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경제학박사학위논문

Solving Macroeconomic Trilemma in Emerging Economies:

Analysis using evolutionary economics simulations and policy implications

신흥국 거시경제에서 삼위일체 불가능성에 대한 해법:

진화경제학적 시뮬레이션에 의한 거시 모델 분석과 정책시사

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한 준 희

Abstract

Solving Macroeconomic Trilemma in Emerging Economies:

Analysis using evolutionary economics simulations and policy implications

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The macroeconomic trilemma states that economies are unable to have all three following policies: fixed exchange rate, free capital mobility and indepenent monetary policy. Thus, choosing the right policy choice has been an essential question for policy makers. To answer this question, this paper is going to find the optimal trilemma policy choice that provides highest economic growth rate for economies with different country specific characteristics: openness (export/GDP) and reserve (foreign reserve/GDP). In order to do so, the paper employs an agent based model in open economy to analyze the impact of each policy regime on macreconomics dynamics in simulation experiments. The paper is going to show two major findings: 1) for economies with low reserve ratio, the

optimal policy choice is a regime with fixed exchange and capital control at any level of export ratio (regime 1). 2) for economies with medium or high reserve ratio, the optimal regime choice depends on the export ratio. The paper finds threshold export ratio that shifts optimal regime choice. If an economy has export ratio lower than the threshold value, the best regime choice is a regime with fixed exchange rate and capital control (regime 1) and vice versa. The paper also finds the optimal amount of capital control that yields highest economic growth rate in the economies that give up free capital mobility as a policy choice.

Keywords: Exchange rate, Capital Control, Openness, Financial Crisis, Trilemma
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Chapter 1. Introduction

Policy makers in open economies face three typically desirable yet jointly unable objectives: to stabilize the exchange rate, to enjoy free international capital mobility and to engage in monetary policy. This, so called macroeconomic trilemma, argues that countries must forgo one of the three objectives. Theoretical underpinnings of the model in open economies are described in 'Mundell-Fleming' Model (Mundell; 1963, Fleming; 1962). The intuition is as follow. Suppose that a central bank decides to decrease its base rate lower than world interest rate. With free capital market, foreign capital would leave the county due to the fall in the yield (interest rate) which directly reduces demand for domestic currency. If a country wants to maintain fixed exchange rate, it has to reduce supply for domestic currency which creates upward pressure for the interest rate. Consequently, the interest rate returns back to the original level. That is, in order to have independent monetary policy, countries need to abandon either autonomy in exchange rate (fixed exchange rate) or free capital market. Since only two of the three policy goals are sustainable, policy makers have to make a choice in the presence of tradeoff between options. The below is the traditional trilemma policy options[1]

1. Fixed exchange rate, Capital Control, Independent Monetary Policy
2. Flexible exchange rate, Free capital Market, Independent Monetary Policy
3. Fixed exchange rate, Free Capital Market, Dependent Monetary Policy

This choice problem exists not only in a theory but also in real life. The example

[1] The paper is going to name the first option as regime 1 (FiE, CC, IM), the second option as regime 2 (FE, FC, IM) and the third option as regime 3(FiE, FC, DM).

comes from the experience of South Korea prior to the 1997 currency crisis. South Korea was initially in the capital control regime (regime 1), but as she became a member of OECD countries, she had to eliminate capital control impose on an economy. As she gradually removed amount of capital control imposed in the economy, there was a surge of capital inflow due to the relatively higher domestic interest rate. This offset the depreciation pressure on the exchange rate created by current account deficit at the time. That is, the desirable policy option for South Korea would be depreciating exchange rate to deal with current account deficit problem. However, it was difficult to do so since a capital market was opened and foreign capital flowed in. That is, she had to choose between free capital mobility and fixed exchange rate. She still faces trilemma regime choice problem even in the present. The central bank of Korea would like to lower interest rate to boost up investment that has been declining for years. However, they are reluctant to do so since lowering the interest would cause capital flight which would reduce investment in return.

Then, a natural question arises: if trilemma choice problem is real, which combination of a policy regime should countries choose? Unfortunately, for emerging economies, there is no economic consensus among scholars in this issue and their view has been changed as the world economy goes through structural changes and crisis. The scope and goal of macroeconomic policy have been altered throughout the history. Fresh from a disastrous experience with floating exchange rates in 1930s, the architects of the Bretton Woods set up a system of fixed exchange rates using U.S dollar (gold standard currency) as a reserve currency. Exchange rate stability was a prime goal and countries maintained exchange rates within 1% band by intervening in foreign exchange markets. However, the entire system had begun to collapse starting from 1960s as U.S. dollar's fixed value against gold overvalued. After the fall of the Bretton Woods system, IMF made an amendment to Article of Agreement (1978) establishing the

right of members to adopt the exchange rate regime of their choice. Since then, choosing the "right" regime has been an issue for policy makers. In early 1990s, it was common for countries to peg the exchange to a strong anchor currency. However, following the East Asian Financial Crisis in 1997, mainstream economics argued that countries should adopt either "hard"peg (dollarization-no monetary policy or dependent monetary policy) or free floating exchange rate regime (IMF report; 1999, Fischer; 2001,). This bipolar view has slowly changed as the world experienced the Argentina Currency Board Collapse in 2001. Since the Argentine crisis (2001), IMF has been favoring a flexible exchange rate regime underpinned by inflation targeting as the only viable regime (IMF Survey; 2006). However, as many experience the rise of china since 2000s, IMF had begun to accept the necessity of capital control as a tool responding to transient surge of in-flows (Ostry et al; 2010). Even at the American Economic Association Meeting of 2016, members argued that there is a need for autonomy in exchange rate for emerging countries.

Currently, many studies argue that countries need a sound basis for selecting the regime best suited to them (Mussa et al, 2000; Rogoff et al, 2004; and Ghosh, Ostry, Ghosh, 1997; Ghosh, Gulde, and Wolf, 2002; Levy-Yeyati and Sturzenegger, 2003; and Reinhart and Rogoff, 2004). However, not many papers discuss specific characteristics that can be linked to choosing the right regime. Before we discuss them on choosing the regime best suited to emerging economies, let us look at major reasons why economies choose a particular regime.

If a policy maker decides to keep exchange rate fixed at the depreciated level, it could raise domestic firms' competitiveness in foreign market. To exploit the benefits of fixed exchange rate, periphery economies are committed to export-led growth by maintaining an undervalued exchange rate (Dooley, Folkerts-Landau, and Garber, 2003). This growth strategy has been successful for many emerging

economies such as China, Taiwan, Singapore or South Korea. What about the free capital market movement? There are pros and cons for having full financial market integration. Having financial market integration appears to improve the allocation of capital (Hubbard, 1997) thereby increasing level of investment that is usually financially constrained (Gertler and Gilchrist, 1994; Bernanke et al 1995). However, capital account liberalization raises the risk of financial instability (e.g., the 1997 currency crisis in East Asia) and capital control can be justified despite its possible distortion because the costs of crisis are far greater than the costs of distortion (Lee et al,; 2010; Sitglitz[2], 2010).

What could be the country specific characteristics that are related to the above advantages (and disadvantages) of choosing a particular regime? The paper regards two country specific parameters of interest that influence choice of a macroeconomic policy regime. One is openness (export/GDP ratio) and another is reserve (foreign reserve/GDP ratio). The former is related to the fixed exchange rate and the latter is related to free capital movement and the balance of payment crisis (currency crisis). The detailed explanation will be given in the following chapter.

The paper is going to present an agent based model based on Dosi et al (2010) which includes variety of interaction in the economy and at the same time addresses policy implication in the analysis. To incorporate behavior of foreign entities who plays key role in each regime, the paper includes features of open economy. For the simplicity of the model, we keep the scale and the interaction between agents relatively simple.

As in evolutionary and ACE (Agent-based Computational Economics)

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[2] As he describes 'putting a new engine in an old car'. It will make the car goes faster but soon or later, it will crash.

perspective, the policy choices are analyzed using computer simulation. The paper is going to find the optimal macroeconomic policy regime which provides highest economic growth rate in the presence of different countries specific characteristics (openness and reserve). In order to do so, the model is going to compare the output (GDP) growth rate for different policy regimes with varying parameter of interest in two different experiments.

The rest of the paper is organized as follows. Chapter 2 shows literature reviews and hypotheses. Chapter 3 presents the research methodology used in the paper. Chapter 4 describes the model. In chapter 5, the paper runs two experiments and shows the optimal policy regime for different values of parameters of interest. Finally, chapter 6 concludes.

Chapter 2. Literature Reviews and Hypotheses

1) Literature Reviews on Trilemma

The origin of macroeconomic trilemma can be found in Mundell' work on an open economy extension of the IS-LM Neo-Keynesian model in the 1960s. In the model, a small economy is choosing an exchange rate regime and the financial integration in the global financial market. The model considers polarized binary choice problem in an exchange rate market (fixed exchange rate and floating exchange rate) and a capital market (free capital mobility or full capita control) and argues that economy cannot simultaneously maintain a fixed exchange rate, free capital mobility and an independent monetary policy. Since then, there have been many empirical studies that shows the existence of macroeconomic trilemma. Obstfeld, Shambaugh and Taylor (2005) finds that change in domestic interest rate is highest for economies with both fixed exchange rate and open capital market compared to economies with either fixed exchange rate or open capital market as implied by trilemma. Frankel, Schmukler and Serven (2004) shows that interest rate of countries with more flexible exchange rate regime adjust more slowly to changes in international interest rate, implying some capacity for monetary independence. Bahmani-Oskooee, Hosny and Kishor (2015) find that countries with fixed exchange rate and free capital market exhibit lowest monetary independence. Aizenman (2010) points out that trilemma is among the few macroeconomic frameworks that has passed the test of time and still remains pertinent today as it was in the past. Aizenman, Chinn and Ito (2012) test the linearity of the trilemma and the weighted sum of three trilemma variables adds up to a constant. Thus, increasing one trilemma variable lowers the weighted sum of other two variables. They argue that context of trilemma is modified due to the massive financial globalization of almost all countries.

Researchers also argue that the policy objectives for each trilemma regime

have changed from when it first appeared. Initially having free capital market was considered to be desirable as it could reduce financial market friction, thus allocate capital appropriately among firms that are usually financially constrained (Gertler and Gilchrist, 1994). However, as the size of financial market grow unprecedently, having free capital market was blamed to bring currency crisis and exchange rate change alone is not enough to insulate the economies from foreign financial shocks (Obstfeld, 2015). There are many studies that emphasizes the important of capital control policy in a trilemma framework. Rey (2015) shows that gains to international capital flow have proved elusive whether in calibrated models or in the data and points out that for some economies, having free capital market is no longer a desirable policy. It would bring higher GDP growth for economies, but it would create significant problems and risk at the same time (Stiglitz, 2010; Joshi, 2003). Joshi (2003) shows that India successfully weathered East Asian Crisis for having trilemma policy regime with selective capital control. Kohli (2011) points out that capital account management strategy employed by India enabled policy makers to balance the exchange rate and price stability. He also finds that the capital control was effective in maintaining the wedge between domestic and foreign interest rates, which is important for pursuing independent monetary policy. Cozzi and Nissanke (2009) also discuss the need for capital control on capital inflows to prevent the build-up of short term foreign liabilities and on capital outflow to provide a time and space for adjustments at the crisis. They argued that in Malaysian experience, capital controls can be a very effective policy instrument in dealing with the macroeconomic trilemma faced by policy makers at the time of crisis.

The above literatures show us that macroeconomic trilemma is real and economies are bounded to choose two either fixed exchange rate or free capital mobility in order to have independent monetary policy despite the facts that having free capital market could not be a desirable policy option. Then, in which

case having free capital market is desirable and in which cases it is not?

Before we answer this question, let us see the actual trilemma policy choice for variety of emerging economies.

2) Trilemma Regime Choice for Emerging Economies.

The table 2-1 shows the actual macroeconomic trilemma (de jure) regime chosen by emerging economies[3] and advanced economies[4].

Table 2-1. Regime Choice for Emerging Economies and Advanced Economies

GDP per Capita	Regime 1 (CC)	Regime 2(FE)	Regime 3(DM)
Below $10,000	Vietnam, Ukraine Bangladesh, Nigeria, Pakistan	India, Philippines	
$10,000 ~ $20,000	Thailand, Argentina, China, Egypt	Mauritius, Brazil, Colombia, Indonesia, Mexico, Peru, South Africa, Turkey	Bulgaria
$20,000 ~ $30,000	Malaysia, Russia	Hungary, Poland, Romania, Chile, Greece	
$30,000 ~ $40,000	Czech Republic, Oman	Slovenia, Korea, Israel, France, Italy, Japan	
Above $40,000		Canada, Germany, the United Kingdom, the United States	

Source: IMF Annual Report on Exchange Arrangement Restrictions 2014.

As in figure 2-1, one can see that every advanced economy (G7 countries) are in the flexible exchange rate regime (Regime 2). On the other hands, there is no consensus among emerging economies at any level of GDP per capita value. For

[3] List of emerging economies are defined as "emerging market" at least one analysts (IMF, BRICS, FTSE, MSCI, S&P EM Bond Index, Dow Jones, Russell and Columbia University EMGP)

[4] G7 Countries (France, Italy, Japan, Canada, the United Kingdom, the United States).

countries with less than $10,000 GDP per capita, Vietnam, Ukraine, Bangladesh, Nigeria and Pakistan have autonomy in exchange rate whereas India and Philippines have floating exchange rate regime. For countries with GDP per capita value between $10,000 and 20,000, Thailand, Argentina, China and Egypt are in pegged exchange rate regime and Mauritius, Brazil, Colombia, Indonesia, Mexico, Peru, South Africa and Turkey are in flexible exchange rate regime. Bulgaria is only emerging economy with no independent monetary policy. There is no consensus in for middle income countries with GDP per capita ratio between $20,000 to 40,000 as well. Malaysia, Russia, Czech Republic and Oman are in pegged exchange rate regime while Hungary, Poland, Romania, Chile, Greece, Slovenia, South Korea and Israel are in floating exchange rate regime. Are they in the right macroeconomic regime? Before explore this issue, let us look at two hypotheses regarding two parameters of interest that would affect economies' trilemma policy choice

3) Two Hypotheses

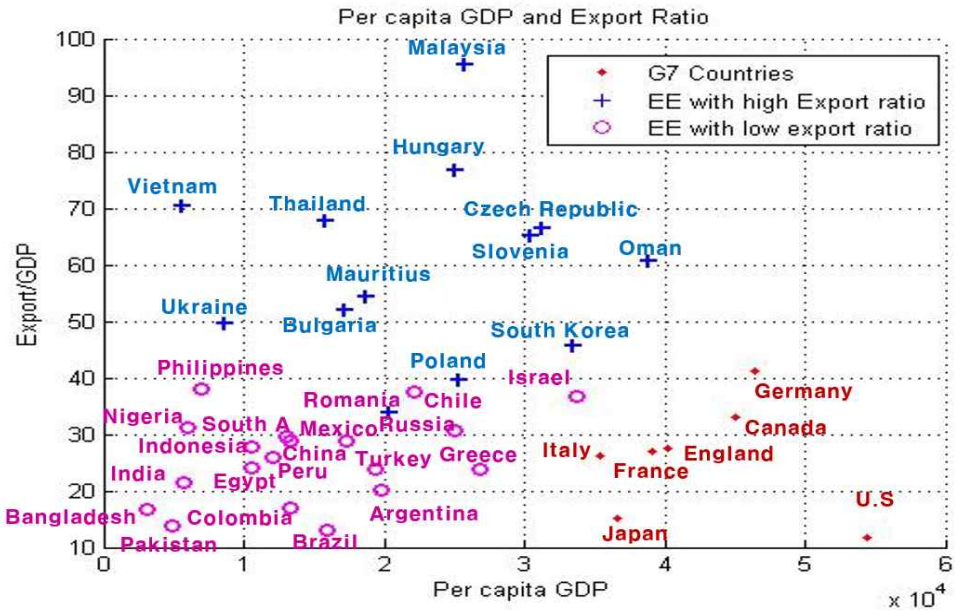
As many scholars have argued, when it comes to choosing macroeconomic policy regime, they have to consider their country specific characteristics. However, not many literatures discuss particular characteristics that can be considered for choosing such policy regime. This section will look at two diversified macroeconomic characteristics (openness and reserve ratio) of emerging economies and we are going to see and come up with hypotheses.

- *Openness and Trilemma Regime Choice*

Figure 2-1 depicts diversified openness (export/GDP) ratio for both emerging economies and advanced economies. Advanced economies (G7 countries) have

relatively low level of export ratio (varies from 12% to 45%). However, for emerging economies, their export/GDP ratio ranges from 15% to 95%. Emerging Economies such as Malaysia, Vietnam, Thailand, Hungary, Czech Republic, Mauritius, Slovenia, Oman, Ukraine Bulgaria, South Korea and Poland have export ratio higher than 40% (noted as cross sign). Other emerging economies such as China, Peru, Mexico, India, Pakistan, Brazil and Argentina have export ratio lower than 40 % (noted as circle sign).

