sharp rupture with previous business behaviors. It is confident that a financial burden on firms in Korea dramatically reduced. Nevertheless, the acceleration effect on net investment through the accessibility to external funding channels, which made it possible to be a remarkably rapid growth of the economy, disappeared.

The high level of the growth rate of capital stock and the external financing stemmed from the pursuit of economic expansion for the rapid growth rather than a certain level of profitability. By demand for the liberalization, however, the card was flipped over. 'The Chun, [who was a military dictator], implemented a number of financial liberalization and internationalization measures' (Kown 2004: 81) in the early 1980s. The striking result was a sudden collapse of net investment by the debt crisis in 1980 and an ensuing gradual decrease of external financing. However, the effect of the Asian crisis in 1997 was much more prominent: a simultaneous radical rupture in the profile of both net investment and the external financing. Therefore, the exceptional situation between the late 1980s and 1990s was *a reprieve* 'combined with favorable external shocks in 1985-86' (Dornbusch and Park, 1987, p. 443) between the gradualness started from the early 1980s and the radicality after the 1997 Asian crisis.⁶ Haggard and

⁶The gradual liberalization effect, the persistence of traditional industrial policies and an increasing autonomy of *Chaebol* are articulated in *the reprieve*

FIGURE 8.15: Debt ratio in the manufacturing sector(S. Korea, 1970-2007): percent



Source: *Financial Statement Analysis* in S. Korea. <http://ecos.bok.or.kr>

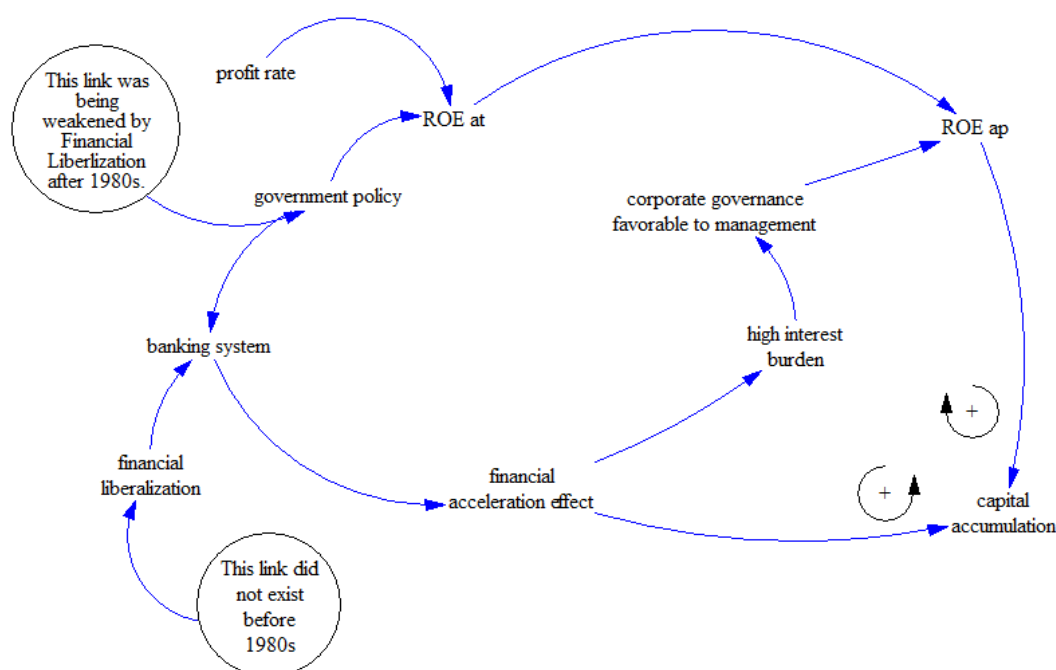
Mo (2000, pp. 200-208) called this the Government-Chaebol-Bank relation in the Korean economy

Diagram 1 illustrates this mechanism relating to capital accumulation before 1997 in S. Korea. The government policy was being weakened after the 1980s but did not entirely evaporate. In virtue of the financial acceleration effect by the banking system, funds available to invest in new capitals could be provided to firms although they suffered from their highly leveraged business—In other words, they had to put up with the high-interest burden for that. Through this mechanism, they could maintain the fast pace of capital accumulation to some degree. This state of affairs in the 1990s was the *reprieve* between the two shocks. We shall deal with that in detail.

8.5 IF ...

The liberalization appeared twice: the first time as a form of gradual penetration and the second time as radicalism. If one of the main reasons that a sustainable economic growth of the country was not possible was the high leverage of

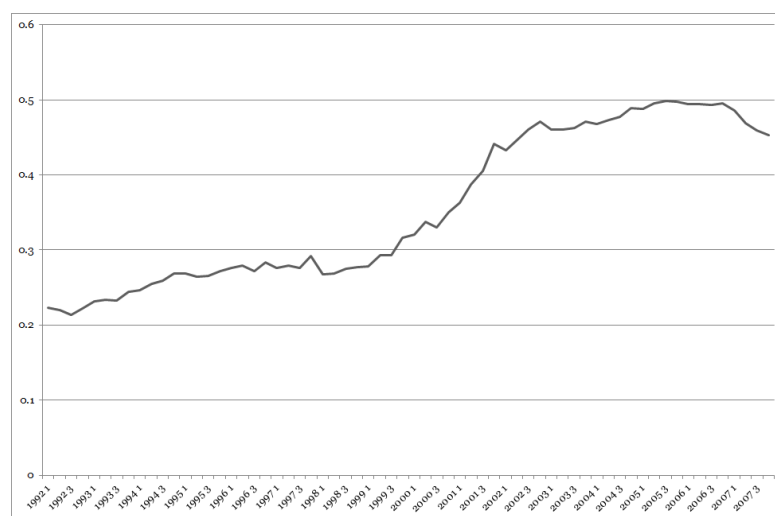
Diagram 1. Accumulation mechanism before 1997 in S. Korea



the firms, why was the growth of capital stock stagnated despite its dramatic reduction? Rather, we suggest that one of the causes of the stagnation is the disappearance of an acceleration effect on capital accumulation in this study. In other words, the level of the after-payment rate of profit has recovered that of the 1980s (Figures 8.9 and 8.10), and the enormous deleverage has achieved, but net investment has not been able to be increased to the previous levels. Above all, we should pay attention to a shift in behaviors in financial institutions.

Figure 8.16 illustrates the profile of the ratio of consumer loan to total loan in commercial banks in S. Korea from the first quarter of 1992 through the fourth quarter of 2007. There is a striking upward pattern caused by the restructuring of the banking sector in the country between the late 1990s and 2003. It means that the high leverage level of firms transferred to households. This result not only stimulated the housing market boom from 2005 but also made the net investment of corporations wither. Thus, the acceleration effect on net investment by external financing disappeared: if the effect had not disappeared, what would have been

FIGURE 8.16: The ratio of consumer loans to total loans(1992/1-2007/4): quarterly



Source: *Loans and Discounts by Industry* in S. Korea. <http://ecos.bok.or.kr>

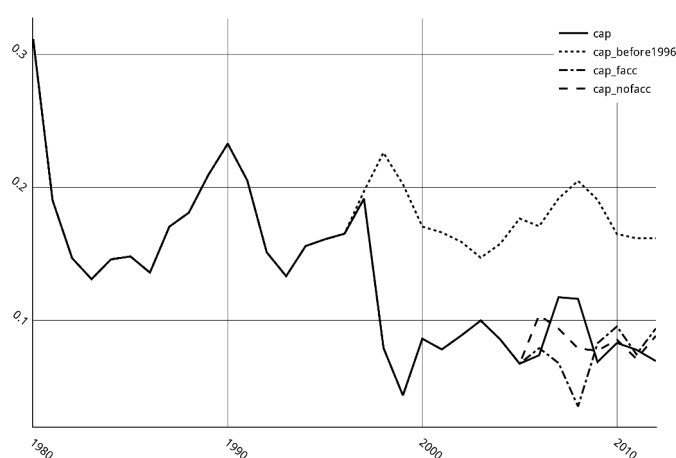
happened in the growth of capital stock in the country?

Figure 8.17 shows the possible paths of the growth rate of capital stock if the 1980-1996 and 1997-2005 relationship was maintained. The baseline model for the 1980-1996 relationship contains the effect of financial acceleration between 1980 and 1996; it extends the external ratio of financing as estimated by the above model, to 2005. On the other hand, cap_{facc} and cap_{nofacc} represent the trajectories with or without the financial acceleration effect, (ROE_{ap} and ROE_{at}) reconstructed by the relationship between 1997 and 2005. This reconstruction spreads over two steps: first, we estimated new ROE_{ap} and ROE_{at} by VAR(2) excluding $DRATIOEX$ from 1997 to 2005; second, the data series of the profit rates were applied to VAR (4) from 1980 through 2005 once again.

Thus, the variable, $cap - before1996$, represents the path of the growth rate of capital that would have been happened if the financial effect had been held together. Because the recovery of the rates of profit following the sudden collapse in the 1997 Asian crisis is taken into account, the financial effect plays a vital role to maintain the levels of the cap -before 1996 in Figure 8.18. The trajectories of the other variables, cap_{facc} and cap_{nofacc} , are not significantly different from the levels of the actual growth rate of capital..

As a result, taxation policy and corporate governance effects on the rate of profits

FIGURE 8.17: Forecasting the growth rate of capital stock (1980-2012)

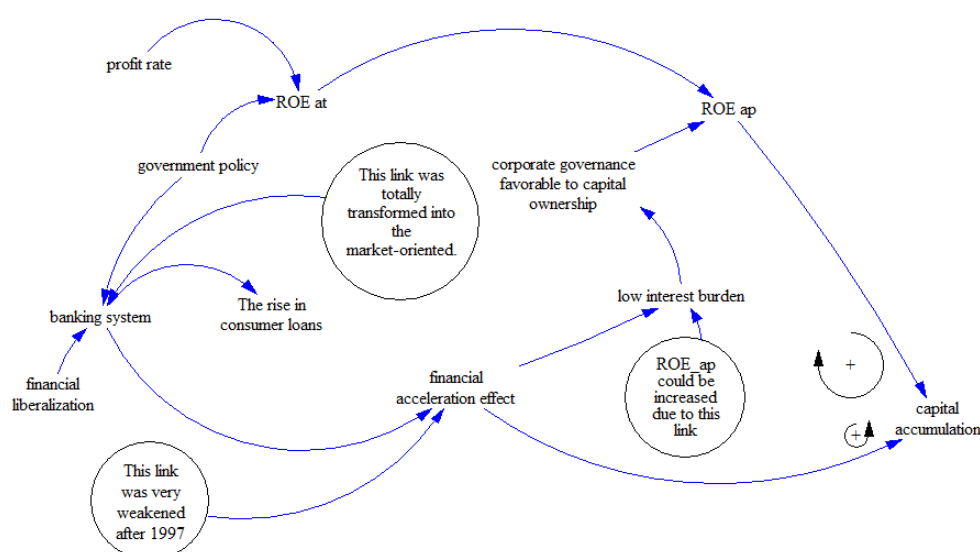


the actual growth rate of net capital stock (*cap*); baseline model 1980-1996 with the financial acceleration effect (*cap-before 1996*) , baseline model 1986-1996 with(*cap-facc*) or without(*cap-nofacc*) the financial acceleration effect

are deeply related to the capital accumulation process in S. Korea, but it should be jointly considered with a financial effect or behavioral change in financial institutions. It appears that, after 1997, the relationship between the ROEs and accumulation rate has been persisted as a more consolidated form of the less dependency of investment on the external financing of the Korean corporations.

Diagram 2 illustrates the relationship relating to capital accumulation in S. Korea. Compared to Diagram 1, an institutional change in the banking system is prominent. The industrial policies of the state considerably weakened because the majority of banks in S. Korea have been privatized. Furthermore, this led to an increase in the consumer loan because the banks are reluctant to lend money to the business sector, and they wanted to provide funds to the profitable consumer loan market at that time. This transformation has resulted in the debt transfer to households. Instead, the high leverage of firms hugely decreased compared with the level before 1997; the low-interest policy by the monetary authority in the country mitigated the interest burden on the business sector. This series of the process leads to the restoration of levels of ROE_{ap} following the 1997 crisis.

Diagram 2. Accumulation mechanism after 1997 in S. Korea

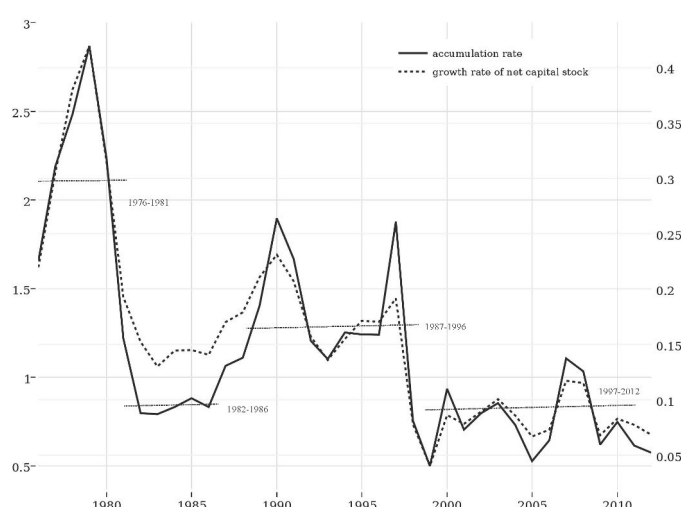


8.6 Discussion: Two Shocks for an Economic Transition

Thus far, the rate of profit is an important index that determines the pace of capital accumulation because the past profit provides funds available to invest in new capital. In S. Korea, however, there is a big gap between the rates of profit and the rate of capital accumulation. In the previous sections, the rate of capital accumulation and the growth of net capital stocks are used in the same meaning, but, in fact, it is worth noting that they don't refer to an exact same concept. The rate of capital accumulation refers to the ratio of net investment to the past profit. That is, it means that how many portions of the profits produced is reinvested. Thus, they have almost the same profile, but their levels would be different as shown in Figure 8.18.

While we suggested successive levels for three periods in Section 2 according to the serious economic recessions in Korea, each period in this section is subdivided into four periods by including the last half of the 1970s and the economic

FIGURE 8.18: The rate of capital accumulation(the left axis) and the growth rate of net capital stocks(the right axis): 1976-2012, nonfinancial sector



Source: *National Accounts and National Balance Sheets* in S. Korea.
<http://ecos.bok.or.kr>

boom between 1986 and 1988.⁷ The dotted horizontal lines in Figure 8.19 display the annual average values for each period. The four values are 2.28 % in 1976-1980, 0.89 % in 1981-1986, 1.31% in 1987-1996, and 0.81% in 1997-2012, respectively. First, the profile of the rate of capital accumulation is fluctuated but has a consistent decreasing trend. Second, average values in two of the four periods (1976-1980 and 1987-1996) recorded higher levels than ones in other two periods, and both of them are greater than 1. Consequently, this means that firms drew the additional funds from the financial sector. Thus, these higher recorded levels of the rate of capital accumulation resulted from the financial acceleration effect. Third, there were two shocks to come to the recent economic state of affairs, and the levels after the shocks are almost the same profile with the actual ones. Furthermore, as shown in Figure 8.9, it is worth noting that ROE_{ap} has almost the same profile with those rates we are observing in this section. Before the first shock between the late half of the 1970s and the beginning of the 1980s, the Korean government repressed finance, and it used the financial

⁷Because the debt-crisis between 1979 and 1980 and the export boom from 1986 through 1988 might have affected investment in the next time, we segment the 1980s and 1990s into two part, 1981-1986 and 1987-1997, respectively.

system to 'support industrial strategy' of the country (Kown 2004, p. 78). At that time, S. Korea was raising big firms through a selected financial support by the so-called "policy finance." Thus, the bureaucrats in the government rather than the capitalist owners in markets took the lead. However, all those things were dramatically changed by the first shock: financial system began to be privatized and deregulated, and then, The levels of capital accumulation were sharply decreased. Under the new circumstances, many foreign banks could extend their business area, and they recorded high returns (Kown 2004, p. 81). Therefore, the financial acceleration effect that was arranged by the industrial policy, namely the heavy-chemical industrialization in the late half of the 1970s, *partly*⁸ *partly* disappeared between 1981 and 1986.

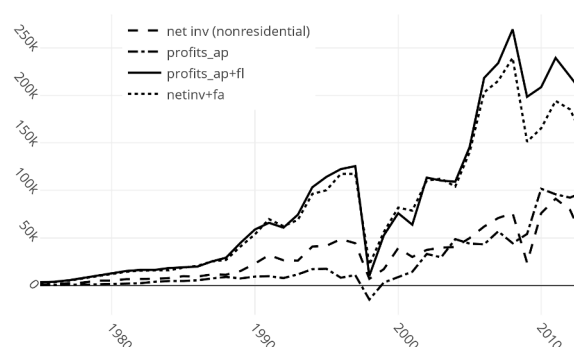
The investment boom between 1987 and 1996 was a mixed result combined with the liberalization, government policies, and the rapid growth of *Chaebol* caused by the export boom between 1986 and 1988. The dramatic increase in the rate of capital accumulation was based on Chaebol's increased profits and other financial sources. During the investment boom following the export boom, the net investment could be substantially increased in the favorable circumstances. On the other hand, financial liberalization at that time facilitated their accessibility to additional funds to expand their capacity. In particular, the financial deregulation in the 1990s allowed the firms to find funds to invest in not only the domestic but also the international financial market. However, this led them to a serious business circumstance in which their debt and interest burden were increased (See Figures 8.9, 8.10)⁹, followed by the second shock in 1997. Above all, it was the biggest problem that they were immediately exposed to the volatility of the international financial market.

After the crisis, the rate of capital accumulation returned to the average level

⁸Despite the liberalization and structural adjustment at that time, the development strategy had never been totally rejected. Dornbusch and Park said that 'Korea's policies clearly do not represent a laissez-faire approach: intervention in the form of trade restrictions, subsidies, and credit allocation is pervasive.' (Dornbusch and Park 1987: 403)

⁹In 1991, Korean government announced a plan for the interest rate liberalization, namely *Four-Stage Plan for Interest Rate Regulation* (Kown 2004, p. 82) and, in 1994, deregulated the commercial paper market, which 'led to the rapid expansion of short-term financing' (Haggard and Mo 2000, p. 204). Furthermore, "entrance into the OECD" in 1996 'was a powerful motive to expedite the financial liberalization of Korea' (Kown 2004, p. 84). The Korean banks were able to borrow in international financial market more than ever (Haggard and Mo 2000, p. 204).

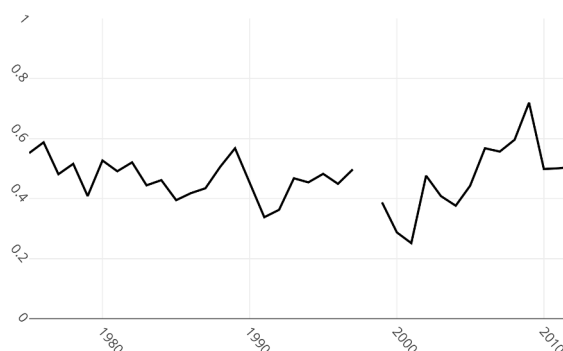
FIGURE 8.19: Flow of funds in the nonfinancial corporation (1975-2012)



Source: *National Accounts and Flow of Funds* in S. Korea. <http://ecos.bok.or.kr>

between 1982 and 1986. Moreover, ROE_{ap} recovered the level in the 1990s or the beginning of 1980s by the benefit of the downward trend of interest and the debt ratio even although the PRM after the 2000s was less than one in the 1980s. The levels between 1987 and 1996 were exceptional compared to 0.97 %, which is the annual average rate of capital accumulation between 1982 and 2005 after the

FIGURE 8.20: Ratio of financial assets purchase to total financial sources plus after payment profits: 1975-2012, nonfinancial corporations



Source: *National Accounts and Flow of Funds* in S. Korea. <http://ecos.bok.or.kr>; The year 1998 that had a minus figure due to the 1997 crisis has been excluded.

first shock. We have already called this a *reprieve* in neoliberal transformation of the Korean economy.

Despite the disappearance of the financial effect on capital accumulation, the nonfinancial corporations have continued to expand a number of liabilities even since 1997. Figure 8.19 and 8.20 give information about the flow of funds in the nonfinancial corporations from 1975 to 2012. As can be shown in Figure 8.19, the level of net investment excluding residential investment ($net\ inv\ (nonresidential)$) surpassed that of after-payment profits excluding all taxes, interest, and dividends ($profits_{ap}$) by 1997. After that, however, these two measures converged. In Figure 8.20, fl and fa respectively refer to financial liabilities in the financial sources of nonfinancial corporations and those purchase of financial assets, and $netinv$ is net investment including the residential investment. The portion leaving out the investment in the nonresidential in the total financial sources ($profit_{ap} + fl$) was used to invest in the augmentation of residential equipment or purchase financial assets. In particular, the proportion of financial assets purchase in the uses of the sources remarkably rose since 1997 as seen from Figure 8.21, which can be seen as a widening gap between $net\ inv\ (nonresidential)$ and $netinv + fa$ in Figure 8.20 as well. As a result, both the disappearance of the financial effect on capital accumulation and the radical change of corporate governance in the Korean economy over the past decades are reflected in this historical process.

Therefore, we need to take account of not only the level of profitability but also the transition of the financial relation of the country in order to see the profile of capital accumulation in the Korean economy. So far, we have interpreted this dependency on the external fund of investment as an acceleration effect, which allowed the country to record the high level of capital accumulation compared to levels of profitability. In the liberalization process, the financial sector in the country was mostly privatized, and it pursued its profitability rather than needs for the industrial development of the country. As a result, the debt accumulation of corporations for investment has been transferred to households with the institutional change in the financial sector. In 2011, the ratio of household debt to gross disposable income of the country reached 163.8 %, which was much greater than 142.8 percent of the US in 2007 ([OECD 2014](#)).

8.7 Conclusion: The cost of the recovery in profitability

In this investigation, the first aim was both to compute the profit rates by using newly available data series and to represent their historical profile in S. Korea. Second, various types of the profit rate to see the influence of government policies as well as corporate governance on profitability are estimated. As seen from the relationship between the profitability trends and capital accumulation in this study, it was crucial to find an additional determinant for capital accumulation in S. Korea. In other words, it is difficult to directly find the visual coincidence between the ROEs and capital accumulation in the Korean economy because there is a big gap between them due to the high dependence on external financing, particularly before the 1997 Asian crisis. Thus, this relationship could be found by the help of an econometric method.

It has shown that there is a significant link between the after-payment ROE and capital accumulation in the Korean economy and that, furthermore, it is the evolution of external financing that is one of the most important aspects related to the link. The disappearance of the financial acceleration effect on capital accumulation by the external funding is one of the main causes of the lower rates of capital growth after the 1997 Asian crisis in S. Korea. Thus, net investment would depend solely on the after-payment ROE in the 2000s.

Furthermore, the taxation impact on the trends of the rate of profit is more complex than the cases in any other countries. Because the profit tax (or direct tax) was substantially low, compared to other countries, such as the US, it had an upward trend in the 1990s and the early 2000s. However, the taxation had a countertendency effect on patterns of the rate of profit not in the long-term but the short-term.

The lower growth rate of capital accumulation led to the lower economic growth rates: the annual average growth rate of GDP fell from 8.23 % (1980-1997) to 4.01 % (1998-2013). All these results represent an itinerary of the Korean economy that began with financial liberalization following the first shock at the beginning of the 1980s. In the mid-1990s, the path-dependency—that is, the Government-Chaebol-Bank relation of this country that remained despite the first shock, and

the export boom that created an anomalous state of affairs— led to the relatively high levels of net investment. However, the second shock arrived. Although the profit rate recovered to the levels of the 1990s, the fast pace of capital accumulation after the 1997 crisis does not exist anymore.

The rates of profit computed in this study are an approximation because they still hold an inconsistency within the data series available to calculate the rates. For example, there is a subtle gap between classifying methods of National Account and Flow of funds. Thus, it is certain that a coming update of the data series by Korean statistical authorities, such as BOK and Statistics Korea, makes it possible to improve the significance of this kind of analysis.

Chapter 9

Domestic Demand under Neoliberalism: the US and Korean Economy

9.1 Introduction

For the past decades, particularly in the US and Korean economy, there has been a widening gap in income distribution between the top income group and the lower income group. Duménil and Lévy (2011) argue that this evolution of inequality in the US economy is associated with the quest for high income based on financialization and globalization under neoliberalism. In both countries, rising inequality among wage-earners accounts for a significant portion of the distributional gaps. Within the Marxist framework of the social classes, moreover, the increase in wage inequality indicates that a new intermediate class, the managerial class, is rapidly emerging among the traditional social classes—capitalists and productive workers—in the capitalist societies (Duménil and Lévy, 2011). Despite the recent rise of the managerial class, the emergence and development of that class have a much longer story in the historical transformation of capitalism, but it is worth noting their achievement relating to income distribution during the neoliberal period (Duménil and Lévy, 2011; Mohun, 2006,

2016; Tavani and Vasudevan, 2014; Vasudevan, 2016).