Figure 2-1. Export Ratio of Emerging Economies and Advanced Economies



Source: World Bank Data, 2014

What caused such discrepancy? Around 1970s, scholars view an export led growth model as a key development strategy for emerging economies (Kubo et al; 1983, Mellor; 1976, Mellor et al; 1968 Paul; 1982, Adelman; 1984) As more and more emerging economies such as Hong Kong, South Korea, Taiwan and Singapore had achieved remarkable growth rate in following such growth theory in following decades, it has become orthodox growth model for emerging

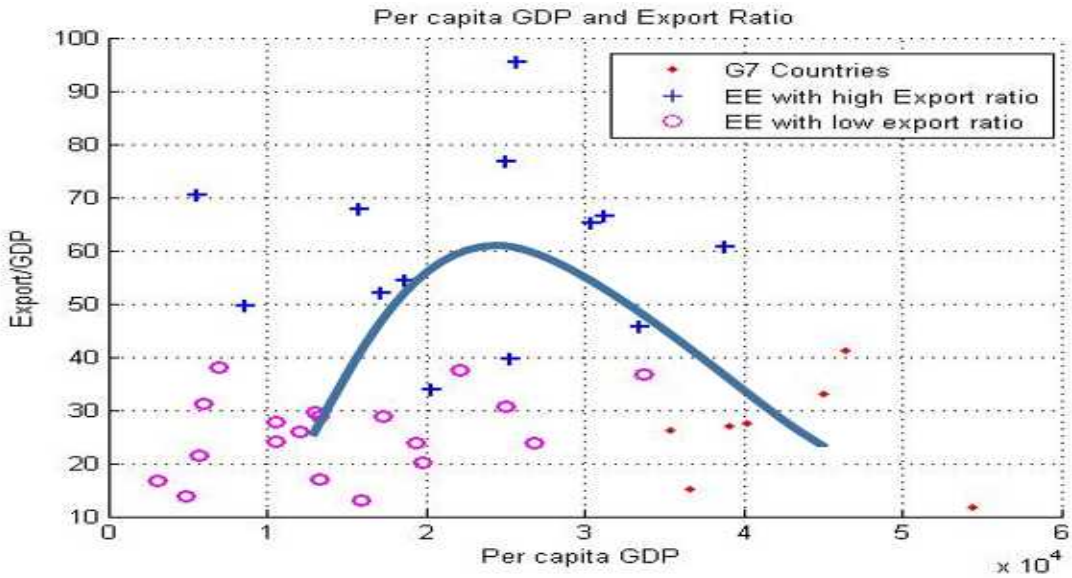
economies. As a result, policy makers in emerging economies started to view achieving growth to somewhat related to increasing export ratio at least at the developing stage. Therefore, one can see the diversity in export/GDP among emerging economies as an outcome of following export led growth model that is derived by country specific characteristics such as size of a domestic market, technological capability to produce and compete in international market and inherent resources.

Table 2-2. Average GDP per Capita for Different Group of Economies

	AE (G7)	EE1 (High Export)	EE2 (Low Export)
Average GDP per capita	4.2456e+004	2.2780e+004	1.4722e+004

As shown in Table 2-2, emerging economies with export/GDP ratio higher than 40% have higher average GDP per capita ($ 22,780) than those with export/GDP ratio less than 40% ($ 14,722).

Figure 2-2. Export Ratio of Emerging Economies and Advanced Economies-



Source: World Bank Data, 2014

Figure 2-2 show the sketch of the relationship between export/GDP ratio and GDP per capita by roughly connecting average GDP per capita value for relevant export/GDP ratio as shown in the above table. Interestingly enough, for economies with GDP per capita lower than $20,000 the export/GDP ratio tend to be low (around 25%). However, for those with GDP per capita in between $20,000 and $35,000, average export/GDP ratio is high (around 55%). For high GDP per capita economies (advanced economies: G7), their export/GDP ratio falls to around 25%. This the inverse U shape strengthens the argument of export led growth model as a strategic choice for developing stage. Keeping the above empirical motivations in mind, let's see the first hypothesis regarding export/GDP ratio and macroeconomic trilemma policy choice.

Hypothesis 1: EE with high openness (export ratio), regime 1(FiE, CC, IM) would provide highest economic growth than other regimes.

There are two reasons for such claim. Firstly, as mentioned above, one of the biggest advantages of having autonomous exchange rate regime is that it enables economies to raise domestic firm's competitiveness in foreign market by maintaining desirable (depreciated) level of exchange rate (Frankel, 2006; Goldstein et al; 2008, Gibson et al; 1992, McCombie; 1994). Therefore, for economies with higher ratio of export oriented firms would benefit more than for economies with low ratio of export oriented firms. For an extreme example, for an economy where no firm engages in export (closed economy), the benefit from such policy would be minimal. Secondly, the exchange rate volatility is much higher for high exporting economies (Hau, 2002) and having high volatility of the exchange rate discourages foreign investment (Kiyota and Urata, 2004; Obstfeld and Rogoff, 1995). That is, benefit of having free capital movement would be much higher for economies with low export ratio.

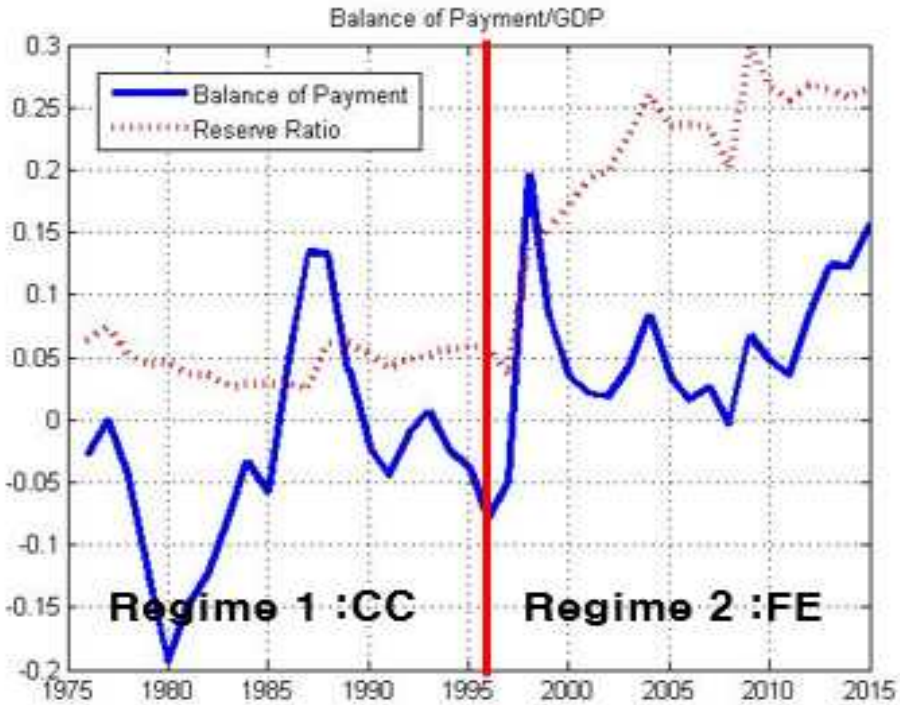
- *Reserve and Trilemma Regime Choice*

The definition of reserve ratio in the paper is total reserves (holdings of foreign currency by a central bank) normalized by nominal GDP. The reasons for holding foreign reserve differs among regimes. For regime 1 (FiE, CC, IM), it is to intervene in foreign exchange rate market to keep the exchange rate within the target band. However, for regime 2 (FE, CC, DM), the reserve plays key role during the time of crisis. Since capital inflow is procyclical (Kaminsky et al, 2004), capital flight occurs during the recession. When it happens, the central bank has to have enough foreign reserves to maintain the economy and failure to do so creates balance of payment crisis or currency crisis. For this reason, many emerging economies with free capital movement hold large amount of reserve ratio to stabilize the economy (Aizenman, 2010)

Figure 2-3 shows historical data for reserves (including holdings of monetary gold, special drawing rights and reserves of IMF) and balance of payment normalized by nominal GDP in Korea from 1976 to 2015. South Korea switched the macroeconomic regime around 1997 as she became a member of OECD countries (from regime 1 to regime 2). The policy makers at the time did not realize the importance of reserves during crisis. South Korea continued to maintain reserve/GDP ratio around 5% (the same as the United States). This was a crucial mistake because the context of using reserve ratio as means to provide economic stability and prevent economic crisis is very different between emerging economies and advanced economies with international currency. let us consider of 2008 financial crisis originated from the United States to have better understanding. When it happened, she dealt with the crisis (paying foreign debts) through quantitative easing (increasing monetary based). However, when financial crisis hit East Asian in 1997, increasing monetary base could not solve

any problem since Korean won is not international currency. That is, they would not accept Korean currency as a payment for the foreign debts. The moment she ran out of the foreign reserves, entire economy fell into currency crisis. After the crisis, policy makers of South Korea have come understand the importance of holding foreign reserves in regimes with no capital control. One can see that South Korea has been maintaining reserve/GDP ratio higher than the balance of payment/GDP ratio.

Figure 2-3: Blance of Payment and Reserve Ratio for South Korea from 1976 to 2015



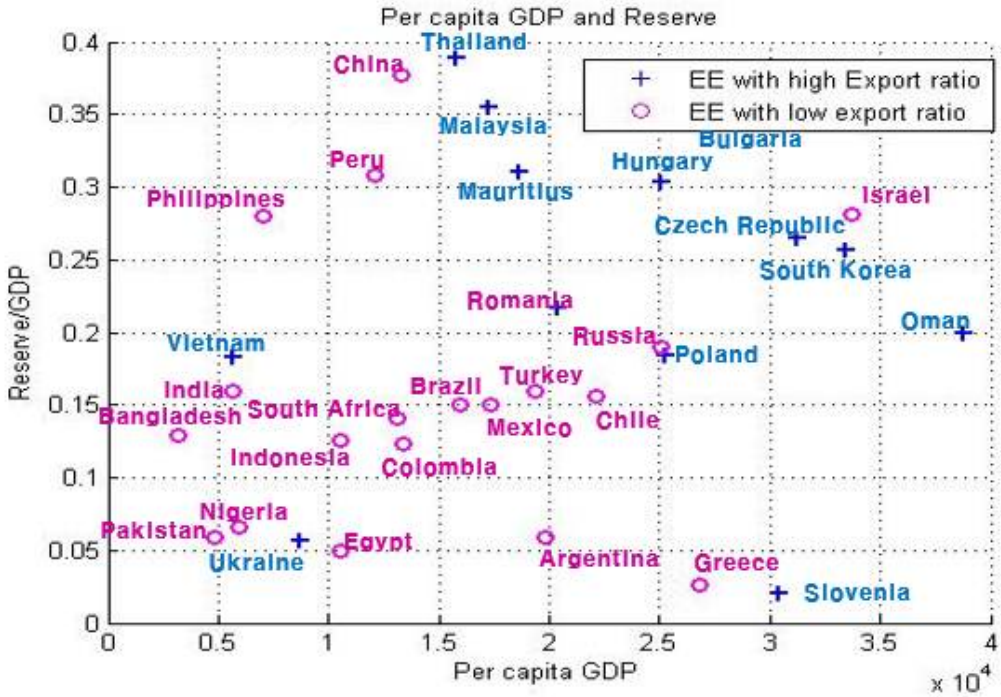
Source: World Bank Data

For emerging economies whose currency is not widely acceptable as means to payment, reserve ratio plays key role during bad times. What makes matter worse during the recession is a built up risk viewed by foreign investors. If they feel that

the economy that they invested is unable to repay the debt, the role over possibility becomes very slim for such economies. That is, having reserve ratio greater than the balance of payment of an economy provides a guarantee that the economy is able to repay the debt even in the bad times.

Figure 2-4 depicts reserve/GDP ratio for high export (export/GDP ratio greater than 40) and low export (export/GDP ratio less than 40). One can see that the reserve/GDP ratio is as diversified as export/GDP ratio.

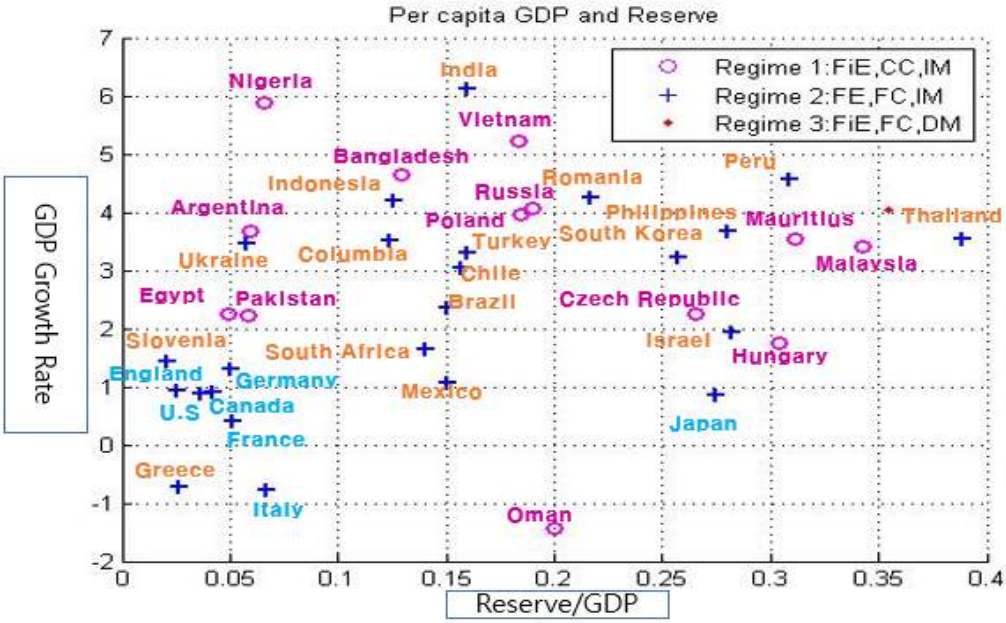
Figure 2-4: Reserve/GDP Ratio and GDP per Capita for High Export and Low Export EEs



Source: World Bank Data, 2014

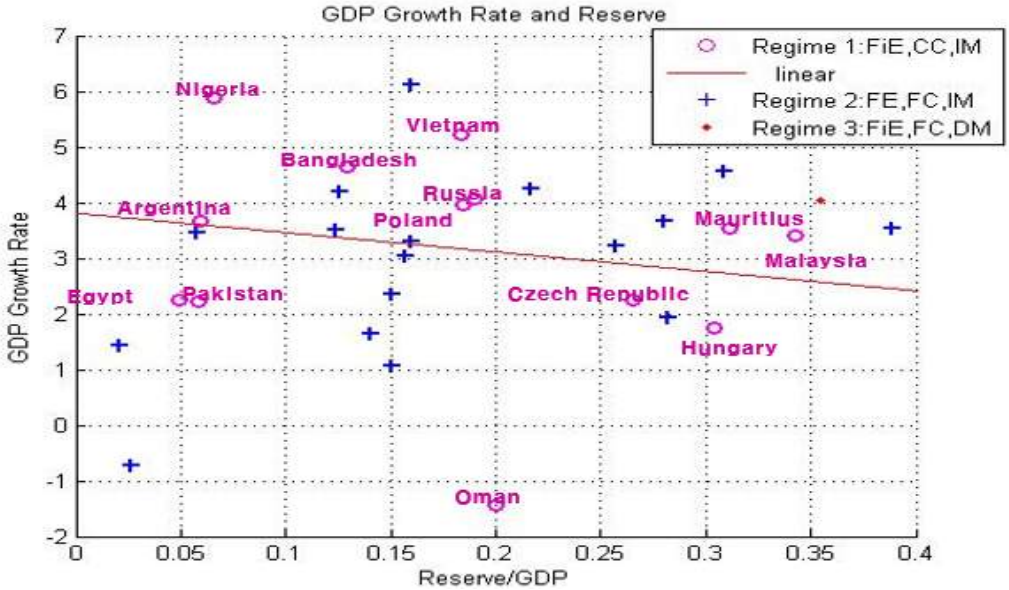
Figure 2-5 shows relationship between five-year average GDP growth rate and reserve/GDP ratio for economies with different regimes. One can see that Reserve ratio is very diversified as the export/GDP ratio.