During the post-war period, 'workers not in power, the capitalist classes were contained, imply the enhanced role and autonomy conferred on the managerial classes (Duménil and Lévy, 2011: 78)'. The managerial classes enjoyed relative autonomy to the capitalist owners, 'with a considerable share of the profits retained within corporations for the purpose of investment (Duménil and Lévy, 2011: 79)'. Those classes in the Korean economy has had a critical position of the country's economic development (Kim, 2011) because the state-led developmental strategy was one of the indispensable elements for the country's economic development (Woo, 1991) and they took a leading role in the neoliberal turn of the country (Pirie, 2008). The excellence talent selected through qualifying exams (Kim, 1987) not only set up a plan for national development but also achieved outstanding achievements in international competition as managers of large corporations represented by chaebols. These qualified persons were considered as people with various privileges; they were regarded as a social class in Korea. Obviously, the achievement of these people in terms of income distribution in the history of the Korean economy has been prominent compared to other countries (Hong, 2015a).

In the early 1980s, capital was back (Piketty and Zucman, 2014). Under the financial hegemony, the capitalist owners reasserted their interests, and the relative autonomy of the managerial class in the post-war period was largely undermined. However, the managerial class survived and strengthened their power and incomes in the neoliberal transition of both countries. A new alliance between top executives in the managerial class and the capitalist owners has represented the social order of the new age (Duménil and Lévy, 2011). In the Korean economy as well as the US economy, the upper classes of managers in both public and private sphere are in the revolving-door despite the dismantling previous economic or developmental strategies. The practices of the managerial class in both countries since the 1980s has become increasingly favorable to the interests of the financial sector or the extremely opened capital markets (Dornbusch and Park, 1987; Glyn, 2006; Lazonic and Sullivan, 2000; Pirie, 2008; Vasudevan, 2016).

The decreasing pace of capital accumulation has constituted one of the popular characters on the evolution of the composition of aggregate demand in many

countries during the neoliberal period, although there was an investment boom of the 1990s in some countries like the US and Korean economy. In the US economy, moreover, an increase in the ratio of consumption to GDP can be observed coupled with the falling rate of investment since 1980. This consumption-led growth regime whose features are the slowdown in the pace of accumulation and the upward trend of the ratio of consumption to GDP accompanied a dramatic increase in household debt in the US (Dos Santos, 2015: 665; Duménil and Lévy, 2011: 146-151). Vasudevan (2016) argued that an increase in the share of capitalist owners and managerial class under the dominance of finance, represented as deregulation, companies' governance shift favorable to finance, and globalization during the neoliberal period, led to a slowing pace of capital accumulation and an upward trend of consumers' debt to GDP, which have been the secular trends of the US economy during the neoliberalism.

Indeed, the declining trend of capital accumulation in the Korean economy can be observed since the Asian financial crisis of 1997-1998, which was one of the most severe crises in the history of the country. However, the significance of consumption in the demand composition of the Korean economy since 1980 would be questionable because there was a long sharp declining trend of consumption relative to GDP in the first half of the 1980s. Contrary to the trends in the US economy, it seems to be difficult to extract a consistent trend relating to the pace of capital accumulation and the ratio of consumption to domestic demand during the neoliberal transition in the Korean economy. It is thought to be related to a long, painful transition process of the Korean economy to neoliberalism because the neoliberal turn of the country meant a disintegration of the country's past developmental strategy linked to the strong authoritarian state.

This study seeks to capture a possible long-term relationship between rising wage inequality, which was one of the important results of the new alliance between the capitalist owners and the upper group of the managerial class, and the macroeconomic trends since 1980 in the US and Korean economy. For this reason, I considered the wage share of the top 10% wage earners without separating wage trends of higher income groups which are more dependent on capital income. In the US economy, "the incomes of executives, managers, supervisors, and financial professionals can account for 60 percent of the increase

in the share of national income going to the top percentile of the income distribution between 1979 and 2005 (Bakija et al., 2012: 27)"; however, in this study, I consider a wider range of the managerial and clerical classes at the top 10% of wage earners. In the case of the Korean economy, the proportion of managers and professionals in the highest income group, for instance, the top 1% income group, is higher. In the lower income group in the top income group of the Korean economy, for instance, the top 1-5% income group, the proportion of clerical workers, in particular those in the law and financial fields, increases (?). Thus, "rising wage inequality in recent decades reflects the rising claims of the top managerial-professional class (Vasudevan, 2016: 400)"

In this study, I try to capture possible regime changes relating to the consumption trend and the pace of accumulation in both countries. For example, in the US economy, the financial crisis in 2008 may be a breakpoint of the relationship between wage inequality and the macroeconomic trends. Similarly, the Asian financial crisis in 1997-8 may be that of the Korean economy; or there may be other hidden potential breaks in both countries. All data series in this study is very likely to include break points during the observation period. Therefore, to capture the structural breaks in the data, I employ the Zivot-Andrews unit root test for the time series data with a single break in the time series. Perron (1989) suggests that the standard unit root tests such as the ADF (Augmented Dickey-Fuller) test tend to fail in case of the data series with structural breaks. Zivot and Andrews (1992) argue that "selecting the break exogenously could lead to an over-rejection of the unit root hypothesis (Narayan 2005)". The Zivot-Andrews test provides information about an endogenously estimated breakpoint in the data. Moreover, this study applies the unit root test with two endogenous structural breaks suggested by Lumsdaine and Papell (1997) to each variable if necessary.

Second, for the estimation of the long-run relationship between wage equality and macroeconomic trends in the US and Korean economy, I use the ARDL (Autoregressive Distributed Lags) model. Beyond the above unit root tests with a structural break on one data series, the Gregory and Hansen (1996) test provides information about a structural break in a cointegration test. The Gregory-Hansen test proposes three models of the structural change: level, trend, and regime shift. I take the regime shift framework in the Gregory-Hansen test into account in

this study. If one finds a breakpoint in data or a cointegration equation, and then estimate a cointegration equation for each period based on the structural break test, the estimations cannot help avoiding a reduced sample size problem even though the number of data has been increased by using monthly or quarterly data. However, the ARDL framework makes it possible to overcome the small sample problem because the ARDL cointegration technique is robust and consistent even with the small sample problem compared with other cointegration technique such as Engel and Granger (1987) or Johansen (1998) methods (Pesaran and Shin, 1999; Haug, 2002; Narayan, 2005). Moreover, It can be selected for this study even if the unit root tests with or without the structural breaks are not consistent because I (1), I (0), and the combination of both orders are allowed in the ARDL technique (Pesaran and Shin, 1999; M. Hashem Pesaran and Richard J. Smith, 2001; Narayan, 2005).

9.2 Model Specification, Data, and Methodology

To examine relationships between inequality and macroeconomic trends in the US and Korean economy, the models take the following forms.

$$const_t = \beta_{10} + \beta_{11}WI_t + \beta_{12}CD_t + \epsilon_{1t} \quad (9.1)$$

$$inv_t = \beta_{20} + \beta_{21}WI_t + \beta_{22}CD_t + \epsilon_{2t} \quad (9.2)$$

The dependent variables, cons and inv, refer to the ratio of consumption to GDP and the rate of capital accumulation in the nonfinancial firms in both countries, respectively. The WI is the share of the top 10% wage earners excluding capital gains and incomes in both countries; The CD is the ratio of households and nonprofit organizations' debt (market instruments) to GDP, which is used to capture the increase in consumer credit under the financial deregulation during the neoliberal period in both countries. I try to estimate long-run effects of two independent variables on the pace of capital accumulation and the consumption composition of GDP in both countries, respectively; thus, I choose an estimation

of each single equation based on the ARDL technique.

The previous studies on neoliberalism expect the positive coefficients of independent variables in the model 1 and the negative coefficients of independent variables in the model 2 as the popular characters of the neoliberal period, particularly in the US. In other words, the evolution of the alliance between the capitalist owners and the managerial class is expected to decrease in the pace of capital accumulation and increase in the consumption ratio to GDP, meaning that domestic consumption demand of the economies is constrained by inequality and the proliferation of financial instruments for consumption. These aspects are what the consumption-led growth (Dos Santos, 2015) and inequality-constrained growth regime (Vasudevan, 2016) describe.

The long-run relationships in the models 1 and 2 were estimated using quarterly time series data for the period 1980-2015 because this study aims to capture the long run relationship within the neoliberal period since 1980, although the start date are being controversial in Korea because, in the 1980s, Korea suffered from the military dictatorship and still maintained the state-led development strategy in many aspects (Pirie, 2008; Lee, 2010). The quarterly data series cannot help being applied to this study because the very small number of observation can be obtained if taking structural breaks in both countries into account. Second, some quarterly data series such as net capital stocks and net investment in the nonfinancial sector in both countries are produced by the cubic spline interpolation method. The data on net capital stocks and net investment in both countries are from and the fixed assets table of BEA (Bureau of Economic Analysis) the flow of funds table published by the FED in the US, respectively, and are obtained from the national balance sheet and national accounts of the Bank of Korea in Korea. The data on wage inequality in both countries, which is transformed into the quarterly data by the interpolation matched to an annual average value in this study, can be obtained in the WID (World Wealth and Income Database) and Hong (2015a). Other quarterly data are directly from the NIPA and the flow of funds table in the US, and the national account and the flow of funds table in Korea, respectively, while the data on consumers and non-profit organizations' debt in the Korean economy was seasonally adjusted by Census X-12 approach. For the unit root test for each variable, I used the two traditional unit root tests: The Augmented Dickey-Fuller test and the Phillips-Perron test. In addition, the

Zivot-Andrews test for one structural break data provides information about the unit roots of each variable if they have one endogenous structural break. Because the traditional unit root tests tend to report ambiguous results in the case of variables with a structural break—a bias that cannot reject the null hypothesis (Perron, 1989; Gregory and Hansen, 1996), the Zivot-Andrews procedure is necessary. This study selects two models allowing for a change in intercept, and both the intercept and slope (Narayan, 2005) suggested by Zivot and Andrews (1992).

The Gregory-Hansen test conducts the test of cointegration in the presence of structural breaks. The null hypothesis of this test is no cointegration when the cointegration relation includes the regime change such as a change in the intercept alone and coefficient changes or both (Gregory and Hansen, 1996). Among the models suggested by Gregory and Hansen (1996), I choose the regime shift model (C/S) for the cointegrating relation between wage inequality, consumers' debt, and macroeconomic trends in the US and Korean economy. Gregory and Hansen (1996) propose statistics, the ADF, $Z\alpha$, and Zt , and their critical values at each significant level, 10%, 5%, and 1%. Moreover, the procedure of Gregory and Hansen detects an unknown date of the structural break in the long-run relation. Ultimately, the ARDL technique is applied to each period corresponding the structural breakpoint estimated by the Gregory-Hansen procedure. The model specification is based on the lag selection criterion such as Akaike Information Criterion (AIC), the serial correlation LM test, Ramsey test. For lack of space, the Durbin-Watson statistics are presented instead of the results of the serial correlation LM test. Moreover, the stability test of CUSUM square test is needed because the structural break in this study refers to changes in slope coefficients (Turner, 2010)

.

9.3 Empirical Results

9.3.1 The US Economy(1980-2014)

Consumption

The ARDL technique does not require the pre-test for unit roots. However, the Gregory-Hansen (G-H) test is validated in $I(1)$ of all variables (Gregory and Hansen, 1996; Narayan, 2005). Table 1 reports the results of the traditional unit root tests—the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. Model A and Model B in Table1 refer to the unit root test model with intercept and the one with both intercept and trend, respectively. Most variables employed in this study are nonstationary, but the ratio of consumption to GDP (cons) and wage inequality (WI) are stationary at the significant 5 % level if the model includes both intercept and trend (Model B); however, one of the variables, WI, is $I(1)$ based on the PP test.

TABLE 9.1: Augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP) for unit roots (US economy, 1980-2015)

	model	ADF	PP
cons	Model A	-1.31	1.26
	Model B	-3.84**	-3.69**
inv	Model A	-2.30	-2.75
	Model B	-2.26	-2.52
WI	Model A	-1.22	-1.05
	Model B	-3.75**	-3.10
CD	Model A	-1.38	-1.17
	Model B	-2.03	-0.77

** indicates significance at 5%.

The results in Table 9.2 are slightly different from those of the traditional unit root tests in Table 9.1. All variables employed in this study are nonstationary according to the Zivot-Andrews test with one structural break. Because the Gregory-Hansen test can be applied to the series with $I(1)$ process, the test can

TABLE 9.2: Zivot-Andrews test for unit roots (US economy: 1980-2015, maxlag=13)

	model	t-stat	B/P
cons	Model A	-4.06	2011:2
	Model B	-4.40	2000:3
inv	Model A	-3.57	1996:2
	Model B	-3.45	2008:1
WI	Model A	-4.22	1996:2
	Model B	-4.37	1997:4
CD	Model A	-3.77	2001:3
	Model B	-3.60	1989:2
Critical Values			
Significance level	Model A	Model B	
1%	-5.34	-5.57	
5%	-4.93	-5.08	
10%	-4.58	-4.82	

B/P in the table refers to the breakpoints calculated from the tests.

be conducted to find an endogenous structural break in an unknown date.

TABLE 9.3: Gregory-Hansen test for cointegration (US economy)

	Model 1 (1980-2015)	Model 2 (1980-2015)
ADF*	-4.43	-5.04
B/P	2005:3	2001:1
Z_α	-30.49	-18.50
B/P	2001:1	1996:1
Z_t	-4.23	-3.15
B/P	2001:1	2008:4
Critical Values		
Significance level	ADF*, Z_t	Z_α
5%	-5.50	-58.33
10%	-5.23	-52.58

B/P in the table refers to the breakpoints calculated from the tests.

As shown in Table 9.3, the Gregory-Hansen test for the regime shift (C/S) tests fails to reject the null hypothesis of no cointegration in the models 1 and 2.

The cointegrating relations for the period 1980-2015 in the models do not hold, and the endogenous structural breaks suggested in the tests need to be taken into account. Thus, I constructed cointegration models around the estimated breakpoints by the Gregory-Hansen test. Note that the estimated breakpoints by the Gregory-Hansen test are somewhat different from the Zivot-Andrews test's results that target one variable. The cointegrating test for the model 1 was conducted around 2001Q3 out of the results endogenously estimated by the Gregory-Hansen test (See Table 3), which is the reference date suggested by Z_α and Z_t statistics. The ARDL bound test 'involves the comparison of the F-statistics against the critical values (Narayan, 2005),' which are from Narayan (2005) for specific sample sizes.

TABLE 9.4: Cointegration test (Model 1 for the US economy, K=2)

ARDL bound test for cointegration		
Calculated F statistic		
Peorid	N	F
1980:1-2000:4 / ARDL(3,4,1)	79	7.05
2001:1-2014:4 / ARDL(1,2,5)	50	12.49
Critical Value bounds of the F-statistic		
	5%[$I(0)/I(1)$]	10%[$I(0)/I(1)$]
N=80, K=2	3.94/5.04	3.26/4.24
N=50, K=2	4.07/5.19	3.33/4.31
Gregory-Hansen test for cointegration		
	1980:1-2000:4	2001:-2014:4
ADF*	-6.07***	-6.47***
B/P	1986:4	2010:3
Z_α	-41.75	48.24
B/P	1983:3	2010:3
Z_t	-5.27*	-6.54***
B/P	1983:3	2010:3

N: The number of observations K: The number of regressors *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 4 reports the results of the bound test for cointegration of the model 1 for 1980:1-2000:4 and 2001:1-2014:4 periods. Because Narayan (2005) provides the critical values for the test corresponding to the observation numbers ranging

from 30 to 80, the calculated F-statistic of the model 1 should be compared with the critical values suitable for the number of observations and regressors. The lag specification of the model 1 for 1980:1-2000:4 is ARDL (3,4,1) selected based on the AIC criterion. The calculated F-statistic of the model 1 for 1980:1-2000:4 is higher than the upper bound critical value of 5.04 at the 5% level. This result suggests that the null of no cointegration can be rejected. Similarly, the F-statistic of the model for 2001:1-2014:4 [ARDL (1,2,5)] is much greater than the critical value of 5.09 at the 5% level. Thus, the variables in model 1 for 2001:1-2014:4 are cointegrated. Moreover, the results of the Gregory-Hansen test in Table 4 protects the cointegrating relation of each model from the intervention of possible breakpoints. These results from the Gregory-Hansen test support those from the bounds tests for two periods.

TABLE 9.5: Estimated long-run coefficients for model 1 (US economy)

	1980:1-2000:4	2001:1-2014:4
β_{10}	0.1902*** (0.0421)	0.5688*** (0.0951)
β_{11}	0.0225 (0.0352)	-0.471** (0.0214)
β_{12}	0.0537** (0.0209)	0.0114* (0.0059)

Standard errors in brackets. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 5 reports the estimation results of the long-run coefficients. For the period 1980:1-2001:4, as many kinds of literature on the US economy under neoliberalism have expected, the long-run coefficients of wage inequality and households' debt are positive. In other words, the increase in wage equality and households' debt in the US economy contributed to an upward trend of the ratio of consumption to GDP for the period 1980:1-2001:4. However, for the period 2001:1-2014:4 including the 2001 crisis and the Financial Crisis in 2008, the coefficient of wage inequality is negative. That is, the rise in wage inequality led to a decrease in the share of consumption in GDP since the 2000s. The sequential crises in the US

economy may disrupt the consumption pattern of the country under neoliberalism. The coefficients of the error correction term in Table A1 are statistically significant at the 1% level with a negative sign for each period. These results support the existence of the long-run relationship between the variables.

Investment

During the neoliberal period, the negative coefficients of the model 2 meaning that the effects of neoliberalism are associated with a decrease in investment are expected. As shown in Table 3, the model 2 for the period 1980-2015 is expected to have a breakpoint by the Gregory-Hansen test. Therefore, the tests were conducted for each period of 1980:1-2008:4 and 2009:1-2014:4. In these tests for investment in the US economy, the breakpoint refers to the Global financial crisis in 2008.

The Gregory-Hansen tests for each period report the rejection of no cointegrations. Moreover, the ARDL bound test (Table 6) and the error correction models for each period (Table A3) support the existence of long-run relationships between investment, consumers' debt, and wage inequality in the US economy. For 1980:1-2008:4, wage inequality had a positive long-run relationship with the rate of capital accumulation, and an increase in consumers' debt decreased the rate in the long term. This result is quite different from the expected relationships between the variables during the neoliberal period. However, for 2009:1-2014:4, that is, after the crisis, the signs of the long-run coefficients are all negative. An increase in both of wage equality and consumers' debt was associated with a decrease in the pace of capital accumulation in the US economy for the period (Table 7).

The test result for 1980:1-2008:4 deviates from the expectation associated with the usual nature of the increase in wage inequality during the neoliberal period on investment. It is necessary to examine this result in various angles. One of the results of the Zivot-Andrews test referred to 2008:1 as the breakpoint of

TABLE 9.6: Cointegration test (Model 2 for the US economy, K=2)

ARDL bound test for cointegration		
Calculated F statistic		
Peorid	N	F
1980:1-2008:4 / ARDL(12,0,3)	101	5.17
2009:1-2014:4 / ARDL(3,3,1)	21	10.40
Critical Value bounds of the F-statistic		
	5%[I(0)/I(1)]	10%[I(0)/I(1)]
K=2 1)	3.10/3.87	2.63/3.35
N=30, K=2	3.53/4.42	2.91/3.69
Gregory-Hansen test for cointegration		
	1980:1-2008:4	2009:1-2014:4
ADF*	-5.89***	-6.76***
B/P	1988:4	2011:1
Z_{α}	-23.42	-28.29
B/P	1987:1	2010:2
Z_t	-3.51	-6.29***
B/P	1987:1	2010:2

N: The number of observations K: The number of regressors *, **, and *** indicate significance at 101) Case 2. Restricted intercept and no trend, Pesaran, Shin, and Smith (2001).

TABLE 9.7: Estimated long-run coefficients for model 2 (US economy)

	1980:1-2008:4	2009:1-2014:4
β_{20}	0.0290 (0.0214)	0.1930*** (0.0076)
β_{21}	0.1833*** (0.0823)	-0.0331 (0.0416)
β_{22}	-0.0981** (0.0208)	-0.1811*** (0.0079)

Standard errors in brackets. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

the slope and intercept of the pace of capital accumulation in the US economy. The Gregory-Hansen test for 1980:1-2007:4 proposes -6.98 and -5.43 of t-stat of ADF procedure and Z_t -stat, and these statistics are significant at the 5% and 10% levels, respectively. Thus, the no long-run level relationship with a breakpoint

can be rejected.

TABLE 9.8: Cointegration test (Model 2 for the US economy, 1980:1-1988:4: B/P: 2007:4)

ARDL bound test for cointegration			
Calculated F statistic			
Peorid	N	F	
1980:1-2007:4 / ARDL(12,5,0)	97	4.66	
2008:1-2014:4 / ARDL(1,2,5)	23	9.47	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]	10%[I(0)/I(1)]	
K=2 1)	3.10/3.87	2.63/3.35	
N=30, K=2	3.53/4.42	2.91/3.69	
Estimated long-run coefficients			
	β_{20}	β_{21}	β_{22}
1980:1-2007:4	0.0798* (0.0414)	-0.0833 (0.1732)	-0.0090 (0.0455)
2008:1-2014:4	0.1398 (0.0237)	-0.0409 (0.0390)	-0.1091*** (0.0202)

N: The number of observations K: The number of regressors *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. 1) Case 2. Restricted intercept and no trend, Pesaran, Shin, and Smith (2001).

Table 8 reports the result of the cointegration test for 1980:1-2007:4 and 2008:1-2014:1. These results are consistent with the expectations concerning the neoliberal pattern, although the statistical significance of the previous model with 2008:4 was slightly reduced. The long-run relationship between wage inequality, consumers' debt, and the pace of capital accumulation is negative over the observation period. Since the 2008 crisis, although it is very small observation span, the constancy of the parameters of the model 2 for 2008:1-2014:4 is supported by the CUSUM square test; however, that of the model 2 for 2009:1-2014:4 failed to be held (See Figure B4 and Figure B6).

Cointegration tests for the annual data series

The cointegration tests for the annual data provide information about the long-run relationship between domestic demand, wage inequality, and consumers' debt for the entire observation period, 1980-2014, in the US economy.

TABLE 9.9: Cointegration test (US economy, 1980-2014)

ARDL bound test for cointegration			
Calculated F statistic			
Model/Peorid	N	F	
Model 1/1980-2014 ARDL(4,4,0)	31	8.83	
Model 2/1980-2014 ARDL(4,4,2)	23	9.47	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]	10%[I(0)/I(1)]	
N=30, K=2	3.53/4.42	2.91/3.69	
Estimated long-run coefficients			
	β_{10}	β_{11}	β_{12}
Model 1/ARDL (4,4,0)	0.4729*** (0.0143)	0.4356*** (0.0534)	0.0133 (0.0138)
	β_{20}	β_{21}	β_{22}
Model /ARDL(4,4,2)	0.0568 (0.0403)	-0.0044 (0.1749)	-0.0327 (0.0484)

N: The number of observations K: The number of regressors *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 9 shows the results of the long-run cointegration tests for the annual data. As mentioned above, the model 1 is constructed to capture a relationship between consumption, wage inequality, and consumers' debt in the long term and the model 2 contributes to the estimation of a long-run relationship between the rate of capital accumulation and other variables. Each result of ARDL bound tests, and the error correction models for each model (Table A3) supports the existence of the long-run relationship between the variables. The lag specification of the model 2 was selected based on the Hannan-Quinn Criterion. That model fulfills the criterion, and thus, the null hypothesis of no levels relationship can be rejected at the significant level 10%. The results of the estimation of the model 1 are consistent with the expected ones during the neoliberal period. A high level of wage inequality and consumers' debt was positively associated with consumption during the period. As mentioned above, the previous estimations

for the model 2 using the quarterly data have also indicated that the relationship between the rate of capital accumulation and wage inequality may vary for each period and lag specification. This ambiguous effect of inequality on the pace of capital accumulation before the crisis in 2008 may result from the investment boom of the 1990s in the US economy.

9.3.2 Korea (1980-2014)

Consumption

Even after 1980, the Korean economy maintained a lot of the old developmental strategies, for example, the industrial policies by the state, state-owned banks, and strong national support for the selected companies, Chaebol, which are the comprehensive effect of the former elements. From 1980 through 1997, there have been many deregulations for globalization and financialization. In short, at that time, there was a mixture of the trend to dismantle the existing development strategy and the economic structure that still depends on it. I tried to capture the effect of the mixture on domestic demand. Moreover, I investigated whether the radicalization of the neoliberal reform since 1997 let the Korean economy settle in neoliberalism.

TABLE 9.10: Augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP) for unit roots (Korean economy, 1980:1-2014:4)

	model	ADF	PP
cons	Model A	-2.27	-2.29
	Model B	-2.03	-2.08
inv	Model A	-1.07	-1.94
	Model B	-2.74	-2.78
WI	Model A	-0.01	-0.27
	Model B	-2.26	-2.05
CD	Model A	-0.81	-0.76
	Model B	-3.37*	-2.96

* indicates significance at 10%.