Figure 2-5. Reserve/GDP Ratio and GDP Growth Rate for Emerging Economies



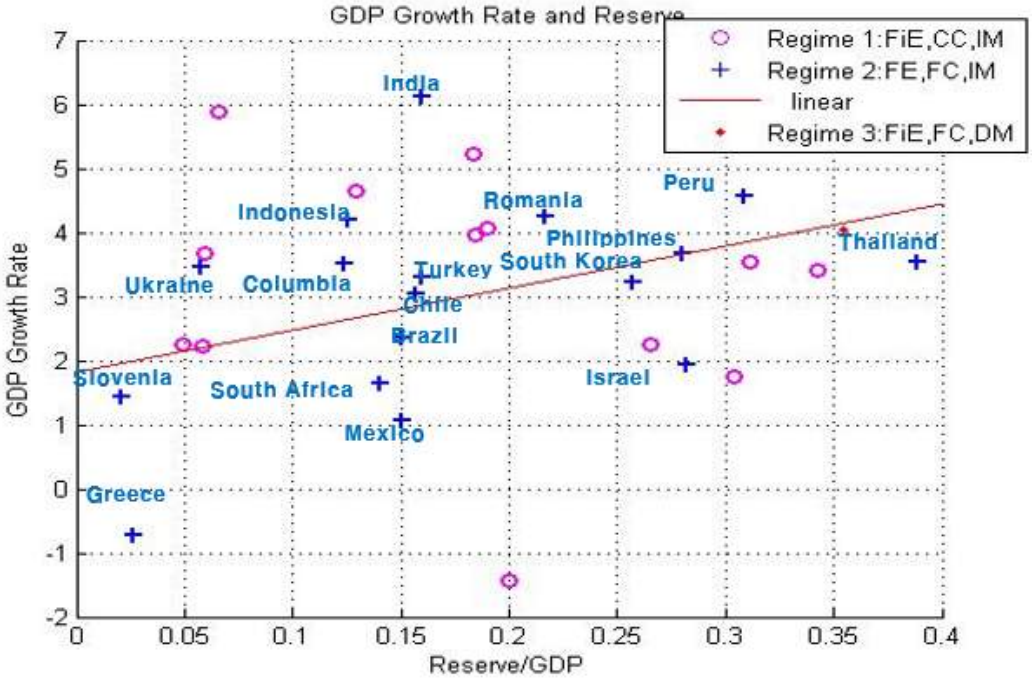
Source: World Bank Data, 2009~2014

Figure 2-6. Relationship Between Reserve Ratio and GDP Growth Rate for EEs in Regime 1.



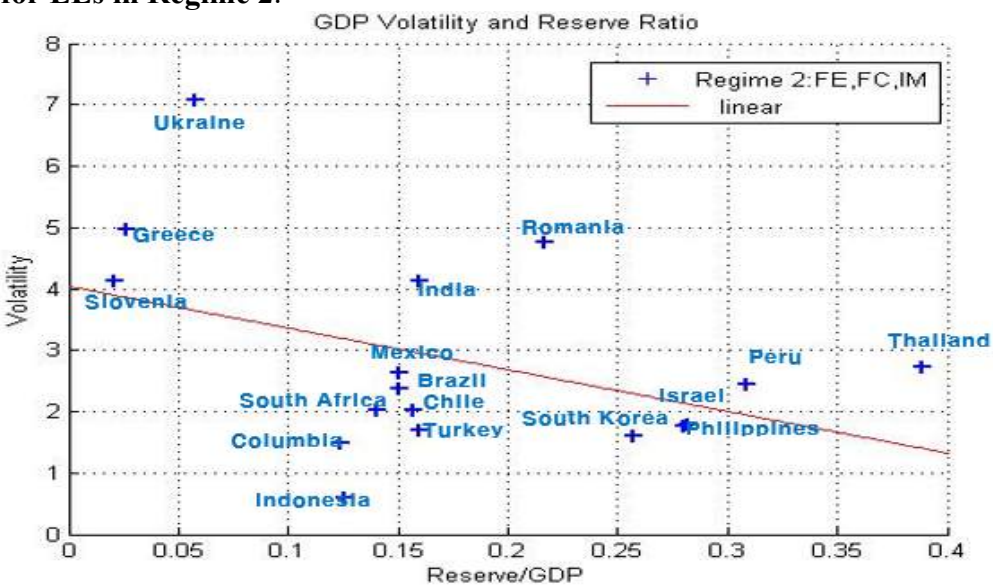
Source: World Bank Data, 2009~ 2014

Figure 2-7. Relationship Between Reserve Ratio and GDP Growth Rate for EEs in Regime 2.



Source: World Bank Data, 2014

Figure 2-8. Relationship Between Reserve Ratio and GDP Growth Volatility for EEs in Regime 2.



Source: World Bank Data, 2009~2014

As shown in figure 2-6, five-year average GDP growth rate and reserve ratio display negative relation for regime 1 (FiE, CC, IM). Reserves are mainly used for exchange rate intervention therefore, having large reserve would not have much influence on GDP growth rate.

Table 2-3. Volatility for Five-year GDP Growth Rate and Reserve Ratio

	Reserve/GDP
GDP Growth	+
GDP Volatility	-

However, figure 2-7 shows five-year average GDP growth rate and reserve ratio display negative relation for regime 2 (FE, FC, IM). As one can notice, having more reserve tend to increase GDP growth rate. Figure 2-8 depicts volatility of five-year GDP growth rate and reserve/GDP ratio. Volatility tend to fall if economies have higher amount of reserves. As summarized in Table 2-3, having more reserve tend to raise GDP growth rate while lower the volatility. The below is the second hypothesis regarding reserve/GDP ratio and macroeconomic trilemma choice.

Hypothesis 2: For EE with low foreign reserve ratio, having free capital mobility would bring financial crisis. Thus capital control regime would provide higher economic growth rate and lower economic volatility than other regimes.

Capital account liberalization raises the risk of financial instability and capital control can be justified despite its possible distortion because the costs of crisis are far greater than the costs of distortion (Lee et al; 2010, Stiglitz; 2010). Suppose that both economies with relative low reserve ratio and economies with relatively high reserve ratio face similar amount of capital flight during the

recession. Once it happens, the reserve gets smaller until the capital flight is stopped. However, if the capital flight is continued till the reserve gets close to zero, the financial crisis (currency crisis) occurs. That is, the chance of having currency crisis would be much higher for economies with low reserve ratio.

For the remaining chapter, the paper is going to prove the listed two hypotheses. We are going to see the baseline agent based model in the next chapter and run two relevant experiments for the analysis.

Chapter 3. Research Methodology

1) Why an Agent Based Model?

When it comes to analyzing economic policies, New Neoclassical Synthesis grounded upon Dynamic Stochastic General Equilibrium Models have worked exceptionally well for normative purpose as well as for descriptive ones (Taylor, 2007; Fagiolo and Roventini, 2012). However, the mainstream DSGE-based macroeconomic models have been proven to be not enough to deal with economic turmoil. Not only orthodox macroeconomists did not forecast the current crisis, but they did not even admit the possibility of such event and, even worse, they did not provide any useful advice to policy makers to put back the economy on a steady growth path (Krugma, 2011 and Stiglitz, 2011). A DSGE model'' have become so mesmerized with its own internal logic that it has begun to confuse the precision it has achieved about its own world with the precision that it has about the real one'' (Caballero, 2010).

Many leading researchers have claimed that the current economic crisis is a crisis for economic theory (Kirman, 2010; Colander et al, 2009; Krugman, 2009; Caballero, 2010; Dosi, 2011; Delong 2011). They argue that basic assumptions of mainstream DSGE models such as rational expectations, representative agents, perfect market and etc., prevent the basic understanding of current economic crisis.

To overcome the limitations of DSGE models, researchers suggest that economists should consider an *e*conomy as a complex evolving system, *i.e.* as an ecology populated by heterogeneous agents whose far-from-equilibrium interactions continuously change the structure of the system (Kirman, 2010; Dosi, 2011; Rosser, 2011). This is the start of Agent Based Models. The model can create the world that can be used to exercise macroeconomic phenomena (See Lebaron and Tesfatsion (2008) for a modeling method). As Fagiolo and Roventini (2012) points out, ABMs provide exceptional laboratory to perform policy exercises

where researchers are able to control microeconomic characteristics such as types, number, action and interaction of agents. Furthermore, most evolutionary agent based models is structural in the sense that it explicitly builds on a representation of what agents do and how they adjust. In that, the model is able to study the relationship among aggregate variables without any explicit microfoundation (Dosi et all, 2010) which produces microbehaviors that are similar to microevidence (Akerlof, 2002).

There has been a rapid growth of agent based modeling in analyzing economic policy. Let us consider the major characteristics of ABMs that are different from DSGE models (For more detail see Fagiolo and Roventini, 2012).

1. A bottom-up perspective.
    - Aggregate properties (macro outputs) must be obtained from micro dynamics from agents
2. Heterogeneity
    - Agents are different in almost all their characteristics
3. The evolving complex system
    - Agents live in complex systems that evolve through time
4. Non-Linearity
    - It does not assume linear relationship at the macro and micro level
5. Direct Interactions
    - Agent interact directly and decisions evolve through adaptive expectations
6. Bounded rationality

- Agents follow myopic optimization rules and assumed to behave as boundedly rational entities with adaptive expectations.

7. The nature of learning

   - Agents actions and interactions are dynamically changing as the entire system evolves.

8. True dynamics

   - Agents observe the past and form expectations about the future on the basis of the past.

9. Endogenous and persistent novelty

   - Agents face true uncertainty and are able to partially form expectations

10. Selection-based market mechanism.

    - Agents typically undergo a selection mechanism. For example, good produced by competition firms are selected by consumers

Due to the flexibility of the ABMs, there are many studies that analyzes implication of policies regarding fiscal policy, monetary policy, bank regulation, and central bank independence. Dosi et al (2012) find that the greater skewness in income distribution towards profits, the greater effects of fiscal policy. Russo (2007) analyzes the impact of average output growth rate to corporate tax rate levied on profits. Haber (2008) showed that having positive tax rate and monetary shocks increase GDP growth and inflation and reduce unemployment. There are also ABMs literatures (Delli Gatti et al, 2005; Oeffner, 2008 and Mandel et al, 2010) which employ Taylor rule to see the effects of monetary policy on the economy and other ABM literatures (Arifovic et al, 2010; Rapaport et al, 2009) that test the

central bank independence.

2) Model Selection and Distinctive Features of the Paper

Agent based models often face a trade-off between descriptive accuracy and explanatory power. As researchers put more realistic assumptions, the system becomes more complicated and it would be hard to see the connection between assumptions and implications of the model. ABM researchers have been developed strategies for making assumptions in the model: 1) Keep It Simple Strategy 2) Keep It Descriptive Strategy 3) Take a previous model and add something new.

For this paper, the third strategy is chosen. We are going to see the extend the model presented in Dosi et al. (2010) which try to bridge Keynesian theories of demand generation and Schumpeterian theories of technology-fueled economic growth (K+S model). The model includes capital goods firms, consumption goods firms, consumers/workers and a public sector. Technology (machine tools) is endogenously generated through R&D activities by capital good firms and they sell their heterogeneous machines tools to consumption good firms. Consumers supply labor to firms and use their income on consumption. The government levies tax and provides unemployment benefits. In the K+S model, they analyzed the impact of fiscal policies on average GDP growth rate, output volatility and unemployment rate. The conclusion of the paper is that Keynesian fiscal policy are a necessary condition for economic growth.

The K+S model, however, is limited in a sense that it neglects foreign activity and only provides an analysis based on closed economy. Since our focus is international macro policies such as exchange rate policy and free capital movement, the model includes actions of foreign entities such as capital investment decision by foreign investors. The model also simplifies S+K model to create better understanding causal relationship between variables and adds analysis of currency

crisis which stems from the heterogeneous agents with adaptive behavior[5].

3) Empirical Validation

Why do we need empirical validation? The agent based models provide an excellent way to analyze macro dynamics and policy implications. However, as discussed by Canova (2008), policy experiments are useful and valid if the models mimic the real data. In other words, agent based modeling is an excellent tool for facilitation of generative explanation (Epstein, 1999) and researchers can show almost any result using features of agent based models under plausible assumptions and parameters. However, for the models to be useful and valid, it must have explanatory power towards an observed macro or micro regularities.

Note that the very structure of ABMs allows researchers to take model into data and empirically validate it. For example, usually many ABMs produce GDP in which researchers can easily compare it with the real observations from particular countries. There is no consensus among researchers regarding the methodology of empirical validation of ABMs. A typical procedure would be testing whether a model can simultaneously reproduce sets of stylized facts that are of interest in the research for a given parameterization. For another method, one can first select among parameters by calibrating the model (e.g., by directly estimate parameters with micro and macro data) and then see how the calibrated model is able to reproduce the stylized facts of interest.

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[5] The occurrence of currency crisis is as follow: If the balance of payment deficit gets lower than existing reserve ratio from a negative foreign demand shock, governments cannot provide bailouts to domestic firms with negative profits. Once this happen, firms with negative profits get destroyed, lowering the period output growth rate. Existence of heterogeneous agent is a key to analyzing impact of the crisis in the overall economy because some firms would get destroyed (disappear from the economic activity) while other firms would survive (engage in economic activities).

For this paper, we use the methodology used by Dosi et al (2010) where they tested the ability to produce both macroeconomic (cross-correlations, relative volatilities, output distributions) and microeconomic (firm size distributions, firm productivity dynamics, firm investment distributions) stylized facts given different sets of parameters. Following this methodology of empirical validation, we are going to see how the model used in this paper are able to generate both macroeconomic and microeconomic stylized facts. For macroeconomic stylized facts, the paper considers co-movement between 1) GDP and investment 2) GDP and capital inflow (financial account) 3) current account and financial account and 4) effectiveness of monetary policy in different regime. For microeconomic stylized facts, the paper considers 1) distribution of firm productivity and 2) pattern of firms' investment.

4) Contribution of the Paper

The contribution of the paper consists of two parts: 1) The model can analyze the effect of macro policy regime on output growth more accurately than other ABMs since it includes actions of foreign entities (an open economy) 2) The model is able to compare and contrast effect of counterfactual regimes.

The focus of the paper is to compare and contrast the effects of macro policy regime that governs exchange rate market, capital market and monetary policy. However, the existing agent based models are unable to provide accurate result since most of them only deals with closed economy. For example, it would not be so accurate to analyze the impact of having free capital mobility on output growth rate if one does not consider the foreign entities who would place investment on domestic firms. For the same token, it would be pointless to compare the effect of exchange rate intervention if one does not concern foreign consumers who would buy domestically produced goods. The paper includes both foreign investors and foreign consumers whose behavior depends on the policy on capital market and

exchange rate market respectively. This would make the model be able to predict the optimal trilemma regime better than any other existing ABMs. The model also present threshold value for certain parameter of interest (export ratio) that makes one regime better than others[6].

Comparing and contrasting two (or more) different regimes are very difficult and no ABMs literature deals with such problem. The difficulty rises from the existence of the counterfactual regimes. The frontier model that deals with similar issue is HFMs (History Friendly Model). The HFMs methodology is composed of three steps. At first, it creates mechanisms (actions and interaction among agents) affecting the evolution process through history based theories. Then, it replicates the history under a certain set of parameter value in simulations (the standard setting). The last step is creating counterfactual or divergent simulation runs by assuming different set of key parameters and the key assumptions from the second step (See Yoon and Lee, 2009). However, one cannot use this methodology for analyzing different regimes because there is no historically driven standard setting. There is no historically given empirical result or theories that makes one regime better than another. To put it simply, there is no historically driven evidence to replicate regarding the trilemma regime choice

To solve this problem, the paper shows an alternative methodology modified from HFMs. As in HFMs, firstly, the model layouts interaction among agents driven from the history (e.g., consumption choice, investment choice and etc.) Then, the paper utilizes two hypotheses discussed in the previous section regarding trilemma regime choice and output growth to create counterfactual standard setting given a set of parameters. As a last step, give different values for key parameters and different assumption to see how the counterfactual standard

[6] The detailed description will be given in the later chapter.

changes. Using this methodology, the paper successfully compares different trilemma regime choice in the absence of factual history. This methodology can be useful in analyzing many economic situations where there is no historically driven data or theory (no standard setting).

Chapter 4. The Model

The economy is composed of consumption producing firms which sells their goods in both foreign and domestic markets. Before describe the model in detail, let us briefly see the timeline of the event occurring in each time step.

1) The Timeline of Events

In any given time period (t), the following micro and macro decisions take place in sequential order:

1. Firms make production plan according to their historically given market demand for both domestic markets and foreign markets.
2. Firms' production technology shock is realized and start producing according to their production plan and optimal inventory choice.
3. Foreign demand shock is realized
4. Firms sell their goods in both domestic and foreign markets
5. Firm's profit is determined and investment plan is set by each firm depending on the profit
6. Depending on the macroeconomic policy regime, stock of total liquid asset is realized
7. Firms start to borrow liquid asset from a financial intermediary to fulfil their investment plan until there is no excessive stock of liquid asset.
8. Creative destruction takes place. Firms with low (negative) profit get destroyed and replaced by new entrants.
9. Depending on the macroeconomic policy regime, government sets monetary policy.

At the end of each step, aggregated variables (GDP, current account, financial account, investment) are computed by adding up relevant microeconomic variables.

2) A Shock Definition

In each time period (t), there are one macroeconomic shock in the whole economy and one microeconomic disturbances among firms.

- Macro demand shock from foreign ($\boldsymbol{\varepsilon^e}$)

$$\boldsymbol{E[D_j^f(t)] = \left(1 + \frac{\Delta e(t)}{e(t)}\right)\left(E\left[1 + f_j^I\right]D_j^f(t-1) + \varepsilon^e(t)\right)}.$$

$\boldsymbol{E[D_j^f(t)]}$ is expectation of foreign sale for firm j and $\boldsymbol{e(t)}$ is exchange rate at time t. Notice that there is no subscript for exchange rate since given time period (t), entire economy is going to have the same exchange rate. The size and sign of the demand shock is a random draw from a beta distribution from the support $[\underline{X}\ \ \overline{X}]$. Detailed explanation of other variables will be given in the following section

- Microeconomic cost minimizing technology disturbance, $\boldsymbol{\varepsilon^a(t)}$, for firms (Supply Shock)

$$\boldsymbol{c_j(t) = y_j(t)/a_j(t)}$$

$$\boldsymbol{a_j(t) = (1 + \varepsilon^a(t))}$$

$\boldsymbol{c_j(t)}$ is the cost that firms have to pay for producing $\boldsymbol{y_j(t)}$ amount of goods for firm j at time t. The cost minimizing technology, $\boldsymbol{a_j(t)}$, at time t, depends on an intendent draw from a beta distribution over the support $[\underline{x}\ \ \overline{x}]$ which is denoted by $\boldsymbol{\varepsilon^a(t)}$. The model assumes that the first moment of cost minimizing technology for each firm is the same across the time period so that at the aggregate level, the expected value of cost minimizing technology for firm j is assume to the same in every period.