TABLE 9.11: Zivot-Andrews test for unit roots (Korean economy: 1980:1-2014:4, maxlag=13)

	model	t-stat	B/P
cons	Model A	-3.17	1998:2
	Model B	-3.48	1989:1
inv	Model A	-3.72	1997:2
	Model B	-4.08	1997:1
WI	Model A	-4.06	2003:2
	Model B	-4.16	1992:2
CD	Model A	-6.67***	1998:2
	Model B	-6.48***	1998:2
Critical Values			
Significance level	Model A	Model B	
1%	-5.34	-5.57	
5%	-4.93	-5.08	
10%	-4.58	-4.82	

*** indicates significance at 1%.

As shown in Table 10, most of the employed variables for the study of the Korean economy have $I(1)$ at the significant level 5%. However, consumers' debt of the Korean economy cannot reject the null if taking account of a breakpoint (Table 11). The Lumsdaine-Papell test, which is the unit root test with two endogenous breakpoints, provides a contradictory result regarding the unit roots of the variable. I conduct Lumsdaine and Papell's CC model of the structural trend and intercept changes for the unit root test (Lumsdaine and Papell, 1997; Dan Ben-David and David H. Papell, 2003; Narayan, 2006), which is the same as Model B for the unit roots in this paper. To conserve space, only results for t-statistics of the existence of the unit root are reported here. The AIC is the criterion of the selected optimal lag.

Consumers' debt is still stationary in the Lumsdaine-Papell unit root test with two breakpoints at the significant 5% level; the other three variables are non-stationary, $I(1)$ (Table 12). Therefore, the Gregory-Hansen test for the Korean economy cannot be conducted for the entire observation period, 1980:1-2014:4, and an endogenous systemic breakpoint cannot be estimated for the period. However, the breakpoints for the ARDL bound tests are selected by choosing the approximately closest points between the results of the two different tests.

TABLE 9.12: Lumsdaine-Papell test for unit roots (Model CC, Korean economy, 1980:1-2014:4, maxlag=13)

	cons	inv	WI	CD
α	-0.24	-0.02	-0.16	-0.40**
t-stats	-5.46	-5.96	-5.02	-7.20
optimal lag	10	13	13	10
B/P	1985:4/1998:1	1992:3/2003:2	1993:2/2005:4	1984:2/1998:2

** indicates significance at 5%. The critical values, from Lumsdaine and Papell (1997, Table 3), are -7.34 (1%), -6.82 (5%), and -6.49 (10%).

For example, the breakpoint of model 1 for the US economy was 2000:1 out of the Gregory-Hansen test breakpoints, which is the closest point out of the result of the Zivot-Andrews test breakpoints. This result is also true of the estimation relating to the rate of capital accumulation. Thus, the breakpoint of consumption, 1989:1, and the breakpoint of investment, 1997:1, estimated by the Zivot-Andrews test are the reference date of estimations for each period.

Table 13 reports the results of the cointegrating bound test of model 1 for the Korean economy. The breakpoint, 1989:1, was estimated by model B of the Zivot-Andrews test. These models included time trends, T , in the cointegrating relations because the time trends make the model more statistically significant. Each independent variable of the ARDL (5,1,0) has a long-run positive relationship with consumption of the Korean economy; in the ARDL (1,0,4), a long-run negative relationship of consumers' debt with consumption is estimated. The former relationship represents the popular neoliberal pattern between inequality, consumers' debt, and consumption; however, the latter is quite different from the pattern. That is, a high level of consumers' debt led to a decrease in the ratio of consumption to GDP during that period. Despite all these results, the impact of the 1997 Asian crisis cannot be excluded. Another breakpoint of the ratio of consumption of the Korean economy estimated by the Lumsdaine-Papell test is 1998:1 as shown in Table 12.

TABLE 9.13: Cointegration test (Model 1 for the Korean economy, 1980:1-2014:4)

ARDL bound test for cointegration			
Calculated F statistic			
Peorid	N	F	
1980:1-1989:1 / ARDL(5,1,0)	33	6.90	
1989:2-2014:4 / ARDL(1,0,4)	106	8.12	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]	10%[I(0)/I(1)]	
N=30, K=2 1)	4.53/5.41	3.77/4.53	
K=2 2)	3.88/4.61	3.38/4.02	
Estimated long-run coefficients			
	β_{11}	β_{12}	T
ARDL (5,1,0)	0.2483 (0.2738)	0.8807*** (0.2841)	-0.0091*** (0.0014)
ARDL(1,0,4)	-0.2021 (0.1451)	-0.6576*** (0.1072)	0.0030*** (0.0004)

N: The number of observations K: The number of regressors. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. 1) Case 4. Unrestricted intercept and restricted trend, Narayan (2005) 2) Case 4. Unrestricted intercept and restricted trend, Pesaran, Shin, and Smith (2001)

TABLE 9.14: Cointegration test (Model 1 for the Korean economy, 1980:1-2014:4)

ARDL bound test for cointegration			
Calculated F statistic			
Peorid	N	F	
1989:2-1997:4:1 / ARDL(1,4,0)	30	4.71	
1998:2-2014:4 / ARDL(1,0,4)	68	7.01	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]		10%[I(0)/I(1)]
N=65, K=2 1)	4.12/4.90	3.53/4.20	
Estimated long-run coefficients			
	β_{10}	β_{11}	β_{12} T
ARDL (1,4,0)	0.5491*** (0.0737)	-0.5514** (0.22242)	0.2237*** (0.0605)
ARDL(1,0,4)		-0.2159 (0.1995)	-0.6884*** (0.1791) 0.0032 (0.0009)

N: The number of observations K: The number of regressors ** and *** indicate significance at 5%, and 1%, respectively. 1)
Case 4 Unrestricted intercept and restricted trend, Narayan (2005)

Table 14 indicates the estimation results of the model 1 for 1989:1-2014:4; the breakpoints is 1998:1 estimated by the Lumsdaine-Papell test as mentioned above. Before the 1997 crisis, the pattern was quite distinct from the estimation result of the model 1 for 1980:1-1989:1. A high level of consumers' debt was positively associated with an increase in the ratio of consumption; however, the rise in inequality decrease the share of consumption in the Korean economy. Since 1997, all explanatory variables in the model 1 for the Korean economy have a long-run negative relationship with consumption. This result is very interesting because "the financial crisis in 1997 was a watershed moment for full-blown neoliberalism in Korea's economy (Lee 2010: 11)." In other words, in terms of the pattern of consumption in neoliberalism, the Korean economy didn't share with that of the US economy. The rise in inequality and consumers' debt known as the popular characters of neoliberalism caused a decrease in the ratio of consumption to GDP in the Korean economy since 1997. The CUSUM square tests of these two models for each period, 1989:2-1997:4 and 1998:1-2014:4, indicate that the estimation results are within the 95% confidence band; the parameters stability is fulfilled contrary to the ARDL for 1989:2-2014:4 (See Figure H3). It is worth noting the two contradict trends of inequality and consumers' debt with the ratio of consumption for 1989:2-1997:4. The positive effect of consumers' debt on the consumption share is in accordance with the result of the ARDL for 1980:1-1989:2; however, during that period, increased inequality led to a decrease in the ratio of consumption. Above all, it should be kept in mind that wage inequality in the Korean economy declined in the mid-1990s due to the strong resistance of workers despite an upward trend in the ratio of consumption (See Figure C2).

Investment

As shown in Figure C2, the rate of capital accumulation in the Korean economy trends downward over the reference period. In particular, the pace of capital accumulation stagnated following exceptionally high levels of the rate before the 1997 crisis. The table below illustrates the estimated long-run relationships

between the pace of capital accumulation and the specific patterns of neoliberalism, that is, an increase in wage inequality and in consumers' debt in the Korean economy since 1980.

TABLE 9.15: Cointegration test (Model 2 for the Korean economy, 1980:1-2014:4)

ARDL bound test for cointegration			
Calculated F statistic			
Peorid	N	F	
1980:1-1997:1 / ARDL(8,0,8)	60	5.90	
1997:2-2014:4 / ARDL(4,6,3)	65	5.34	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]	10%[I(0)/I(1)]	
N=60, K=2	4.00/5.05	3.27/4.26	
N=65, K=2 1)	4.01/5.08	3.30/4.25	
Estimated long-run coefficients			
	β_{20}	β_{21}	β_{22}
ARDL (8,0,8)	1.0963 (0.8062)	-4.1795 (3.3617)	-0.0154 (0.1740)
ARDL(4,6,3)		-0.0194 (0.1459)	0.0896** (0.0425)

N: The number of observations K: The number of regressors. 1) case 3. unrestricted intercept and no trend, Narayan (2005). ** indicates significance at 5%.

It is very difficult to capture a cointegrating relationship for 1997:2-2014:4 in the Korean economy. The coefficient signs of the wage inequality were positive in some specific periods. However, in those periods, the F-statistics was lower than the upper bound critical value, and thus, the cointegrating relationship cannot be captured.

The CUSUM square test for the ARDL (4,6,3) model for 1997:2-2014:4 does not support the parameter constancy of the model over the entire observation period and there was a structural break between 2008 and 2010; however, it is difficult to see it as a fundamental and persistent structural break because, in the following periods, the test shows the results within the confidence intervals. The estimation result of the model for 1997:2-2014:4 is the same as those of the US economy. Even after the 1997 Asian Crisis, the pace of capital accumulation

in the Korean economy has a negative relationship with wage inequality and consumers' debt. Thus, the massive increase in wage inequality and consumer debt during that period led to a decline in investment in the Korean economy.

Cointegration tests for the annual data series

Table 16 indicates the results of the cointegrating bound test providing overall information about the long-run pattern between the variables in the Korean economy from 1980 through 2014. As shown in Table 16, the effect of inequality and consumers' debt on consumption and investment are consistent with the expected neoliberal patterns. An increase in inequality and consumers' debt increases the ratio of consumption to GDP; a slower pace of capital accumulation is associated with a rise in inequality and consumers' debt in the Korean economy. As for the case of the model 2 for the annual data, not only is the model 2 without the dummy variable statistically insignificant, but also it loses the constancy of the parameters according to the CUSUM tests.

TABLE 9.16: Cointegration test (Korean economy, 1980-2014)

ARDL bound test for cointegration			
Calculated F statistic			
Peorid	N	F	
Model 1/1980-2014 ARDL(1,5,3)	31	4.88	
Model 2/1980-2014 ARDL(2,0,0) 1)	31	5.08	
Critical Value bounds of the F-statistic			
	5%[I(0)/I(1)]	10%[I(0)/I(1)]	
N=30, K=2	3.53/4.42	2.91/3.69	
Estimated long-run coefficients			
	β_{10}	β_{11}	β_{12}
ARDL(1,5,3)	0.8053*** (0.1631)	-1.5813* (0.8689)	0.2853 (0.1649)
	β_{20}	β_{21}	β_{22}
ARDL(2,0,0)	0.0766*** (0.185)	-0.0778 (0.0778)	0.0013 (0.0156)

N: The number of observations K: The number of regressors * and *** indicate significance at 10% and 1%, respectively. 1) This ARDL model includes a dummy variable, 0=year<1997, as the fixed regressor.

9.4 Discussion and Conclusion

In both countries, the estimations of the annual data series indicated the expected signs of the neoliberal patterns of demand. A rise in wage inequality and consumers' debt is positively associated with consumption and negatively associated with investment. If taking the breakpoints into account, however, what is interesting about this study is that the effects of wage inequality and consumers' debt on the consumption ratio to GDP are different for each period. Before the subsequent crises of the 2000s, the signs denote the same as the

TABLE 9.17: Long-run relationships for each period (US economy: 1980-2014)

US economy				
	cons		inv	
	1980:1-2000:4	2001:1-2014:4	1980:1-2007:4	2008:1-2014:4
WI	+	-	-	-
CD	+	+	-	-

expected relationships of neoliberal patterns. "Deficient accumulation rates are a basic component of the trajectory of the US economy, but these trends are not, alone, the cause of the crisis. Conversely, the rise of consumption, (...), is at the center of the mechanisms that led to the crisis (Duménil and Lévy, 2011: 53)." Furthermore, the upward trends of consumers' debt and wage inequality stimulated consumption in domestic aggregate demand and are negatively associated with investment demand. The unlimited profit seeking of the financial institutions and the deregulation during the neoliberal period allowed for the growth of tremendous consumers' debt. The pursuit of high income, coupled with globalization, has brought tremendous benefits to top managers of financial institutions, in the form of high wages (Duménil and Lévy, 2011). Since 2001, however, a high level of wage inequality has had a long-run negative effect on the ratio of consumption despite the positive relationship of consumers' debt with the consumption ratio. Thus, the rise in wage inequality has decreased domestic demand in the US economy since the major crises in the 2000s. As shown in Figure C1, there has been a constant upward trend of wage inequality since those crises whereas consumers' debt reached a peak in 2008 and fell steadily.

All these trends had a negative impact on domestic demand, and thus, the US economy had to rely on government spending to stop shrinking demand for the economy. In sum, neoliberal trends where a rise in inequality and consumers' debt led to "overconsumption, paralleling under-accumulation ([Duménil and Lévy, 2011](#): 37)" and resulted in a general contraction following the crises of the 2000s coupled with a decline in consumer debt that was at an unsustainable level in domestic demand.

TABLE 9.18: Long-run relationships for each period (Korean economy: 1980-2014)

Korean economy		cons				inv	
		1980:1-1989:1	1989:2-1997:4	1998:1-2014:4	1980:1-1997:1	1997:2-2014:4	
WI		+	-	-	-	-	-
CD		+	+	-	-	-	-

Table 18 indicates the estimation results of the cointegration bound tests for each periods of the Korean economy. As for the ratio of consumption, wage inequality and consumers' debt wage positively associated with that ratio. This result is the same as that of the US economy before the 2000s. From the 1990s, the long-run relationship of the Korean economy became the same as that of the US economy since the crises. Even after the crisis in 1997, the ratio of consumption had a long-run negative relationship with wage inequality and consumers' debt. Moreover, those upward trends of inequality and consumers' debt was accompanied by the slower pace of capital accumulation. Since 1997, when neoliberalism was supposed to be settled in the country, the neoliberal patterns of wage inequality and consumers' debt have stagnated domestic demand of the country. Thus, instead of traditionally restrained fiscal spending, this country had to depend on foreign demand, that is, the export of the country. These results of the country were interconnected with those of the US economy. The US trade deficit and overconsumption contributed to a dramatic increase in the export of the Korean economy coupled with the rapid growth of the Chinese economy. Moreover, these estimation results can compare with the argument that grouped the countries like US and UK as the debt-led growth regime and China or Japan as the export-led growth regime (Stockhammer, 2013). Stockhammer argued that "increasing inequality leads potentially to a stagnation of demand, since lower income groups have higher consumption propensity (Stockhammer, 2013: 950)." As shown in the above, however, rising inequality if taking wage inequality and consumers' debt into account did not decrease domestic demand consistently. In the estimations using the yearly data, a rise in wage inequality decreases investment but increases the ratio of consumption in the both countries. Nevertheless, the rise in wage inequality and consumers' debt after the 2000s led to a decrease in domestic demand in the Korean economy; in the US economy, the rise in wage inequality after the 2000s decreased domestic demand, although consumers' debt is still positively associated with consumption.

Conclusion

In this dissertation, I reviewed the nonlinear dynamics in mathematics and the system dynamics approach and applied the two methods for representing business cycles and economic growth (Chapter 1 and Chapter 2). According to the results in the chapters, the irregular and unpredictable patterns of business cycles stem from changes in each sensitivity of management, finance, and policy authorities. In particular, an unfortunate intersection of such sensitivities can lead to the sudden collapse of the macroeconomy. Although the central authority is a vital role for stabilizing the economy, the stabilizing actions are an afterthought. If there is a broad range of stabilization devices, it would be a delicate monitoring and supervision of changes in the sensitivities of management and finance (Chapter 3 and Chapter 4).

In Chapter 6, the stochastic technical change model reconstructed the actual trajectories of technology and distribution in the Korean economy using the system dynamics method. I provided the system dynamics codes for building the technical change model. Now is easy to think that you have a model under any circumstances, it is applied to real economic data.

In both of the theoretical chapter (Chapter 5) and the empirical chapter (Chapter 8), capital accumulation in the Korean economy since 1997, the Asian Foreign Exchange Crisis, mostly depends on the outside fundings from the financial sector, which is commanded by the state policies. In the theoretical chapter, a financial behavioral shift from the business sectors to the household sectors led to a slowdown in the pace of capital accumulation. The disappearance of support for capital accumulation by the financial sector in the real economy of Korea is associated with the prolonged stagnation of capital accumulation since 1997. I have demonstrated this by comparing forecasting systems through the

VAR method.

In Chapter 7, I have presented various macroeconomic data, which can be used to diagnose the current situation of the Korean economy, with the newly calculated profit rate data. The Korean economy is experiencing heterogeneity in many aspects. In the technological side of the country's economy, a profitability gap is deepening among the different sectors. Moreover, like the other countries' economy, the heterogeneity among the wage earners is increasing. The distributional gap between the top wage earners and the lower income group of workers is getting wider. There is a close connection between these two heterogeneities because the high-income group of employees may be employed in the high competitive part of the export-centered manufacturing companies. However, these heterogeneities make it difficult for the Korean economy to cope with severe economic fluctuations (Chapter 8). In the last chapter (Chapter 9), a long run relationship between domestic demand, wage inequality, and household debt in the US and Korean economy during the neoliberal period could be captured. The estimation results were consistent with the expected ones, that means that a rise in inequality and household debt is positively associated with consumption and decreases investment. However, since the 2000s crisis, the impacts of inequality and household debt on investment have been the same but the rise in consumers' debt in the US economy has still increased consumption. Nevertheless, the actual decrease in consumers' debt after the crises decreased consumption. In the Korean economy, after the 1997 crisis, inequality and consumers' debt has a negative relationship with domestic demand. Korea could not help depending on foreign demand instead of government spending historically restrained.

Appendix A

Bifurcation in the Reproduction model

There is a Hopf bifurcation in the N-G-M model. Let ϵ_c a critical value to find the Hopf bifurcation process. By $AB - C = 0$, the stability conditions of the characteristic equation (9), we can easily find the critical value, ϵ_c , as follows

$$\epsilon_c = \frac{\zeta((1-a)(u_d^t + \Gamma u^* \zeta) + \Gamma m^* \zeta(b + \nu) - u_d^t \nu)}{(1-a)(u_d^t(1 + 2\Gamma u^* \zeta) + \Gamma u_d^{t2} \zeta^2) + \Gamma m^* b \zeta(u_d^t + b \zeta) - (1-a \zeta) \zeta}$$

The N-G-M system has a limit cycle at $\epsilon = \epsilon_c$ because its characteristic roots are pure imaginary numbers under the condition, $AB - C = 0$. If $\epsilon < \epsilon_c$, this system is locally stable. In other words, it can be stabilized as the production times are getting shorter and shorter when the other conditions do not change. However, it is nearly impossible to product instantly without any delay. If, moreover, the other conditions, such as the financial sensitivity, changed, the time to adjust production discrepancies may get longer. Therefore, firms in modern economies hold the time delay constraint permanently. This is the premier condition to present the persistence and irregular cycles in this research.

Figure A.1 illustrates dynamics of u as a function of ϵ . And then, the period-doubling process appears around the region $4 < \epsilon < 5$ if $\epsilon > \epsilon_c$. Furthermore, the region around the nearby $\epsilon = 6$ in Figure A.1 allows us to see the chaotic motion exists in the system. In this way, Figure 18 provides information about

the process reached from the local stability to the chaotic motion via limit cycle, which is called as the Hopf bifurcation mathematically.

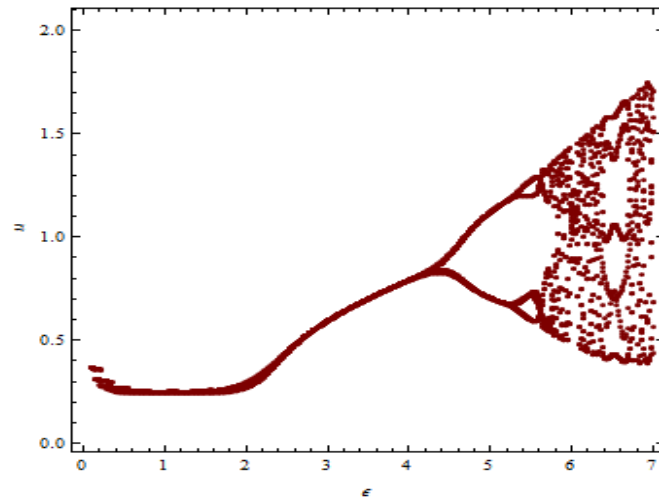


FIGURE A.1: Bifurcation diagram to ϵ , $a = 0.7, b = 0.3, \nu = 4.15, \zeta = 0.45, \rho = 0.4, u_0 = 0.3, v_0 = 0.2, m_0 = 0.3$

Appendix B

The Canonical Lorenz Attractor and Rössler Attractor

There are two representative models of the strange attractor which have been known to us, that is Lorenz attractor and Rössler attractor, which also represent the chaotic motion. In particular, as compared with their power spectrum, it allows us to check whether the chaotic motion exists in the reproduction model with Rössler band.

The power spectrum analyses of the two typical strange attractors are shown in the (c) in Figure B.1 and B.2. The common features of both models are to emerge an unusual spike, followed by a dramatically declining pattern. This is the same with the one of the N-G-M model. In addition, their autocorrelation function, subfigures, (d) in Figure 19 and 20, converge toward 0 with fluctuating patterns.

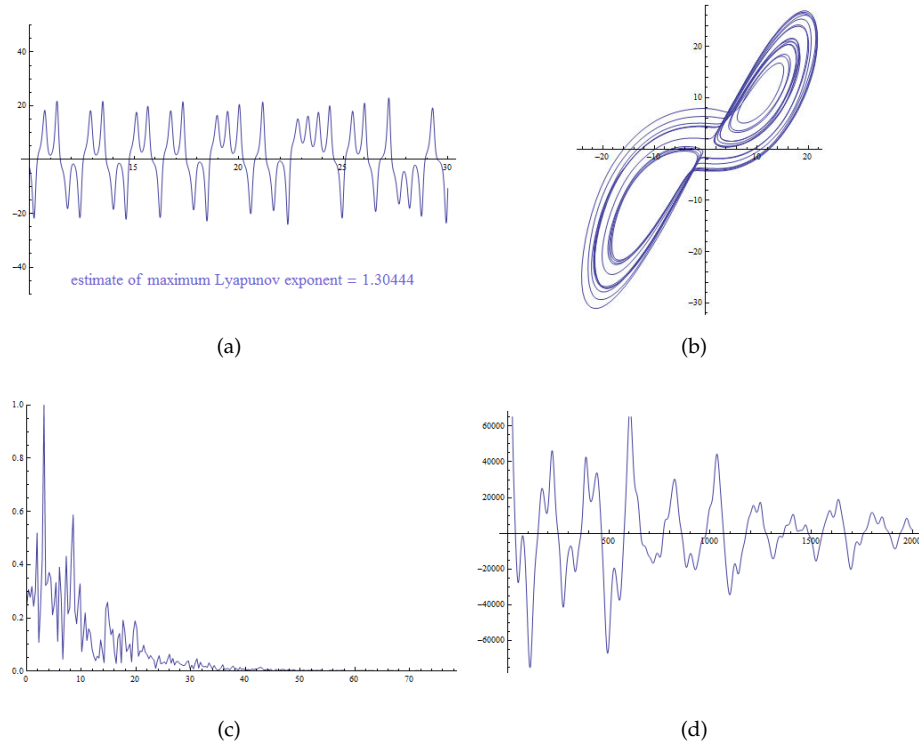


FIGURE B.1: The canonical Lorenz attractor, $x_0 = 19$, $y_0 = 20$, $z_0 = 50$, $\sigma = 16$, $r = 43$, $b = 2.9$: (a) The time series of x in the Lorenz System; (b) The phase space between x and y in the Lorenz System; (c) The power spectrum in the Lorenz System; and, (d) The autocorrelation function in the Lorenz System.