3) Features of Open Economy

To analyze the effect of macroeconomic policy in an open economy, the paper

adds behaviors of foreign entities in the model. That is major macroeconomic variables such as output and investment would depend on the actions of foreign investors or consumers. Before we explain actions of domestic firms in details, let us look at how behavior of foreign investors and consumers are integrated in the model.

- Sales

In S+K model (Dosi et al, 2010), sales (market share) depend on historically given demand (in one market) which evolves in adaptive nature. In this model, however, there are two markets (domestic market and international market) and thus each firm face different demand from each market. The demand condition of firms in the domestic market interact the same as that of S+K model, but for the international market, foreign demand is a function of historically given demand, exchange rate and foreign demand shock at time t. Appreciated exchange rate discourages foreign consumers to buy domestic goods and depreciated exchange rate increases demand for domestic goods. Total sales are going to constitute GDP which is a parameter of interest in the paper.

- Investment

The investment choice of each firm is determined by the evolution of stock of liquid assets which is a function firms' profit and internal funds of firm j in S+K model. In order to analyze effect of capital control on investment, the model includes capital inflow as a variable that affects stock of liquid assets. In the model, the higher capital inflow from foreign encourages investment.

- Balance of Payment

The model includes Balance of payment which is a sum of current account (aggregated export less import) and financial account (aggregated capital inflow). The change in exchange rate depends on change in balance of payment. This aggregated variable is a key to analyze balance of payment crisis.

4) Consumption Good Industries (Firms)

In this section, we are going to see the actions of heterogeneous firms in open economy. For simplicity of the model, we do not consider capital-goods firms appear on the S+K model in which they adaptively strive to increase their market demand to improve technology through innovation and imitation. Instead, in this model, consumption good industries make homogenous goods and they receive random cost minimizing technology draw from a beta distribution. This is because the focus of the paper is not to analyze endogenous innovation process that evolves over time but to understand the mechanism of balance of payment which would affect the trilemma regime choice.

- *Demand for consumption good firms*

The economy consists of J number firms homogenous in terms of products and heterogenous in terms of historically driven demand, capital stock and cost minimizing technology shock . Firms j plan their production , $Q_j^d(t)$, according to adaptive demand expectations, $E[D_j(t)]$ at time t.

$$\mathbf{E}[\boldsymbol{D_j}](\mathbf{t}) = \mathbf{f}(\mathbf{D_j}(\mathbf{t}-\mathbf{1}), \mathbf{D_j}(\mathbf{t}-\mathbf{2}), \dots, \mathbf{D_j}(\mathbf{t}-\mathbf{h}),$$

where $D_j(t-1)$ is the demand (sales) faced by firm j at time $t-1$ and h is greater than 0. For the simplicity, the model assumes h to be 1 as in Dosi et al (2010). Before we look at the formation of demand expectation at time t, let us look at the sale structure of firms.

Firms sell a fraction, $\boldsymbol{\gamma_j}$, of good in an international market and sell the rest, $1 - \boldsymbol{\gamma_j}$, in a domestic market. Historically given total demand, $\boldsymbol{D_j}$, therefore, are composed of domestic sales, $\boldsymbol{D_j^d}$, and international sales, $\boldsymbol{D_j^f}$.

$$\boldsymbol{D_j(t-1) = D_j^d(t-1) + D_j^f(\mathrm{t}-1)}$$
$$\boldsymbol{D_j^d(t-1) = \gamma_j(t)D_j(t-1)}$$
$$\boldsymbol{D_j^f(\mathrm{t}-1) = (1-\gamma_j)(t)D_j(t-1)}$$

The demand expectation at time t forms different for domestic market and international market :

$$\boldsymbol{E\left[D_j^d(t)\right] = \left(1 + E\left[d_j^I(t)\right]\right)D_j^d(t-1)}$$
$$\boldsymbol{E[D_j^f(t)] = \left(1 + \frac{\Delta e(t)}{e(t-1\quad)}\right)\left(E\left[1 + f_j^I\right]D_j^f(t-1) + \varepsilon^e(t)\right).}$$

$\boldsymbol{E[d_j^I]}$ is an expectation of rise in domestic sales due to the increse in the total size of the domestic market. $\mathrm{E}[\boldsymbol{f_j^I}]$ is an expectation of rise in international sales due to the increse in the total size of a foreign market. As size of the market increase, the sales of the market also increases. $\boldsymbol{e(t)}$ is exchange rate and $\boldsymbol{\varepsilon^e(t)}$ is a foreign demand shock at time t as mentioned above. The expected demand at time t is the sum of expected demand in the domestic market and an international market.

$$\mathbf{E}\left[\boldsymbol{D_j}\right](\mathrm{t}) = \boldsymbol{E\left[D_j^d(t)\right] + E[D_j^f(t)]}$$

The desired level of production y_j depends on the expectation demand, the desired inventories $n_j(t)$ and actual stock of inventories $n_j(t-1)$:

$$\boldsymbol{y_j(t) = E[D_j](t) + n_j(t) - n_j(t-1)},$$

where $n_j(t) = \tau D_j^e(t), \tau \ni [0,1]$.

- *Cost minimizing Technology*

The cost minimizing technology reduces the unit cost for production. Total cost, $\boldsymbol{c_j(t)}$, is going to depend on the production plan, $\boldsymbol{y_j(t)}$ and the technology $\boldsymbol{a_j(t)}$ for firm j.

$$\boldsymbol{c_j(t) = y_j(t)/a_j(t)}$$

In each period, firms take random draw of cost minimizing technology, a_j, based on based line cost minimzing technology , A, which is average of all cost minimizing technology from the perivous period.

$$\boldsymbol{a_j(t) = A(t)(1 + \varepsilon^a)}$$

- *The profits*

The profit of each consumption-good firm is

$$\boldsymbol{\pi_j(t) = s_j(t) - c_j(t) - r(t)Debt_j(t)},$$

where $s_j(t) = p_j(t)D_j(t)$. $\boldsymbol{Debt_j}$ represents stock of debt for firm j and $\mathbf{r(t)}$ is interest rate at time t. As discuss above, cost minimizing technology is a random draw from beta distriubtion.

Firm j borrows fraction, $\mu_j(t)$, of from domestic financial intermediary

and the rest, $(1-\mu_j)$, from foreign investors depending on the macropolicy regime[7]. Firm j's total debt at time t, $debt_j(t)$, is summation of doestmic debt, $debt_j^d$(t) and foreign debt, $debt_j^f(t)$ at time t.

$$\boldsymbol{debt_j(t) = debt_j^f(t) + debt_j^d(t)}$$

$$\boldsymbol{debt_j^f = \mu_j(t) debt_j(t)}$$

$$\boldsymbol{debt_j^d = (1-\mu_j)(t) debt_j(t)}$$

- *Investment choice for firms*

The production of consumption-good firms is constrained by the capital stock that they have. If the desired capital stock is higher than the current capital stock, they plan to make investment to expand their production. Investment plan, i_j^p(t), depends on the chainge in profit, $\Delta\pi_j(t)/\pi_j(t-1)$, and the historically given actual investment, $i_j(\mathrm{t}-1)$, for firm j:

$$\boldsymbol{i_j^p = (1+\varphi_\pi[\frac{\Delta\pi_j(t)}{\pi_j(t-1)}])i_j(t-1)}$$

Given their investment plan, i_j^p, firms borrow funds from financial intermediary among the stock of total liquid asset, $NW(t)$ which depends on domestic savings, $Sav(t)$, and capital inflow from foreign investors.

$$\boldsymbol{NW(t) = Sav(t) + FA(t)}$$

[7] For economies with capital control regime (regime 1), $\mu_j(t) = 1$ and for other regimes, $\mu_j(t) \ni [0\ \ 1]$

To only focus on the firms behavior, the model does not consider households' savings choice. Instead, it makes an simple assumption that domestic saving is determined on the marginal propensity to save for the economy.

$$\mathbf{Sav}\ (\mathbf{t}) = \boldsymbol{\sigma}\mathbf{GDP}(\mathbf{t})$$

Firms borrow fraction of their investment share, θ_j^s, depending on the amount of capital that firms possess. That is, the bigger the size, the more the firms can borrow.

$$\boldsymbol{\theta_j^s} = \frac{\boldsymbol{k_j}}{\sum_J \boldsymbol{k_j}}$$

Amount of liquid asset that firm j can borrow is determined by stock of total liquid asset in a financial intermediary, $NW(t)$, and the investment share, θ_j^s.

$$\boldsymbol{nw_j(t) = \theta_j^s NW(t)}$$

The actual investment is thus

$$\boldsymbol{i_j(t) = \mathrm{m\,in}\left(nw_j(t), i_j^p(t)\right)}.$$

The law of motion for capital is

$$\boldsymbol{k_i(t+1) = i_i(t) + (1-\delta)k_i(t)}.$$

- *Creative Destruction (exit and entry)*

At the end of the period, firms with negative profit get destroyed and new firms

replace them in the next period. For the simplicity, the model assumes that number of destroyed firms and the number of created firms are the same. In a line with the empirical paper on firm entry (Bartelsman et al, 2005), the paper assumes that entrants are on average smaller than the encumbents with the capital stock. For technology of entrants, they are assumed to have at least average technology of the entire firms.

To ananlze effect of macroeconomic regimes, the model considers role of government in the exit and entry process. As what happens in real economy, government provides bailout for the fraction, β,of the otherwise-destoryed firms depending on the monetary regime when negative demand shock from aboard hits the economy. Amount of bailouts provides by government is just enough to pay the debt for time t.

- *Aggregation*

The aggregated production of consumption firms constitute GDP in the model.

$$\boldsymbol{GDP(t) = \sum_{j=1}^{J} y_j}$$

Government holds fraction of GDP as a foreign reserves.

$$\boldsymbol{R(t) = \omega\, GDP}$$

The aggregate investment is sum of all investment for firms in time t

$$\boldsymbol{I(t)} = \sum_{\boldsymbol{j=1}}^{\boldsymbol{J}} \boldsymbol{i_j}$$

The aggregated export is sum of foreign sales for all firms in time t.

$$\boldsymbol{EX(t)} = \sum_{\boldsymbol{j=1}}^{\boldsymbol{J}} \boldsymbol{y_j^f(t)}$$

For extreme simplicity of the model, we makes an assumption that domestic demand for foreign goods is perfectly inelastic. That is, import is not affected by exchange in exchange rate or other disturbances in the model. the change in current account is only affected by change in export.

$$\Delta \boldsymbol{Ca(t)} = \Delta \boldsymbol{Ex(t)}$$

5) Policy Operations for Different Macroeconomic Trilemma Regimes

In the previous section, we have discussed the baseline agent based model structure and how agents interact within. In this section, we will look at how agents are influenced by different regimes

1. Fixed Exchange Rate, Capital Cotrol and Independent Monetary Policy

For regime 1, government sets exchange rate based on target exchange rate, $e^*(t-1)$.

$$e(t) = e^*(t-1)$$

The capital inflow, $\psi_i(t)$, is restricted :

$$\psi_i(t) = (1-\eta(t))\left(r(t) - \left[r^*(t) + E\left(\frac{\Delta e(t)}{e(t)}\right)\right]\right),$$

where $r(t)$ is domestic interest rate, $r^*(t)$ is world interest rate, $E\left(\frac{\Delta e(t)}{e(t)}\right)$ is expected in exchange rate and $\psi_i(t)$ is amount of capital control that takes value between 0 and 1. Sine exchange rate is fixed, $E\left(\frac{\Delta e(t)}{e(t)}\right)$=0.

The government adjust interset rate following the taylor rule .

$$r(t) = \varphi(y - y^*) + r(t-1)$$

Under the rule, if output is above the target y^*, the government raises interest rate to reduce investment to drag the output level back to the tartget level and vice versa. Government can also provide bailouts.

2. Flexible Exchange Rate, Free Capital Movement and Independent Monetary Policy

In the flexible exchange rate regime, it depends on the change in the balance of payment, $\frac{\Delta Bop(t)}{Bop(t)}$:

$$e(t) = (1 + \left[\frac{\Delta Bop\,(t)}{Bop\,(t)}\right])e(t-1)$$

where balance of payment is sum of current account (export less import) and financial account (capital inflow).

Capital inflow is not restricted (full capital mobility).

$$\psi_i(t) = r(t) - \left[r^*(t) + E\left(\frac{\Delta e(t)}{e(t)}\right)\right]$$

Expected change in exchange rate, $\frac{\Delta e(t)}{e(t)}$, depends on the change in expected change exchange rate which is affected by change in current account, $\frac{\Delta Ca(t)}{Ca(t)}$.

$$E\left(\frac{\Delta e(t)}{e(t)}\right) = -\phi_e(\frac{\Delta Ca(t)}{Ca(t)})$$

When there is a surplus in current account, the exchange rate is expected to appreciate in the following period because there are more domestic currency

demand than supply of foreign currency. When it happens, foreign capital flows in. In regime 2, when the negative sign of balance of payment is greater than the reserve ratio, the economies goes to balance of payment.

$$Bop(t) + R(t) < 0 \quad : Crisis \quad - no\ bailouts$$
$$Bop(t) + R(t) \geq 0 \quad : No\ Crisis$$

When this happens, government is unable to provide bailouts to firms and more firms get destroyed

The monetary policy is the same in regime 1.Government follows talyor rule to set period interest rate and provides bail outs in the bad times.

3. Fixed Exchange Rate, Free Capital Movement and Dedependent Monetary Policy

Exchange is fixed at target rate and there is no capital control. Government cannot provide bail-outs to domestic firms and unable to adjust interest rate. Table 4-1. summarizes the policy operation in different regimes.

Table 4-1. Summary Equations for Each Regime

Fields	**Regime 1** **FiE, CC, IM**	**Regime 2** **FE, FC, IM**	**Regime 3** **FiE, FC, DM**
Exchange rate	$\boldsymbol{e(t) = e^*(t-1)}$	$\boldsymbol{e(t) = (1 + \left[\frac{\Delta Bop(t)}{Bop(t)}\right])e(t-1)}$	$\boldsymbol{e(t) = e^*(t-1)}$

Capital mobility	$\boldsymbol{\psi_i(t) = 0}$	$\boldsymbol{\psi_i(t) = r(t) - \left[r^*(t) + E\left(\frac{\Delta e(t)}{e(t)}\right)\right]}$	$\boldsymbol{\psi_i(t) = r(t) - \left[r^*(t) + E\left(\frac{\Delta e(t)}{e(t)}\right)\right]}$
Monetary Policy	$\mathbf{r(t)} = \boldsymbol{\varphi(y(t) - y^*)} + \mathbf{r}(\boldsymbol{t-1})$ **-Bailout**	$\mathbf{r(t)} = \boldsymbol{\varphi(y(t) - y^*)} + \mathbf{r}(\boldsymbol{t-1})$ **-Bailout**	$\mathbf{r(t)} = \boldsymbol{r^*(t)}$ **-No Bailout**

The main shock that bring major changes in the economy is the foreign demand shock where every domestic firm is affected. For the next section, we will see how different size and sign of the foreign demand shock influences the the economy.

6) Dynamics of the Model

Given a demand shock (either positive or negative), economic variables (current account, financial account, exchange rate, interest rate, investment and output) changes depending on the regime choice.