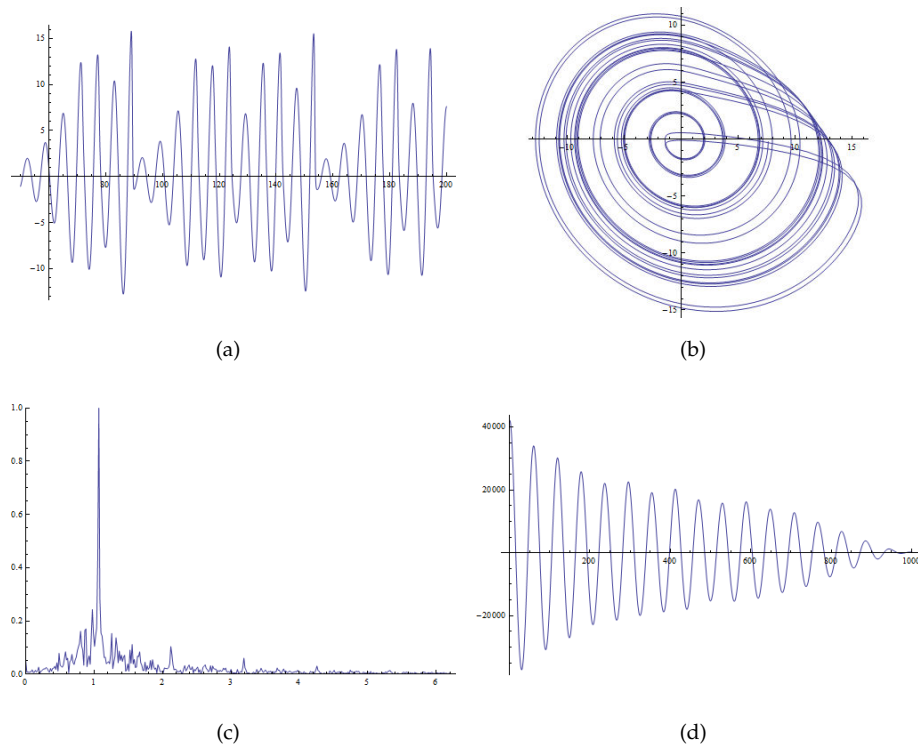


FIGURE B.2: The canonical Rössler attractor, $x_0 = 0.2$, $y_0 = 0.3$, $z_0 = 0.50$, $a = 0.2$, $b = 0.17$, $c = 7.9$: (a) The time series of x in the Rössler System; (b) The phase space between x and y in the Rössler System; (c) The power spectrum in the Rössler System; and, (d) The autocorrelation function in the Rössler System.

Appendix C

A Stability Analysis of the MSMM

The MSMM system that has an assumption concerning the capital accumulation process consists of three differential equations, (2.17), (2.18), (2.19). The fixed points of this system are as follows.

$$(u^*, s^*, m^*) = (0, \frac{-\bar{s}\epsilon\bar{u} - \bar{s}v}{\epsilon}, 0) \quad (C.1)$$

$$= (-\frac{\bar{u} - \bar{u}\zeta\rho}{\zeta\rho - 1}, -\frac{\bar{s}\epsilon(1 - \zeta\rho) + v(\bar{u} - \bar{u})}{\epsilon(\zeta\rho - 1)}, -\frac{(a - 1)(\zeta\rho - \bar{u})}{b(\zeta\rho - 1)}) \quad (C.2)$$

The fixed points (C.1) including zero rate of the capacity utilization and the negative fixed points of (C.2) must be excluded because that circumstances directly contradict with the economic reality. If $u = \bar{u}$, the fixed points are $u^* = \bar{u}$, $s^* = \bar{s}$, $m^* = ((1 - a)\bar{u})/b$. Accordingly, the Jacobian matrix for the local stability analysis of the MSMM system is as follows.

$$J = \begin{pmatrix} -\frac{1}{\epsilon} & -\frac{1}{v} & 0 \\ (1 - a) & 0 & -b \\ (\frac{\rho\zeta - 1}{\zeta})m^* & 0 & (\frac{\rho\zeta - 1}{\zeta})(u^* - \bar{u}) \end{pmatrix}$$

Appendix D

Vensim Equations for Simulations

All of the equations below are constituted by Vensim PLE for Windows Version 6.2.

- A positive or self-reinforcing feedback(Figure 1.4).Integartion Type: Euler, time step=1

(1) FINAL TIME = 100

Units: Month

The final time for the simulation.

(2) flows= growth rate*stocks

(3) growth rate= 0.025

(4) INITIAL TIME = 0

Units: Month

- A negative or self-correcting feedback(Figure 1.5). Integartion Type: Euler, time step=1

(1) desired level= 5

(2) FINAL TIME = 20

Units: Month

The final time for the simulation.

(3) flows= (desired level-stocks)/time delay to adjust

(4) INITIAL TIME = 0

Units: Month

The initial time for the simulation.

- Oscillation process of a System(Figure 1.6). Integartion Type: Euler, time step=0.25

(01) discrepancy1= (target1-Stock2)/timedelay1

(02) discrepancy2= (target2-Stock1)/timedelay2

(03) FINAL TIME = 100

Units: Month

The final time for the simulation.

(04) INITIAL TIME = 0

Units: Month The initial time for the simulation.

(05) Rate1= discrepancy1

(06) Rate2= discrepancy2

(07) SAVEPER = TIME STEP Units: Month [0,?] The frequency with which output is stored.

(08) Stock1= INTEG (Rate1, 1)

(09) Stock2= INTEG (-Rate2, 1)

(10) target1= 30

(11) target2= 30

- The simple production-distribution model (Figure 1.7 and 1.8). Integartion Type: Euler, time step=1.

(01) desired production= Factory Order Backlog/target production delay

(02) Factory Order Backlog= INTEG (retail orders-factory production, 200)

(03) factory production= SMOOTH(desired production, time to adjust production)

(04) FINAL TIME = 50 Units: Week

The final time for the simulation.

(05) INITIAL TIME = 0 Units: Week

The initial time for the simulation.

(06) Inventory discrepancy= (target inventory-Retail Inventory)/time to adjust inventory

(07) Retail Inventory= INTEG (factory production-retail sales, 400)

(08) retail orders= Inventory discrepancy

(09) retail sales= TEST input

(10) SAVEPER = TIME STEP Units: Week [0,?]

The frequency with which output is stored.

(11) target inventory= 400

(12) target production delay= 1 Units: Week

(13) TEST input= 100+STEP(20, 10)

(14) TIME STEP = 1 Units: Week [0,?]

The time step for the simulation.

(15) time to adjust inventory= 5.5

(16) time to adjust production= 1.125 Units: Week

- A transformation of a nonlinear system into system dynamics(Figure 1.10 and 1.11). Integration Type: RK4 Auto, time step=1

(01) discrepancy x= level x-target x

(02) discrepancy y= level y-target y

(03) FINAL TIME = 300 Units: Month

The final time for the simulation.

(04) INITIAL TIME = 0 Units: Month

The initial time for the simulation.

(05) level x= INTEG ((discrepancy x/time delay1)-(discrepancy y/time delay 2), 0.3)

(06) level y= INTEG ((discrepancy x/time delay 3)-(discrepancy y/time delay 4), 0.3)

(07) SAVEPER = TIME STEP Units: Month [0,?]

The frequency with which output is stored.

(08) target x= 0.8

(09) target y= 0.7

(10) time delay 2= 2.75

(11) time delay 3= 4.25

(12) time delay 4= 3.8

(13) time delay1= 3.75

(14) TIME STEP = 1 Units: Month [0,?] The time step for the simulation.

- Persistent fluctuations of Nonlinear System (Figure 1.12 and 1.13) Integration Type: RK4 Auto, time step=0.25.

01) coefficient e= 0.05

(02) control target= 7

(03) discrepancy x= level x-target x

(04) discrepancy y= level y-target y

(05) FINAL TIME = 300 Units: Month The final time for the simulation.

(06) INITIAL TIME = 0 Units: Month The initial time for the simulation.

(07) level x= INTEG ((discrepancy x/time delay1)-(discrepancy y/time delay 2)-level z, 0.3)

(08) level y= INTEG ((discrepancy x/time delay 3)-(discrepancy y/time delay 4), 0.3)

(09) $level\ z = INTEG (coefficient\ e + level\ z * ((level\ x - control\ target) / time\ delay\ 5), 0.3)$

(10) $SAVEPER = TIME\ STEP$ Units: Month [0,?] The frequency with which output is stored.

(11) $target\ x = 0.8$

(12) $target\ y = 0.7$

(13) $time\ delay\ 2 = 2.75$

(14) $time\ delay\ 3 = 5.625$

(15) $time\ delay\ 4 = 8.5$

(16) $time\ delay\ 5 = 1.5$

(17) $time\ delay\ 1 = 3.75$

(18) $TIME\ STEP = 0.125$ Units: Month [0,?] The time step for the simulation.

- Simple reproduction without the financial sector (Figure 2.4 and 2.5) Integration Type: RK4 Auto, time step=1.

(01) consumption propensity to the rate of change= 1 (Figure 2.4) or 0.7 (Figure 2.5)

(02) $FINAL\ TIME = 300$ Units: Month
The final time for the simulation.

(03) $INITIAL\ TIME = 0$ Units: Month
The initial time for the simulation.

(04) inventory adjustment delay= 4.125

(05) $output = INTEG ((the\ rate\ of\ change\ of\ output\ growth\ rate) * output, 1)$

(06) output adjustment delay= 11.5

(07) $SAVEPER = TIME\ STEP$ Units: Month [0,?]
The frequency with which output is stored.

(08) the growth rate of demand= consumption propensity to the rate of change*the rate of change of output growth rate

(09) the rate of change of inventory growth rate= INTEG (the rate of change of output growth rate-the growth rate of demand, 0)

(10) the rate of change of output growth rate= INTEG (-(the rate of change of output growth rate/output adjustment delay)-(the rate of change of inventory growth rate /inventory adjustment delay), 0.01)

(11) TIME STEP = 1 Units: Month [0,?]

The time step for the simulation.

- Simple Reproduction with the financial sector(Figure 2.6) Integration Type: RK4 Auto, time step=0.125.

(01) balanced growth rate= 0

(02) consumption propensity to the rate of change= 0.7

(03) FINAL TIME = 500

Units: Quarter

The final time for the simulation.

(04) INITIAL TIME = 0

Units: Quarter

The initial time for the simulation.

(05) inventory adjustment delay= 15.37

(06) inventory rate= INTEG (output rate-(the growth rate of demand+monetary parameter*money stock change rate), 0)

(07) monetary parameter= 0.3

(08) monetary sensitivity= 0.675

(09) money stock change rate= INTEG (output rate*monetary sensitivity*money stock change rate-policy making, 0.03)

(10) output= INTEG ((output rate)*output, 1)

(11) output adjustment delay= 1.5

(12) output rate= INTEG (-(output rate/output adjustment delay)-(inventory rate/inventory adjustment delay), 0.01)

(13) policy delay= 0.038

(14) policy making= ((output rate-balanced growth rate)/policy delay)*money stock change rate

(15) SAVEPER = TIME STEP

Units: Quarter [0,?]

The frequency with which output is stored.

(16) the growth rate of demand= consumption propensity to the rate of change*output rate

(17) TIME STEP = 0.125

Units: Quarter [0,?]

The time step for the simulation.

- Expanded Reproduction with the financial sector(Figure 2.12 and 13) Integration Type: RK4 Auto, time step=0.125.

(01) balanced growth rate= 0.025

(02) consumption propensity to the rate of change= 0.7

(03) FINAL TIME = 500

Units: Quarter

The final time for the simulation.

(04) INITIAL TIME = 0

Units: Quarter

The initial time for the simulation.

(05) inventory adjustment delay= 5

(06) inventory rate= INTEG (output rate-(the growth rate of demand+monetary parameter*money stock change rate), 0)

(07) monetary parameter= 0.3

(08) monetary sensitivity= 0.675

(09) money stock change rate= INTEG (output rate*monetary sensitivity*money stock change rate-policy making, 0.03)

(10) output= INTEG ((output rate)*output, 1)

(11) output adjustment delay= 5.3

(12) output rate= INTEG (-(output rate/output adjustment delay)-(inventory rate/inventory adjustment delay), 0.01)

(13) policy delay= 0.05

(14) policy making= ((output rate-balanced growth rate)/policy delay)*money stock change rate

(15) SAVEPER = TIME STEP

Units: Quarter [0,?]

The frequency with which output is stored.

(16) the growth rate of demand= consumption propensity to the rate of change*output rate

(17) TIME STEP = 1

Units: Quarter [0,?]

The time step for the simulation.

- Business cycles in the MSMM(Figure 3.2-3.5). Integration Type: RK4 Auto, time step=0.125

(01) capacity utilization= INTEG (-(utilization discrepancy /time delay utilization)-(inventory discrepancy/time delay inventory), 1)

(02) demand= utilization parameter*capacity utilization+money stock parameter*real money stock +demand shock

(03) demand shock= RANDOM NORMAL(-0.5, 0.5 , 0 , 0.025 , 0)

(04) FINAL TIME = 400 Units: Month The final time for the simulation.

(05) financial sensitivity= 0.3+SMOOTH(STEP(0.1, 75), 30)-STEP(0.9, 150)+SMOOTH(STEP(0.9, 150), 20)

(06) INITIAL TIME = 0 Units: Month The initial time for the simulation.