Figure 4-1. Impulse Response of Macro Variables from Positive Foreign

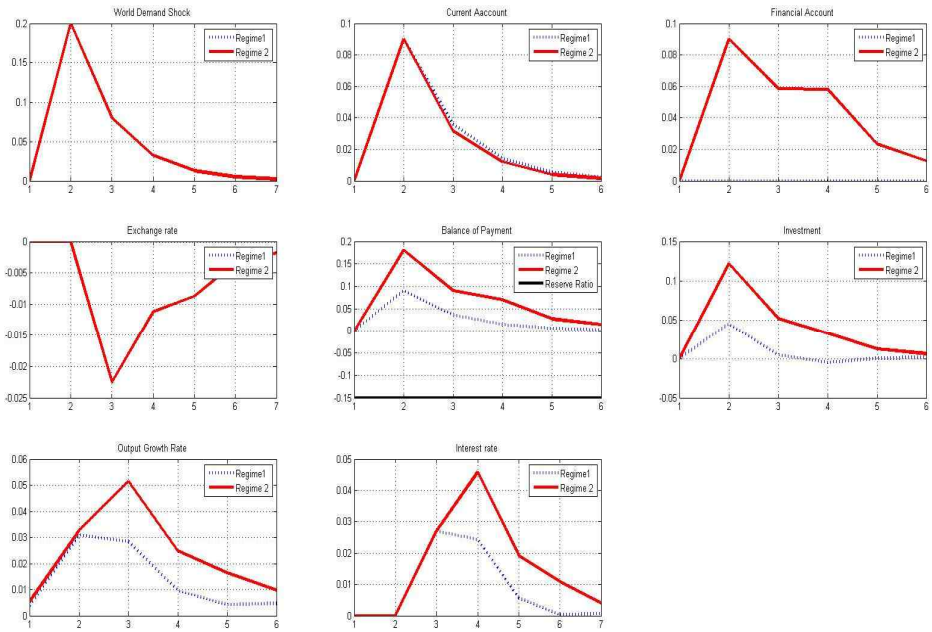


Figure 4-1 shows the impulse response of aggregate variables given a positive shock (with parameter $\gamma = 0.45$, $\omega = 0.15$. When there is a demand shock, there is a rise in the demand for domestic firms which increases current account. As one can see, there is not much difference between regime 1 and regime 2 up to this point. The size of current account change depends on the openness parameter, γ. The Higher γ, the more change in current account from a demand shock. When there is a current account change, foreign investors expect changes in exchange rate. For regime 1, exchange would not change. However, for regime 2, surplus in current account creates an appreciation pressure in the exchange rate which would create arbitrage in exchange rate market. As a result, there is going to be a capital inflow for a positive shock and capital outflow for a negative shock. One can see that the impulse of output change of regime 1 is much greater than that of regime 2.

Figure 4-2. Impulse Response of Macro Variables from Negative Foreign Demand Shock

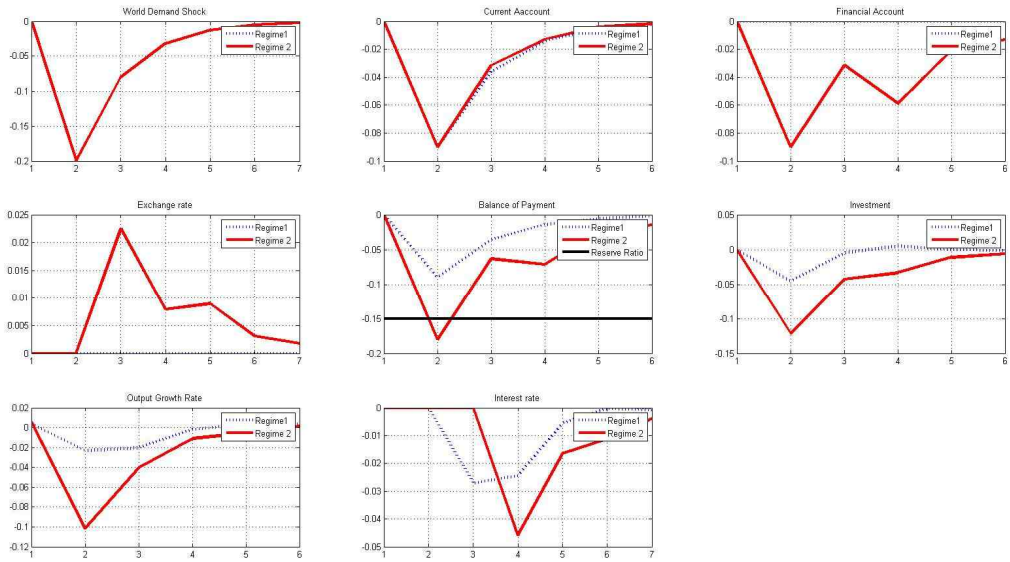
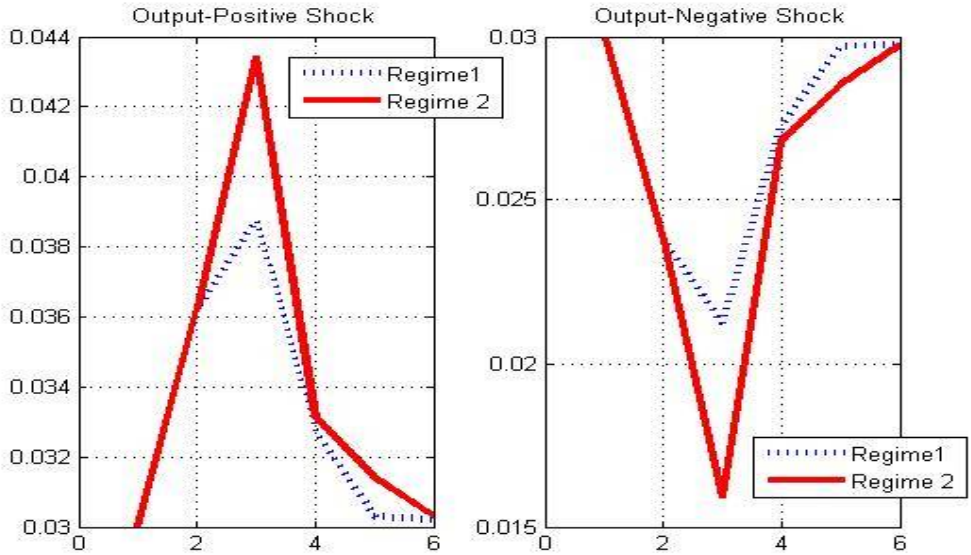


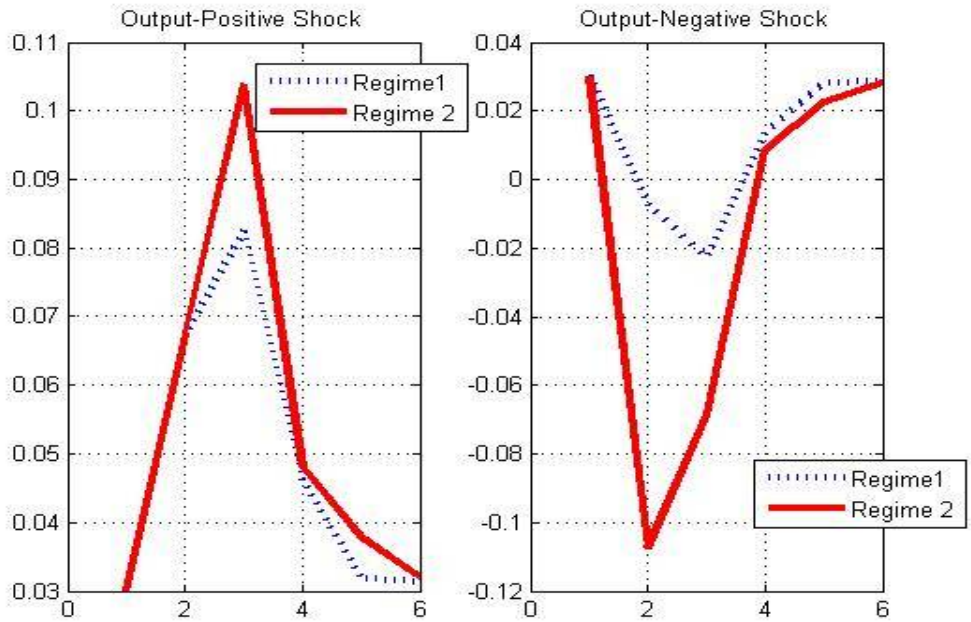
Figure 4-2 depicts a negative shock big enough to override the reserve ratio of an economy. As long as a negative shock does not make balance of payment deficit less than the amount of reserve of an economy, there is going to be a symmetry between positive shock and negative shock in both regimes as in figure 4-3.

Figure 4-3. Impulse Response of Output for a Small Positive and Negative Shock



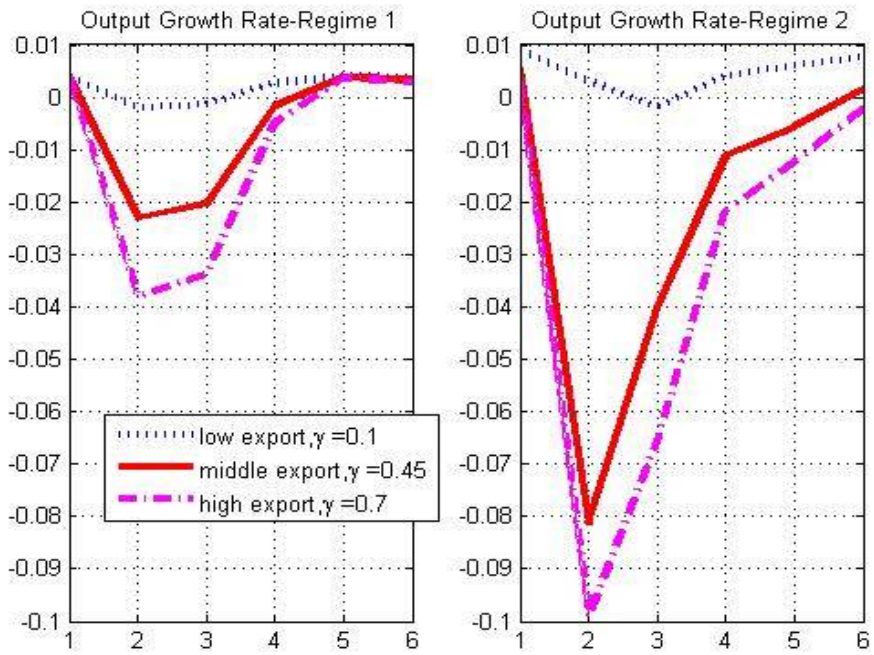
However, when balance of payment deficit gets larger than the reserve, the economy falls into balance of payment crisis. When it happens, government is unable to provide bailouts to domestic firm increasing the number of defaulted firms. Since it takes time for new firms to replace them (one period in the model), economic growth declines even further for regime 2 (depicted in figure 4-4). Notice that for regime 1, there is no balance of payment crisis since domestic firms do not have foreign debt. Balance of payment crisis is a feature that only exist in economies with no capital control.

Figure 4-4. Impulse Response of Output for a Large Positive and Negative Shock



For economies with high export ratio, there is a higher chance of having balance of payment crisis than those with low export ratio. As shown in the right panel of figure 4-5, given a same size of shock, for economies with export ratio 0.1 does not face balance of payment crisis whereas the economies with export ratio above 0.45 experience balance of payment crisis. This is because amount of expected change in exchange rate is much higher for economies with high export ratio. When foreign investors expect higher appreciation (depreciation) of exchange rate, more foreign capital come in (out). When there is a capital control as shown in the left panel of figure 4-5, there is no balance of payment crisis, but output growth rate response more strongly for economies with high export ratio.

Figure 4-5. Impulse Response of Output for Different Value of Export/GDP ratio.



7) Parameters and Initial Variables

The model does not have analytical, closed form solutions. The general ABM distinctive features stems from the non-linearities present in agent decision rules and their interaction patterns, and it forces us to run computer simulation to analyze the properties of the stochastic processes governing the coevolution of micro and macro variable (Dosi, 2010). We will start with looking at the benchmark parameters. Then, we will explore the ability of the model to reproduce the major stylized facts regarding macro aggregates 1) GDP and investment 2) GDP and capital inflow 3) current account, financial account and exchange rate 4) effectiveness of monetary policy and micro characteristics 1) technology disturbances and 2) investment distribution. Initial conditions and parameters for different type of countries are given in the table 4-2.

Table 4-2. Benchmark Parameters

Description	Symbol	Value
Number of Firms	J	1000
baseline cost minimizing technology (average)	A	1
Initial capital of firms (average)	k_i	1
Debt Structure	μ_i	Regime 2 and 3→ ~ Beta(3,3) w/ support [0 1] Regime 1→0
Effect of current account change on expected exchange rate	ϕ_e	.12
Investment decision parameter on profit	φ_π	1
Capital inflow parameter on exchange rate volatility	φ_σ	1
Fraction of firms that receive bailouts	β	0.4
Domestic Savings (Marginal propensity to save)	σ	0.2
Initial Openness (export/GDP ratio)	$\boldsymbol{\gamma}_j$	0.15~ 0.7
Reserve/GDP ratio	ω	0.05~0.35
Target Exchange rate	e^*	Experiment 1: 1.05 (Depreciated level) Experiment 2: 1.0
Amount of Capital Control	η	Regime 2 and 3→ 0

		Regime 1→ 1 Experiment 2: Find the optimal amount of capital control for regime 1
Micro Cost Minimizing Technology Disturbance	ε^{a}	~Beta (3,3) w/ support [-0.15 0.15]
Macro Foreign Demand Shock	ε^{e}	~Beta (3,3) w/ support [-0.2 0.2]

The key parameter of interest is export ratio and reserve ratio which are related to the hypothese. We are going to see how change in the export ratio and reserve ratio[8] affects output growth in different regimes in two experiment where 1) economies can set exchange rate at the depreciated level, e^{*}=1.05, 2) economies are unable to set depreciated exchange rate as a target ($e^{*} = 1$). As mentioned above, there are two shocks in the model. One is macroeconomic foreign demand shock and another is microeconomic cost minimizing technology disturbance. For next section, we will see how the model is able to replicate macro and micro stylized facts as discussed in the previous chapter.

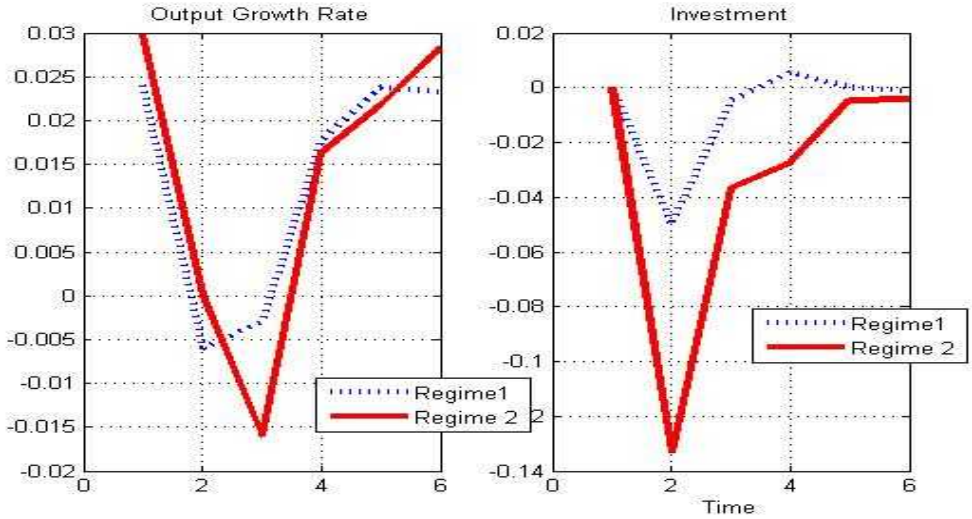
8) Macroeconomic Aggregates

- *GDP and Investment*

The model generates self-sustained growth patterns as in real data (Stock and Watson; 1999) Both consumption and investment appear to be procyclical with investment having higher volatility than GDP. As in figure 4-6, in both regime, investment is shown to be procyclical and is more volatile to GDP for both regimes.

[8] Give different value only in the initial setting and they evolve through the time

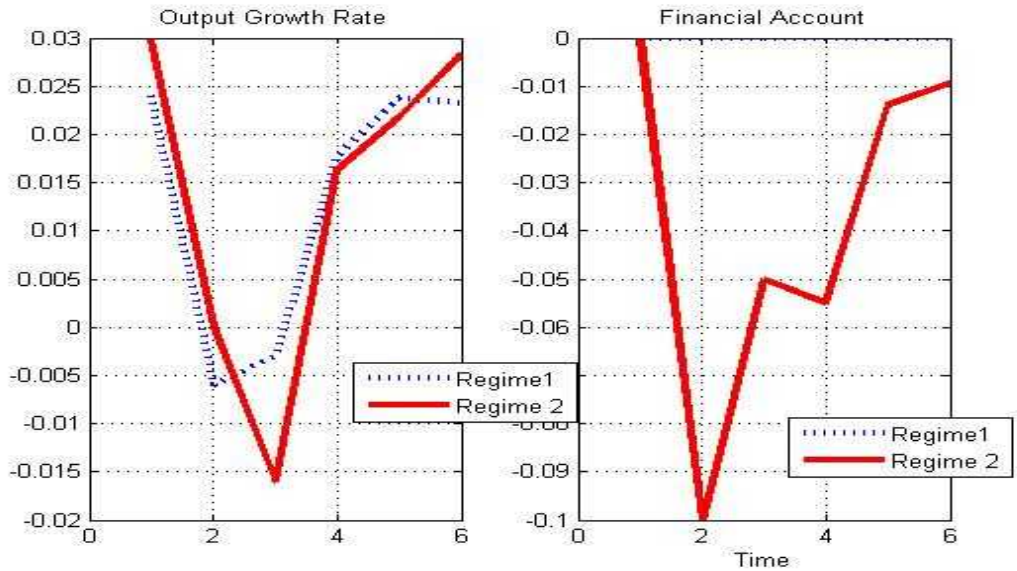
Figure 4-6. Relationship Between Output and Investment



- *GDP and Capital Inflow*

For regime 1, there is no capital inflow but fore regime 2, capital inflow shows procyclical (Kaminsky et al 2004) to GDP as in figure 4-7.

Figure 4-7. Relationship Between Output and Financial Account



- *Current Account, Financial Account and Exchange Rate*

For current account, financial account and exchange rate, there is no clear stylized facts. In theory, positive surplus in current account should be offset by the deficit in financial account to make balance of payment close to zero. However, in real life, this rarely happens. The most obvious counter example is the fact that capital inflow (capital account) shows procyclical to GDP. In both theoretical and empirical perspective, export led growth model provided strategic growth path for many emerging economies. In other words, since export directly influences current account, those countries enjoyed economic prosperity derived from current account surplus (South Korea, Taiwan, Singapore or China). If financial account indeed offsets the current account imbalance, financial account should have shown counter cyclical movement to GDP movement for many emerging economies.

Figure 4-8. Three Variable VAR analysis for Current Account Shock

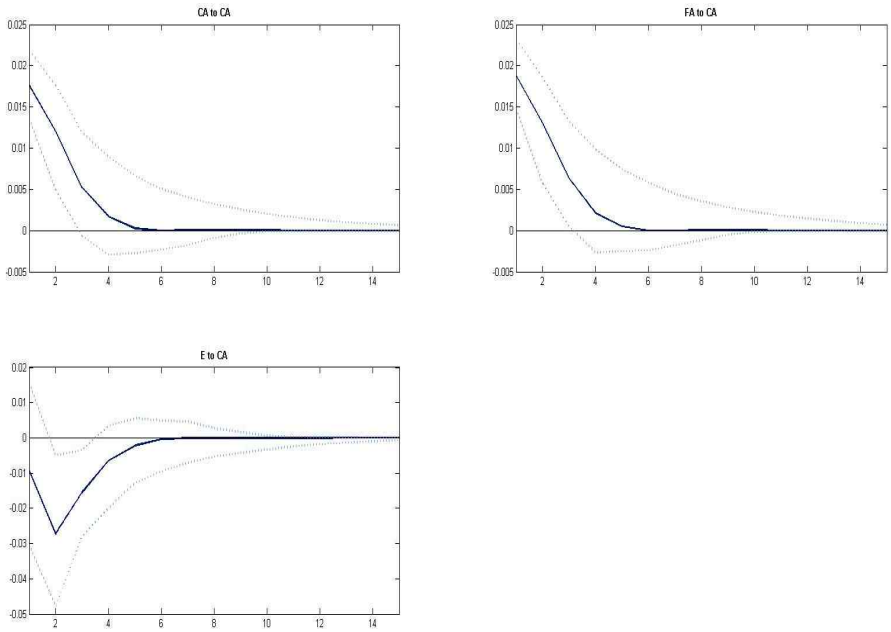
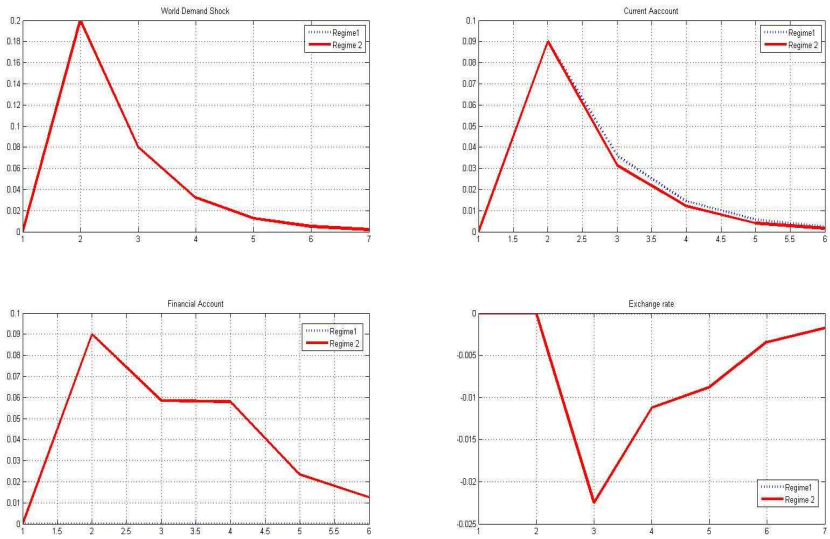


Figure 4-9. Impulse Response from the Model



As depicted in figure 4-8, unlike theoretical perspective, Vector Autoregression analysis from Korea data[9] shows that financial account does not offset the current account. Instead, it moves in the very similar way. One can see that the response of those variables in the model (figure 4-9) is very close to the VAR result.

Correlation structure of aggregate series are listed in table 4-3 and table 4-4

Table 4-3. Correlation Structure –Regime 1

Series	t	t+1	t+2	t+3	t+4
Demand shock	**-0.2050 (0.1169)**	**-0.0820 (0.0468)**	**-0.0328 (0.0187)**	**-0.0131 (0.0075)**	**-0.0052 (0.0030)**
Current Account	**-0.0923 (0.0526)**	**-0.0369 (0.0210)**	**-0.0148 (0.0084)**	**-0.0059 (0.0034)**	**-0.0024 (0.0013)**

[9] Current account/nominal GDP , Financial account/nominal GDP and percentage change of exchange rate from 1999 to 2014

Exchange Rate	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
Financial Account	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
Investment	**-0.0461 (0.0263)**	**-0.0046 (0.0026)**	**0.0051 (0.0029)**	**-0.0000 (0.0000)**	**-0.0011 (0.0006)**
Interest Rate	**0 (0)**	**-0.0277 (0.0158)**	**-0.0249 (0.0142)**	**-0.0058 (0.0033)**	**-0.0002 (0.0001)**
Output growth	**-0.0037 (0.0158)**	**-0.0009 (0.0142)**	**0.0182 (0.0033)**	**0.0238 (0.0001)**	**0.0233 (0.0004)**

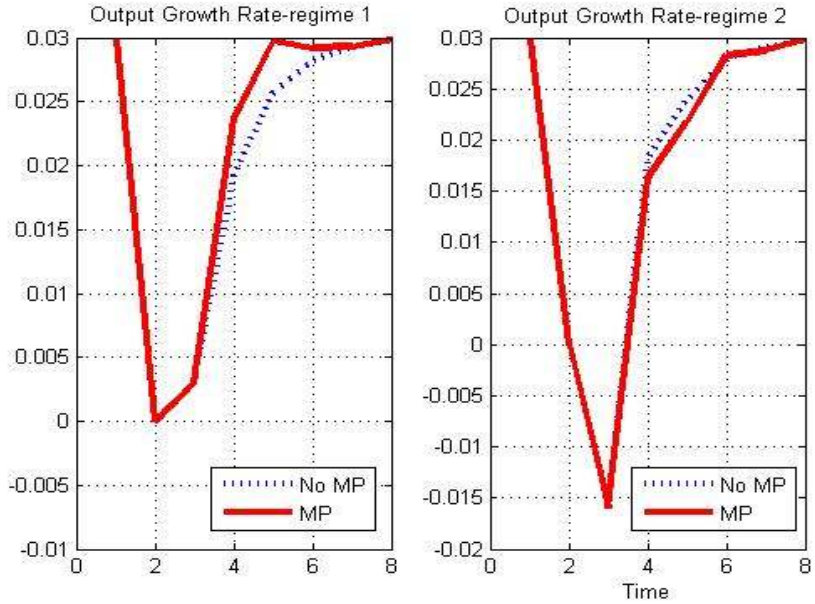
Table 4-4. Correlation Structure –Regime 2

Series	t	t+1	t+2	t+3	t+4
Demand shock	**-0.2050 (0.1169)**	**-0.0820 (0.0468)**	**-0.0328 (0.0187)**	**-0.0131 (0.0075)**	**-0.0052 (0.0030)**
Current Account	**-0.0923 (0.0526)**	**-0.0185 (0.0105)**	**-0.0110 (0.0064)**	**-0.0017 (0.0031)**	**-0.0013 (0.0009)**
Exchange Rate	**0 (0)**	**0.0923 (0.0127)**	**0.0187 (0.0054)**	**0.0210 (0.0064)**	**0.0053 (0.002)**
Financial Account	**-0.0923 (0.0526)**	**-0.0190 (0.0099)**	**-0.0309 (0.0189)**	**-0.0090 (0.0104)**	**-0.0083 (0.0036)**
Investment	**-0.1207 (0.0644)**	**-0.0244 (0.0125)**	**-0.0216 (0.0087)**	**-0.0043 (0.0057)**	**-0.0040 (0.0019)**
Interest Rate	**0 (0)**	**-0.0005 (0.0015)**	**-0.0199 (0.0192)**	**-0.0073 (0.0074)**	**-0.0070 0.0029)**
Output growth	**-0.0647 (0.0158)**	**-0.0347 (0.0142)**	**-0.0016 (0.0033)**	**0.0260 (0.0001)**	**0.0313 (0.0004)**

- *Effectiveness of Monetary Policy*

Figure 4-10 shows effectiveness of monetary policy in regime 1 and regime 2. Left panel shows that for regime 1, when there is a negative shock, having monetary policy (MP) bring GDP growth rate back to the target growth rate (0.03) much faster than in case where there is no monetary policy (No MP). However, for regime 2, there is not much difference between having monetary policy and no monetary policy. To see why, let us consider the goal of monetary policy of the model. In the model, central bank follows Taylor rule to adjust interest rate to maintain the economy at the target rate. For example, when a negative (positive) demand shock hits the economy, there is fall (rise) in GDP. The central bank reduces (raises) the interest rate to encourage (discourage) investment. As a result, GDP returns to the target level (0.03 in the figure). Unlike regime 1, for regime 2, the possibility of capital inflow or outflow hinders this mechanism to work. Foreign capital inflow occurs in two channel in the model: change in interest rate and change in expected exchange rate. When a central reduces interest rate to encourage investment, foreign capital flows out from the economy since the return on the domestic investment is reduced. As a result, the effect on investment would be ambiguous in regime 2 where foreign capital can freely come in and out. This is in a line with Rey (2015) who argues that global financial cycle has transformed trilemma into "dilemma": independent monetary policies are possible if and only if the capital account is managed and there is need for restricting capital mobility.

Figure 4-10. Effectiveness of Monetary Policy for Two Regimes

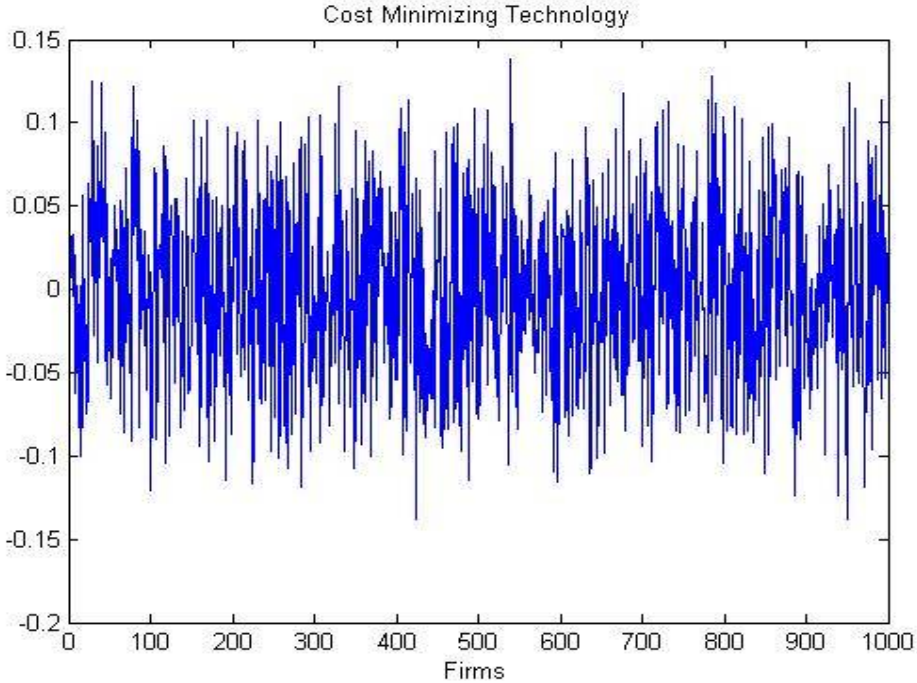


9) Microeconomic Characteristics

- *Technology Distribution*

Together with the ability to match the macroeconomic stylized facts, how does the model account for mircoeconomic heterogeneity in firms? Figure 4-11 shows firms productivity which is in a line with the empirical evidence (Bartelsman and Doms; 2000, Dosi; 2007) where firms are different in terms of technology.

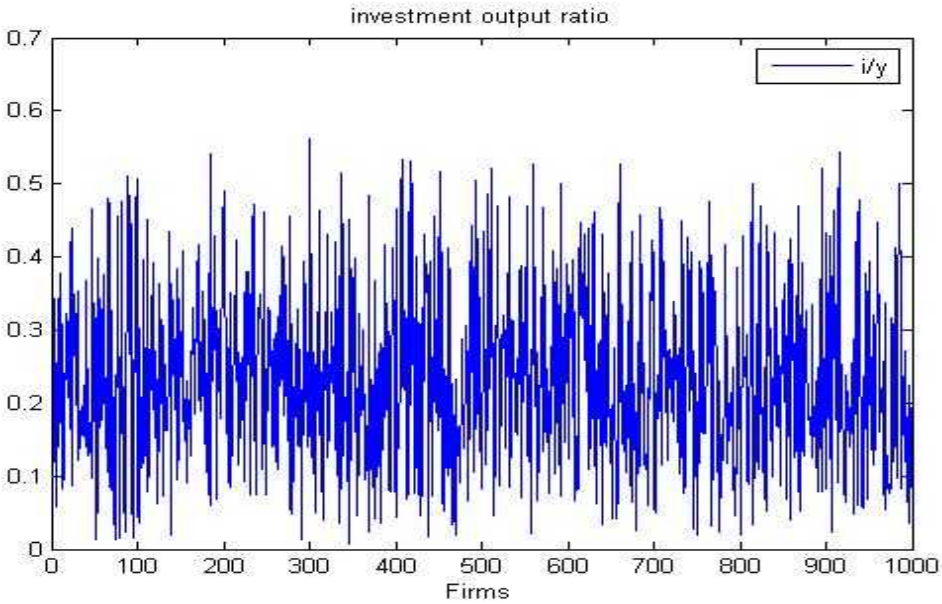
Figure 4-11. Technology Distribution for Firms



- *Investment Distribution*

For investment patterns, the model is able to generate familiar investment lumpiness (Doms and Dunnes, 1998) where firms with near zero investment coexist with firms with investment spikes (See figure 4-12 and compare it with Dosi et al (2010).

Figure 4-12. Investment Distribution for Firms



Chapter 5. Simulation Experiments

In the previous chapter, we have seen that the model is quite robust and that it accounts for many empirical regularities. In this chapter, let us experiment with different country specific characteristic (openness ratio and reserve ratio) to compare the output growth rate for different policy regimes. First experiment regards the case where economies are able to keep their exchange rate depreciated (5% level) at the initial stage (initial value) in regime 1. However, for some researchers, this is a too big assumption. For the second experiment, this assumption no longer applies in regime 1. Economies are not able to set foreign exchange rate at the depreciated level as an initial value, but they are able to adjust amount of capital control in regime 1.

In each experiment, we are going to compare the average economic growth (GDP growth) rate for different regimes in 1000 times simulation. Each experiment has four kinds of macro foreign demand shocks: no shock, negative shock, positive shock, both shocks. For each experiment, the paper considers only regime 1 and regime 2 since regime 3 is suboptimal choice for any level of export ratio in the analysis.

1) **Experiment 1: Openness and Reserve Ratio – Determining the Best Policy Regime**

For experiment 1, the paper considers regime 1 and regime 2 since regime 3 is suboptimal choice for any level of export ratio. We are going to compare economic growth rate for different regimes with varying export and reserve in the presence of both macro foreign demand shock and micro technology disturbances. For simplicity of the model, this experiment only considers three variability for each parameter (total nine cases).

Table 5-1. Considered Parameter Values for Experiment 1

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Compare the average simulated economic growth rate for two regimes that provides highest economic growth rate in 9 cells**		
	Middle (0.40)			
	High (0.70)			

Table 5-1 shows the 9 different cases for the analysis. The paper is going to compare the average output growth rate for different regimes for 1000 simulation to make a claim regarding the optimal policy choice. We are going to compare average simulated GDP growth rate in different macro foreign demand shocks: no shock, negative shocks, negative shocks, both shocks.