(07) inventory discrepancy= inventory stock-target inventory

(08) inventory stock= INTEG (capacity utilization-demand, 0.6)

(09) money stock parameter= 0.5

(10) policy delay= 1.95

- (11) policy gap= (capacity utilization-policy target)/policy delay
- (12) policy target= 0.75
- (13) private finance= financial sensitivity*real money stock*utilization discrepancy
- (14) public finance= policy gap*real money stock
- (15) real money stock= INTEG (private finance-public finance, 0.4)
- (16) SAVEPER = TIME STEP Units: Month [0,?] The frequency with which output is stored.
- (17) target inventory= 0.6
- (18) target utilization= 0.75
- (19) time delay inventory= 5.8
- (20) time delay utilization= 0.8+STEP(4, 150)-SMOOTH(STEP(4, 150), 10)
- (21) TIME STEP = 0.125 Units: Month [0,?] The time step for the simulation.
- (22) utilization discrepancy= capacity utilization-target utilization
- (23) utilization parameter= 0.7

- The MSMM with Capital Accumulation (Figure 5.2). Integration Type: RK4 Auto, time step=0.25

- (01) accumulation rate= 0.7
- (02) capacity= 0.36
- (03) capacity utilization rate= INTEG (-(discrepancy utilization/time delay to adjust production)-(discrepancy inventory /time delay to adjust inventory), 0.75)
- (04) capital stock= INTEG (gross investment-depreciation, 100)
- (05) consumer loan= consumer loan ratio*real money stock
- (06) consumer loan ratio= 0.3
- (07) delay monetary control= 1.25
- (08) Demand= consumer loan+gross investment+(wages/price level)+((1-accumulation rate)*profits/price level)

(09) depreation rate= 0.025

(10) depreciation= depreation rate*capital stock

(11) discrepancy inventory= invetory ratio-target inventory

(12) discrepancy utilization= capcity utilization rate-target utilization

(13) FINAL TIME = 300

Units: Month

The final time for the simulation.

(14) gross invenstment= accumulation rate*profit rate*capital stock+productive loan

(15) inflation rate= (discrepancy utilization/price adjustmet delay to utilization)-
(discrepancy inventory /price adjustmet delay to inventory)

(16) INITIAL TIME = 0

Units: Month

The initial time for the simulation.

(17) inventory= INTEG (production-Demand, 50)

(18) invetory ratio= inventory/(capacity*capital stock)

(19) loan provison= loan sensitivity*discrepancy utilization

(20) loan sensitivity= 0.025

(21) monetary control= inflation rate/delay monetary control

(22) price adjustmet delay to inventory= 5

(23) price adjustmet delay to utilization= 6

(24) price level= INTEG (inflation rate*price level, 1)

(25) production= capacity*capcity utilization rate*capital stock

(26) productive loan= (1-consumer loan ratio)*real money stock

(27) profit rate= (profits-(price level*depreciation))/(price level*capital stock)

(28) profits= (price level*production)-wages

(29) real money stock= INTEG (loan provison*real money stock-monetary control*real money stock, 15)

(30) SAVEPER = TIME STEP

Units: Month [0,?]

The frequency with which output is stored.

(31) target inventory= 0.5

(32) target utilization= 0.75

(33) time delay to adjust inventory= 2.55

(34) time delay to adjust production= 0.788

(35) TIME STEP = 0.25

Units: Month [0,?]

The time step for the simulation.

(36) wage share= 0.7

(37) wages= production*wage share*price level

Appendix E

Vensim Equations for The Stochastic Model of Technical Change

All of the equations below are constituted by Vensim PLE for Windows Version 6.2.

- profit rates by simulating the stochastic model (Figure 6.9).Integration Type: RK4 Auto, time step=0.25

(01) capital productivity= INTEG (capital productivity*capital productivity criterion, 0.61)

(02) capital productivity criterion= IF THEN ELSE(capital productivity growth rate>criterion value pK, capital productivity growth rate , 0)

(03) capital productivity growth rate= RANDOM UNIFORM(min capital, max capital , seed)

(04) criterion value pK= (-wage share/(1-wage share))*labor productivity growth rate

(05) criterion value pl= (-(1-wage share)/wage share)*capital productivity growth rate

(06) FINAL TIME = 40 Units: Year The final time for the simulation.

(07) INITIAL TIME = 0 Units: Year The initial time for the simulation.

(08) labor productivity= INTEG (labor productivity*labor productivity criterion, 0.13)

(09) labor productivity criterion= IF THEN ELSE(labor productivity growth rate>criteria value pl, labor productivity growth rate , 0)

(10) labor productivity growth rate= RANDOM UNIFORM(min labor, max labor , seed)

(11) max capital= 0.25

(12) max labor= 0.4

(13) min capital= -0.3

- profit rates by simulating the stochastic model including capital accumulation : An Application to S. Korean Economy (From Figure 6.10 and Figure 16).Integration Type: RK4 Auto, time step=1

(01) acc rate= 0.33-STEP(0.25 , 10)+STEP(0.18, 15)-STEP(0.11, 20)-STEP(0.18, 25)+STEP (0.14,30)

(02) capital accumulation= INTEG (acc rate*profit rate*capital accumulation, 629.4)

(03) capital productivity= INTEG (capital productivity*capital productivity criterion, 0.61)

(04) capital productivity criterion= IF THEN ELSE(capital productivity growth rate>criteria value pK, capital productivity growth rate , 0)

(05) capital productivity growth rate= RANDOM UNIFORM(min capital, max capital , seed)

(06) criteria value pK= (-wage share/(1-wage share))*labor productivity growth rate

(07) criteria value pl= -(1-wage share)/wage share)*capital productivity growth rate

(08) FINAL TIME = 40 Units: Year The final time for the simulation.

(09) INITIAL TIME = 0 Units: Year The initial time for the simulation.

- (10) labor productivity= INTEG (labor productivity*labor productivity criterion, 0.13)
- (11) labor productivity criterion= IF THEN ELSE(labor productivity growth rate>criteria value pl, labor productivity growth rate , 0)
- (12) labor productivity growth rate= RANDOM UNIFORM(min labor, max labor , seed)
- (13) max capital= 0.25
- (14) max labor= 0.4
- (15) min capital= -0.3
- (16) min labor= -0.2
- (17) profit rate= capital productivity*(1-(wage rate/labor productivity))
- (18) SAVEPER = TIME STEP Units: Year [0,?] The frequency with which output is stored.
- (19) seed= 0
- (20) TIME STEP = 0.25 Units: Year [0,?] The time step for the simulation.
- (21) wage rate= INTEG (wage rate*labor productivity criterion, 0.08)
- (22) wage share= wage rate*(1/labor productivity)

Appendix F

The additional results

- Serial Correlation LM test and Heteroskedasticity Test :

$$DPROFTAX = C(1)*DPRM(-1) + C(2)*DPROTAX(-1)$$

TABLE F.1: Serial Correlation LM test

F-statistics	0.854531	Prob. F(1,33)	0.3620
Obs*R-squared	0.786688	Prob. Chi-Square(1)	0.3751

TABLE F.2: Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistics	1.873320	Prob. F(2,33)	0.1696
Obs*R-squared	3.670514	Prob. Chi-Square(2)	0.1596

Appendix G

The Derivation of Equation and Stability Analysis

G.1 The Derivation of Equation (1.19)

$$\begin{aligned} \max \quad & \int_0^\infty e^{-\rho t} \left[\log C(t) - \frac{N(t)^{1+\psi}}{1+\psi} \right] dt \\ \text{subject to} \quad & PC + \dot{B} = WN + [(1-i)a + i]B \\ & B(0) = B_0 \\ & \lim_{T \rightarrow \infty} B_T \geq 0 \end{aligned}$$

where N is labor. The Hamiltonian for this maximization problem is

$$H = \log C(t) - \frac{N(t)^{1+\psi}}{1+\psi} + \mu [WN + [(1-i)a + i]B - PC]$$

$$\begin{aligned} \frac{\partial H}{\partial C} &= \frac{1}{C} - \mu P = 0 \\ \dot{\mu} - \mu \rho &= -\frac{\partial H}{\partial B} = -\mu [(1-i)a + i] \end{aligned}$$

Since

$$\frac{\dot{C}}{C} = -\frac{\mu}{\mu} - \frac{\dot{P}}{P}$$

We have

$$\frac{\dot{C}}{C} = [(1-i)a + i] - \pi - \rho$$

where $\pi = \dot{P}/P$. In equilibrium $C = Y$ where Y is output

$$\frac{\dot{Y}}{Y} = \frac{\dot{C}}{C} = [(1-i)a + i] - \pi - \rho$$

If a relation between natural output, Y^n , and natural real interest rate, r is as follows,

$$\frac{\dot{Y}^n}{Y^n} = r - \rho$$

we have

$$\dot{x} = i + (1-i)a - r - \pi$$

where $x \equiv \log X = \log Y - \log Y^n$.

G.2 Stability Analysis

If $\phi_x > 0$, the system (7) becomes as follows.

$$\begin{aligned}\dot{x} &= (1-a)i + (1-a)\phi_x x + a + ((1-a)\phi_\pi - 1)\pi - r \\ \dot{\pi} &= \rho\pi - \kappa x\end{aligned}\tag{G.1}$$

The Jacobian matrix of (8) is as follows.

$$\mathbf{J} = \begin{pmatrix} f'(1 - i^* - \phi_\pi \pi^*) + [1 - f'x^* - f]\phi_x & (1 - f')\phi_\pi - 1 \\ -\kappa & \rho \end{pmatrix}$$

The stability condition of this system is $tr(J) < 0$ and $DetJ > 0$. Around the fixed point, $x^* = 0, \pi^* = 0$, which is the first best of monetary policy, $tr(J) = f'(1 - i^*) + (1 - f)\phi_x + \rho$ and $Det(J) = f'(1 - i^*) + (1 - f)\phi_x \rho + \kappa(1 - f')\phi_\pi - 1$. Since $\phi_x > 0, \phi_\pi > 0, \kappa > 0$, and ρ , this system can be stabilized under the condition, $f > 1, f' < 0$, and $\kappa(1 - f')\phi_\pi > 1$.

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Résumé

Il est essentiel d'étudier la dynamique non linéaire en mathématiques et nous permet d'interpréter des phénomènes aussi irréguliers et imprévisibles à la suite de processus déterministes, et non de simples erreurs ou chances statistiques. La dynamique du système est une méthodologie ainsi qu'une méthode pour implémenter des mouvements dynamiques non linéaires. Par ces deux méthodes, nous capturons la crise dans les cycles économiques et testons l'accumulation de capital, et les changements techniques dans le cadre du modèle Macro Stock Management et les appliquons à ceux de l'économie sud-coréenne. Divers outils d'analyse des séries chronologiques sont utilisés pour estimer les effets de l'investissement sur les taux de profit et les effets de l'inégalité salariale et de la dette des consommateurs sur la demande intérieure depuis la crise financière mondiale de 2008. Le Structural Vector Auto-Regressive model impose des restrictions à long terme ou à court terme sur le système VAR, il utilise pour distinguer deux variables avec des caractéristiques similaires. Perron (1989) fait valoir que les tests de racine unitaire traditionnels tels que le test Augmenté Dickey-Fuller sont susceptibles de ne pas détecter la stationnarité ou la non-stationnarité des données si elles ont des ruptures structurelles. Zivot et Andrews (1992) et Lumsdaine et Papell (1997) proposent le modèle de test racine unitaire avec ruptures structurelles endogènes. Le test Gregory-Hansen fournit des informations sur une rupture structurelle dans un test de co-intégration. Le modèle ARDL (Auto Regressive Distributed Lags) est utilisé pour capturer les relations à long terme entre les variables.

Mots-clés: Dynamique non linéaire, Dynamique du système, Modèle de gestion

des stocks de macro, Modèle économétrique de time series, Économie sud-coréenne

Abstract

It is essential to study nonlinear dynamics in mathematics, and it gives us room to interpret such irregular and unpredictable phenomena as a result of deterministic processes, not mere statistical errors or chances. System dynamics is a methodology as well as a method to implement nonlinear dynamic movements. By these two methods, we capture the crisis in the business cycles and test capital accumulation, and technical changes within the framework of the Macro Stock Management model and apply them to those of the Korean economy. In the latter part of this study, various time series analysis tools are used to estimate the effects of investment on the rates of profit and the effects of wage inequality and consumers' debt on domestic demand since the global financial crisis of 2008. Because the Structural Vector Auto-Regressive (SVAR) model impose on the long run or short run restrictions on the VAR system, it uses to distinguish two variables with similar characteristics, such as the after-tax rate of profit and the rate of profit after payment of interests and dividends excluding taxes (the after-payment rate of profit). Perron (1989) argues that the traditional unit root tests such as the Augmented Dickey-Fuller test are likely to fail to detect the stationarity or non-stationarity of the data if it has structural breaks. Zivot and Andrews (1992) and Lumsdaine and Papell (1997) propose the unit root test of the time series data with a single or two breaks in the time series. The Gregory-Hansen test provides information about a structural break in a cointegration test. The Auto Regressive Distributed Lags (ARDL) model is used to capture long-run relationships between variables.

Keywords: Nonlinear Dynamics, System Dynamics, Macro Stock Management Model, Time Series Econometrical Model, Korean Economy