Figure 5-1. Average Output Growth with Different Openness and Reserve for Different Regimes (No Shock)

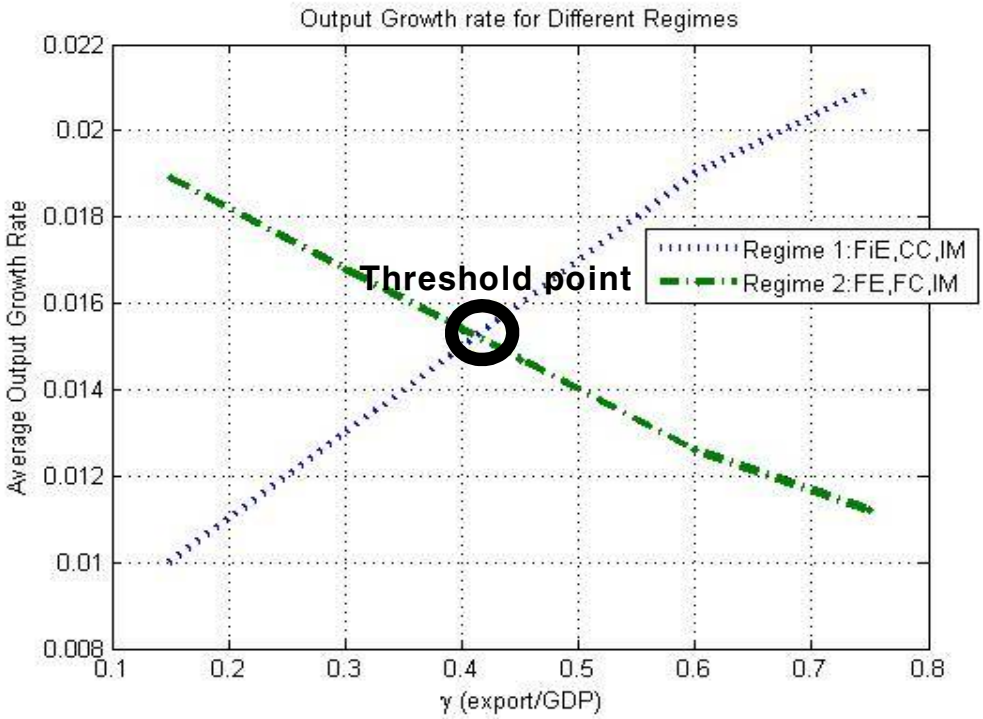


Figure 5-1 compares average output (GDP) growth rate at different export ratio when there is no macro shock. Since the rise in export ratio increases GDP growth rate in regime 1 and decreases GDP growth rate in regime 2, there is going to be a single crossing point which makes choosing regime 1 and regime 2 indifferent. One can see that there is a threshold value for export ratio at the single crossing point (around export ratio .41). It means that when export ratio is above 40% it would be better for economies to choose regime 1 whereas when export ratio is below 40% the optimal regime would be regime 2. In this experiment the GDP growth rate for regime 3 is suboptimal for every level of export ratio. The table 5-2 shows the best regime choice for different value of export ratio. Note that since there is no macro demand shock, the average GDP ratio is the same for all level of reserve ratio.

Table 5-2. Best Policy Regime Choice for Experiment 1 (No Shock)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 2**		
	Middle (0.40)	**Regime 1/Regime 2**		
	High (0.70)	**Regime 1**		

Figure 5-2 shows the average GDP growth rate with different openness and reserve in case where there is only positive foreign demand shock. In this cases, since there is no possibility of balance of payment crisis, one can see the symmetry of average GDP growth rate for any level of reserve ratio that economies have. Unless economies depend heavily on foreign export, economies would have highest average GDP rate in regime 2 (FE, FC, IM). The threshold point exists at export rate around 0.65. The best regime choice is summarized in table 5-3.

Figure 5-2. Average Output Growth with Different Openness and Reserve for Different Regimes (Positive Shocks)

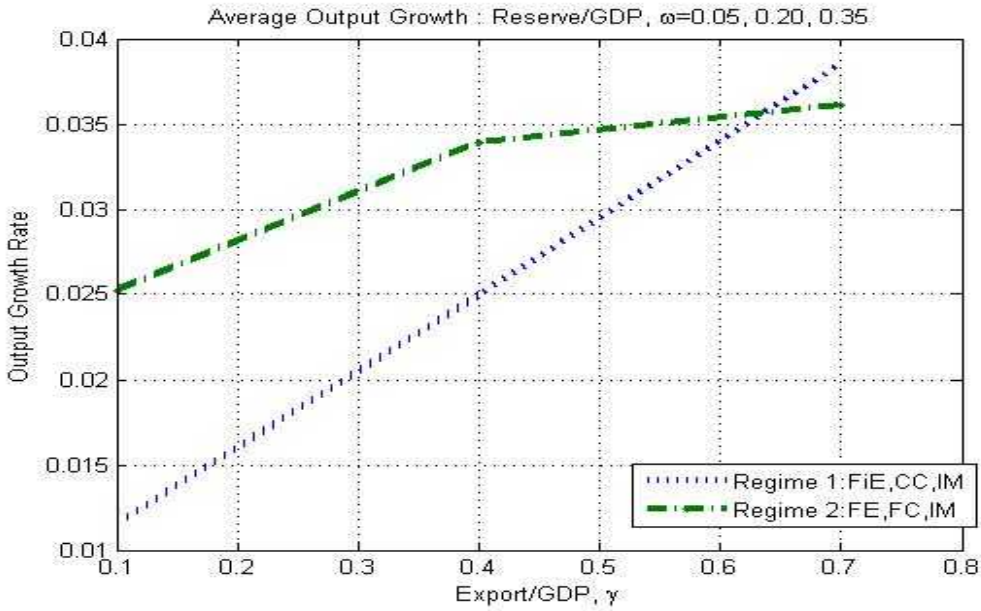


Table 5-3. Best Policy Regime Choice for Experiment 1 (Positive Shocks)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 2**		
	Middle (0.40)	**Regime 2**		
	High (0.70)	**Regime 1**		

Figure 5-3 shows the average simulated GDP growth rate for different values of reserve ratio in negative shocks. For economies with low reserve ratio (0.05) regime 1 provides highest economic growth rate that is because the frequency of balance of payment is too frequent, lowering the average GDP growth rate. For economies with middle reserve ratio (0.20), the average GDP ratio for economies in regime 1 is also greater than that for economies in regime 2 for the

similar logic. However, when economies have high reserve ratio, economies with low export ratio, having regime 2 yields highest average GDP growth rate while for economies with higher export ratio, regime 1 is the best choice. This is because having higher export ratio creates greater change in exchange rate expectation thus creates higher capital outflow. The best policy option is summarized in table 5-4.

Figure 5-3. Average Output Growth with Different Openness and Reserve for Different Regimes (Negative Shocks)

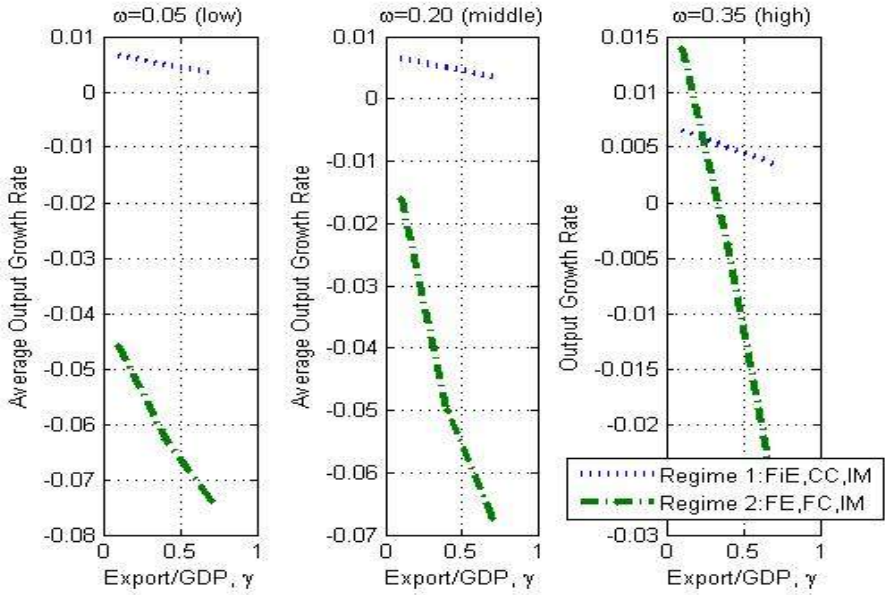


Table 5-4. Best Policy Regime Choice for Experiment 1 (Negative Shocks)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 1**	**Regime 1**	**Regime 2**
	Middle (0.40)	**Regime 1**	**Regime 1**	**Regime 1**
	High (0.70)	**Regime 1**	**Regime 1**	**Regime 1**

Figure 5-4 compares average GDP growth rate for different regimes in both positive and negative shocks. When reserve ratio is low, the regime that yield highest economic growth is regime 1. This is in a line with the above findings where economies with low reserve ratio, the chance of getting currency crisis is higher. The average GDP growth rate in regime 2 rises as economies have more reserve ratio (0.20 and 0.35). One can see that the threshold point for export ratio gets higher with higher reserve ratio.

Figure 5-4. Average Output Growth with Different Openness and Reserve for Different Regimes (both Positive and Negative Shocks)

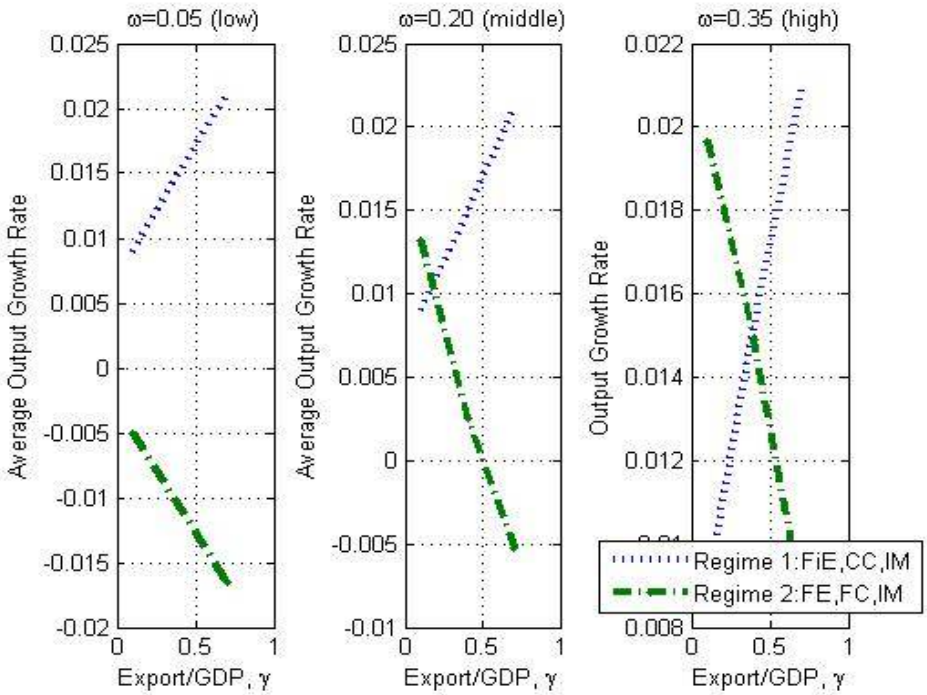


Table 5-5 summarized the above result showing the best regime in 9 different cells. For economies with high export ratio, it is optimal for economies to choose regime 1 and for economies with low reserve ratio, it is optimal not to

choose regime 2.

Table 5-5. Best Policy Regime Choice for Experiment 1 (Both Shocks)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 1**	**Regime 2**	**Regime 2**
	Middle (0.40)	**Regime 1**	**Regime 1**	**Regime 1/ Regime 2**
	High (0.70)	**Regime 1**	**Regime 1**	**Regime 1**

2) Experiment 2: The Best Policy Regime and Optimal Amount of Capital Control

We are going to lose the assumption that countries can keep the exchange rate depreciated in capital control. Instead, economies in regime 1 can allow fraction of foreign capital inflow parameterized as η. In this setting, we are going to compare average GDP growth for two different regimes with 9 different cases of parameters (as in experiment 1) under various macro foreign demand shock (no shock, postive shocks, negative shocks, both shocks) and find opimal amount of capital control (η) that would provide highest GDP growth for economies in regime 1.

Figure 5-5. Average Output Growth with Different Openness and Reserve for Different Regimes (No Shock)

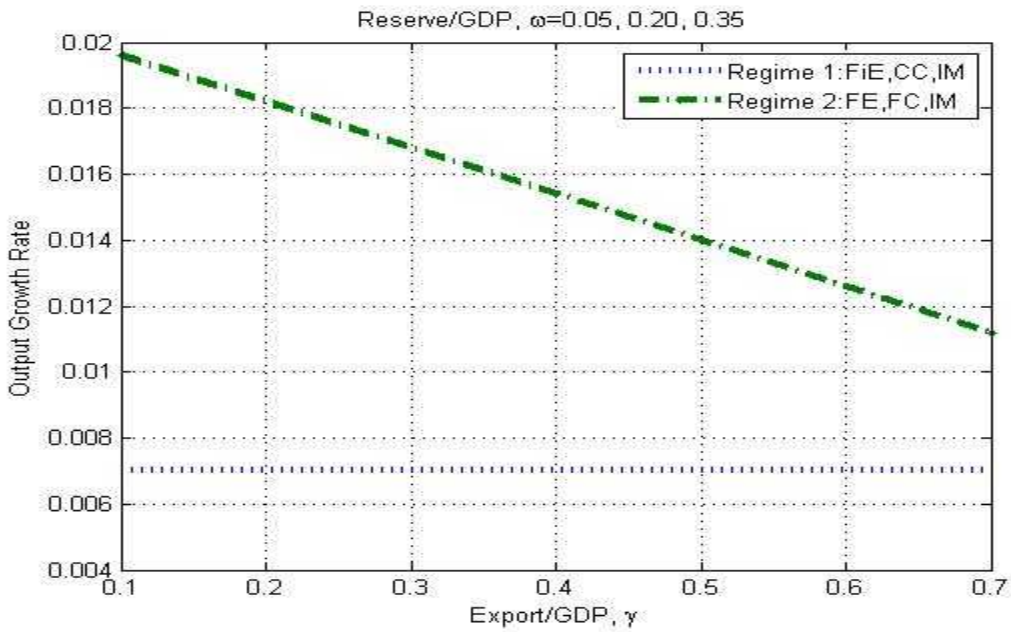


Figure 5-5 shows the average GDP growth in the absence of macro foreign demand shock. As one can see, economies achieve highest average GDP growth rate in regime 2 at any level of export ratio. Since economies are unable to maintain depreciated exchange rate, the average GDP growth rate would be the same for every value of export ratio. The average GDP growth rate falls as export ratio goes up in regime 2 because high openness creates higher variability in exchange rate thus lowering the foreign capital investment. Table 5-6 summarizes the result of no shocks

Table 5-6. Best Policy Regime Choice for Experiment 2 (No Shock)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	Middle (0.20)	High (0.35)
Export ratio (γ) : Export /GDP	Low (0.10)	Regime 2		
	Middle (0.40)	Regime 2		
	High (0.70)	Regime 2		

Figure 5-6 compares average GDP growth rate in positive macro foreign demand shocks. Since there is no financial crisis in positive shocks, the average GDP growth rate is the same regardless of reserve ratio as in figure 5-8. The optimal regime in this case is again regime 2 in every case. Table 5-7 summarizes this result.

Figure 5-6. Average Output Growth with Different Openness and Reserve for Different Regimes (Positive Shocks)

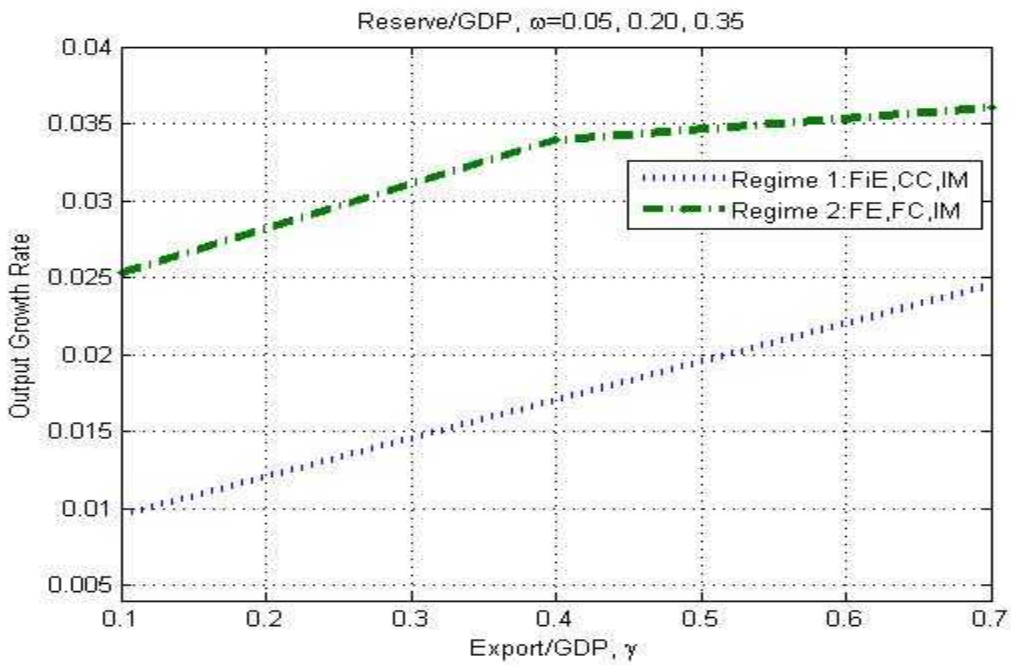


Table 5-7. Best Policy Regime Choice for Experiment 2 (Positive Shocks)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	Middle (0.20)	High (0.35)
Export ratio (γ) : Export /GDP	Low (0.10)	Regime 2		
	Middle (0.40)	Regime 2		
	High (0.70)	Regime 2		

Figure 5-7 depicts average GDP growth rate in negative foreign demand shocks. For economies with lower reserve ratio, the chance of having balance of payment crisis is gets higher, lowering the average GDP growth rate. The average GDP growth rate for regime 1 is the same for any level of reserve ratio because there is no crisis in regime 1 even under negative foreign demand shocks. Table 5-8 shows the summary result.

Figure 5-7. Figure 5-6. Average Output Growth with different Openness and Reserve for Different Regimes (Negative Shocks)

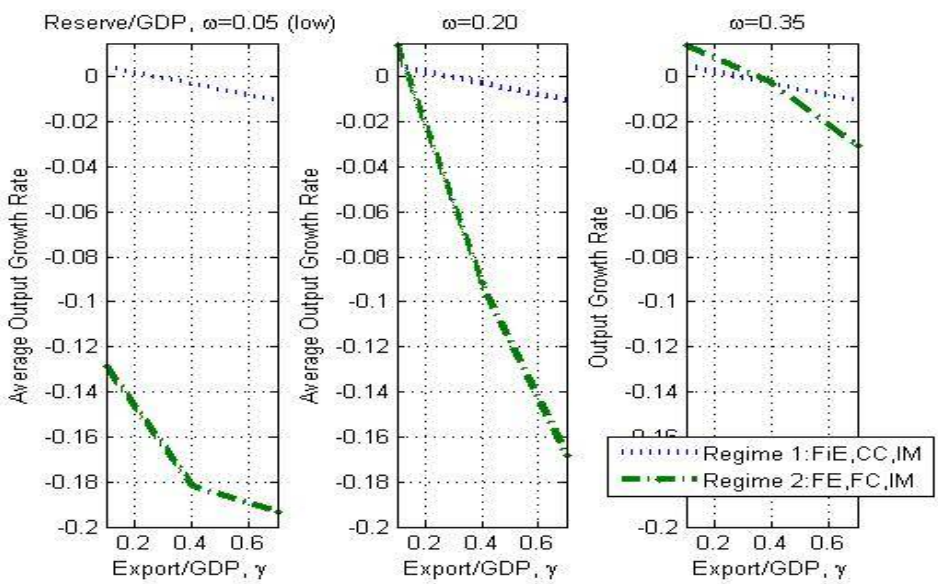


Table 5-8. Best Policy Regime Choice for Experiment 2 (Negative Shocks)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 1**	**Regime 2**	**Regime 2**
	Middle (0.40)	**Regime 1**	**Regime 1**	**Regime 1/ Regime 2**
	High (0.70)	**Regime 1**	**Regime 1**	**Regime 2**

Figure 5-8. shows the average GDP growth rate in the presence of both positive and negative shocks. One can see that economies with low reserve ratio (ω=0.05), regime 1 is still the optimal choice as in experiment 1 and with high reserve ratio (ω=0.35), economies are better off in regime 2. When reserve ratio is at 0.20, the optimal regime changes depending on the threshold export ratio (0.25). Table 5-9 summarizes the result.

Notice that the best regime in experiment 1 and 2 are very similar (table 5-5 and 5-9). The result from experiment 2 shows us that for economies with low reserve ratio ($\boldsymbol{\omega = 0.05}$), the optimal regime is always regime 1 which is the same result as in experiment 1. When the reserve ratio is at 0.20, the best regime choice depends on the export ratio. Both experiment 1 and 2 show that for economies with low export ratio ($\boldsymbol{\gamma = 0.10}$), regime 2 provides highest average GDP growth and for economies with middle and high export ratio, ($\boldsymbol{\gamma = 0.40, 0.70}$), regime 1 is the optimal regime. Experiment 2 shows us that with high reserve ratio, regime2 is the best regime choice for any level of export ratio, However, for experiment 1 shows that for economies with high export ratio, regime 1 is the optimal regime even with high reserve ratio. This is because the model assumes that economies can maintain depreciated exchange rate in regime 1. As the assumption disappears in experiment 2, the best regime choice for economies with high export and high reserve ratio becomes regime 2.

Figure 5-8. Average Output Growth and Export Ratio with Different Reserve Ratio with both Positive and Negative Demand Shocks

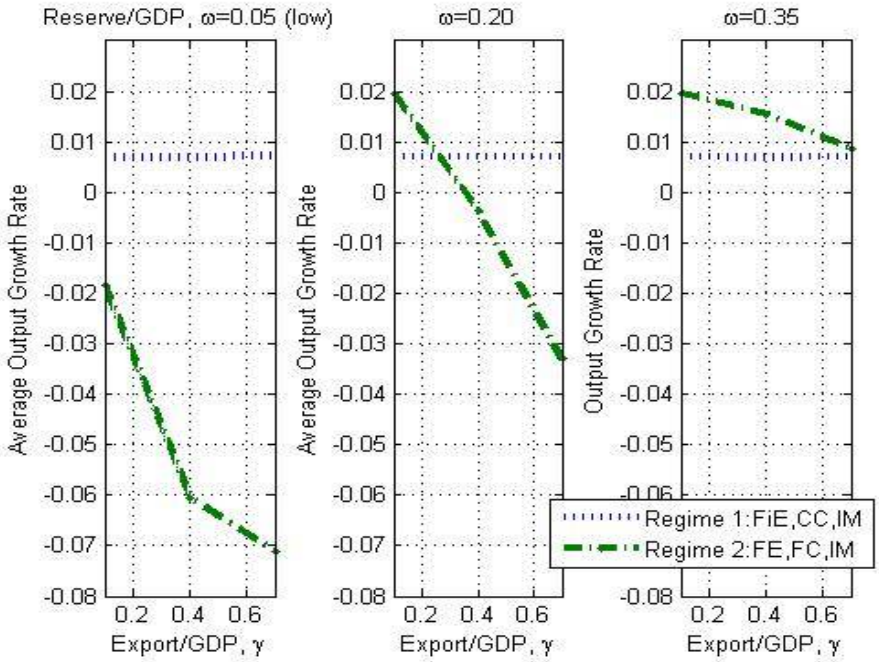


Table 5-9. Best Policy Regime Choice for Experiment 2

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	**Middle (0.20)**	**High (0.35)**
Export ratio (γ) : Export /GDP	**Low (0.10)**	**Regime 1**	**Regime 2**	**Regime 2**
	Middle (0.40)	**Regime 1**	**Regime 1**	**Regime 2**
	High (0.70)	**Regime 1**	**Regime 1**	**Regime 2**

What does this tell us? If an economy has low reserve ratio, they need to impose capital control (regime 1) regardless the ability to intervene in exchange rate market (to keep the exchange rate depreciated). How much capital control should economies impose? There is a trade-off for having capital control. As we have seen in the above experiments, loosening up amount of capital control would

increase the possibility of having balance of payment crisis but, at the same time, foreign capital inflow would increase GDP growth by raising the investment. Figure 5-9 shows the average output growth rate at different amount of capital control with reserve ratio ($\boldsymbol{\omega = 0.05,\ 0.20}$). For economies with low export ratio ($\boldsymbol{\gamma = 0.10}$), the optimal amount of capital control that would bring highest economic growth would be 0.7 and 0 respectively. The optimal amount of capital control rises as the export ratio increases. This is because economies with higher export ratio have higher exchange rate volatility which would increase expected change in the exchange rate change in the presence of foreign demand shocks. For high export ratio ($\boldsymbol{\gamma = 0.70}$), the optimal amount of capital control is 0.9 and 0.3 respectively. Table 5-10 shows the best regime choice and optimal amount of capital control. Note that for regime 2, the optimal amount of capital control is 0 since there is no restriction on capital inflow in a regime with free capital mobility.

Figure 5-9. Average Output Growth at Different Amount of Capital Control

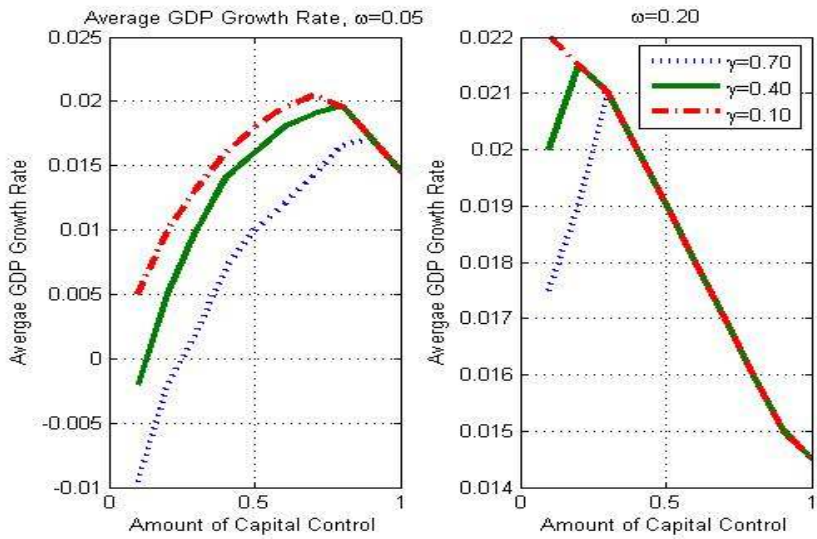


Table 5-10. Best Policy Regime Choice and Optimal Amount of Capital Control (CC)

		Reserve ratio (ω): Reserve/GDP		
		Low (0.05)	Middle (0.20)	High (0.35)
Export ratio (γ) : Export /GDP	Low (0.10)	Regime 1 CC: 0.7	Regime 2 CC:0	Regime 2 CC:0
	Middle (0.40)	Regime 1 CC:0.8	Regime 1 CC:0.2	Regime 2 CC:0
	High (0.70)	Regime 1 CC:0.9	Regime 1 CC:0.3	Regime 2 CC:0

3) Policy Implications

In the first experiment, the paper assumes that economies are able to initially set the target exchange rate level at the depreciated level in regime 1 and economies are unable to adjust amount of capital control in regime 1. In this setting, the competitiveness of domestic firms goes up as the demand for domestically produced good rises (cheaper than foreign goods) and the amount of GDP growth rate would be affected by export ratio (the higher export ratio, the higher GDP growth rate). In the absence of macro foreign demand shock, the optimal regime choice would be regime 1 (FiE, CC, IM) for economies with export ratio greater than the threshold value, depicted in figure 5-1, and the optimal regime would be regime 2 (FE, CC, IM) for those with export ratio less than that. In the presence of positive foreign demand shocks, GDP growth rate rises for both regimes, but due to the procyclicality of capital inflow, GDP growth rate rises much higher in the regime with free capital mobility (regime 2). As a result, the threshold value becomes higher (figure 5-2). In the presence of negative shocks, one can see that GDP growth rate for regime 2 falls much more than regime 1 (figure 5-3). However, there is no symmetry between figure 5-2

and 3 due to the existence of balance of payment crisis in regime 2. For low and middle level of reserve ratio, the optimal policy choice would be regime 1 but if economies have high reserve ratio to absorb large capital outflow driven from negative foreign demand shock, the best regime choice would depend on the threshold value, figure 5-3 right panel. When there are both positive and negative shocks, which is the most realistic case, for economies with low reserve ratio, regime 1 is the best policy choice and for those with middle and high reserve ratio, the optimal policy choice would depend on the threshold value (higher threshold value for economies with higher reserve ratio. What should economies choose in this case? If economies have high reserve ratio and high export ratio the best policy choice is regime 1. Having depreciated exchange rate (regime 1) is going to help their export oriented firms in international market. Since their exchange rate variability is also high, not many foreign investors would like to place domestic investment even in free capital market (regime 2). If economies have low reserve ratio, it would be their best interest to choose regime 1 regardless of their export ratio unless they believe that they are likely to have positive foreign demand shocks for a given number of periods. If there is a chance of negative demand shock, the probability of having balance of payment crisis would be too high. For economies with middle and high level of reserve ratio, they need to choose regimes depending on their export ratio and the threshold value.

For the second experiment, the paper assumes that economies are unable to set the target exchange rate to at the depreciated level but able to set amount of capital control in regime 1. In this experiment, the obvious reason for choosing regime 1 is eliminated (having fixed exchange rate regime would not raise competitiveness of domestic firms in a foreign market) and we will see how the policy implication is being altered in this case. When there is no foreign demand shock, figure 5-5, the optimal policy regime would always be regime 2 since the

major advantages for having fixed exchange rate is removed. The result does not change even when there are positive demand shocks. As seen in experiment 1, capital inflow is procyclical to foreign demand shock. Thus, when there are positive demand shocks, procyclical capital flows in, raising the GDP growth rate. The best regime choice would be regime 2 in any level of export ratio. However, when there are negative demand shocks, we can see that there are some changes in the best regime choice. The GDP growth rate for regime 1 falls under negative demand shock, but it falls even more for regime 2 under the same shock. For economies with low reserve ratio (economies with most frequent financial crisis), the best regime choice would be regime 1 and for economies with higher reserve ratio, the best regime choice depends on export ratio and the threshold value. Under both positive and negative shocks, the result is very similar to the first experiment. When reserve ratio is low, the optimal regime is regime 1, (left panel in figure 5.8) and when the reserve ratio is at the middle, optimal regime choice depends on the export ratio and the threshold value (middle panel in figure 5.9). Lastly, when reserve ratio is high, the optimal regime choice is regime 2 at any level of export ratio (right panel in figure 5.8). One can summarize the result from the experiment as follow. For economies with high reserve ratio, the best policy choice would be regime 2 and for economies with low reserve ratio, the optimal policy choice would be regime 1 regardless of sign and magnitude of foreign demand shocks. This is not surprising because having financial integration (regime 2) would reduce friction for firms which are financially constrained and thus raise GDP growth. For middle value of reserve ratio, there exist a threshold value and the best regime choice would depend on their export ratio. As shown in the model, the higher openness, the higher exchange rate market volatility and thus the higher procyclicality of capital inflow. In other words, for economies with medium level of reserve ratio, the frequency of currency crisis would be higher in economies with higher openness (export ratio).

Figure 5-9 Trilemma Regime Choice for different Openness and Reserve

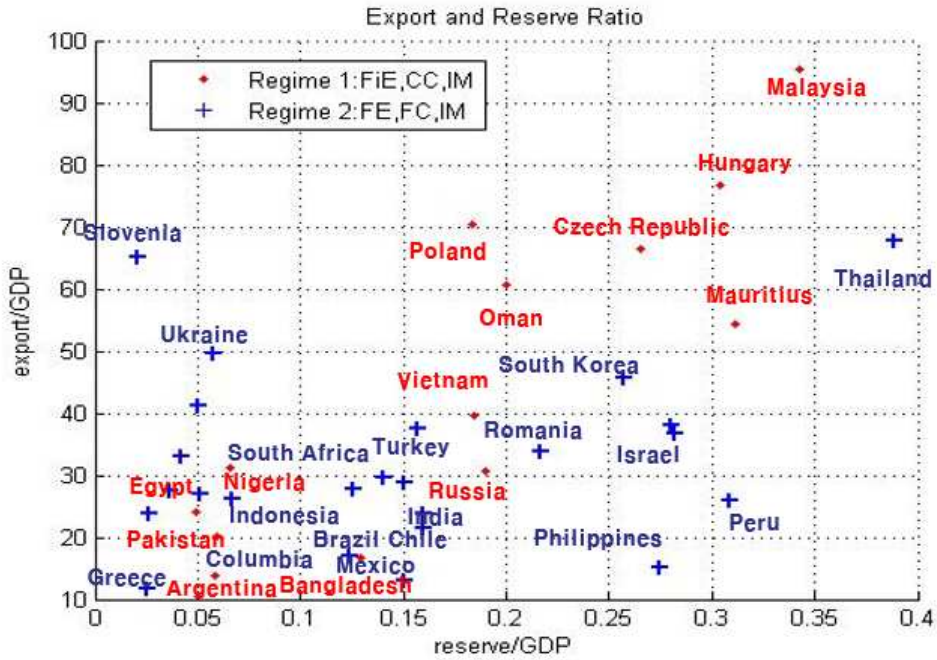


Figure 5-9 depicts trilemma regime choice of emerging economies for different value of openness and reserve. Let us examine whether they are in the optimal regime based on the result of the paper. High export (export/GDP ratio greater than .40) economies such as Malaysia, Hungary, Mauritius, Poland, Oman Vietnam are under regime 1 whereas Thailand Slovenia, Ukraine, South Korea are in regime 2. According to the policy implication of the paper, Malaysia, Hungary, Czech Republic, Mauritius, Vietnam, Oman, Poland, essentially all the high exporting economies in regime 1 are in the right regime if their target exchange rate is at the depreciated level. However, for Slovenia and Ukraine, they have large export/GDP ratio (.68 and .50 respectively) and at the same time they have low reserve ratio (0.02 and 0.06 respectively). The paper suggests that they need to reconsider their macro policy regime choice since their vulnerability against currency crisis is greater and the benefits for having depreciated exchange rate would be greater than those economies with low export ratio. For Thailand

and South Korea, the best policy regime would be regime 1 if it could set target exchange rate at the depreciated level, but if they cannot do so, they are standing at the right regime (in regime 2).

For economies with low reserve ratio, the paper suggests that they need to avoid regime 2. Economies with low reserve ratio (reserve/GDP less than 0.2) such as Egypt, Pakistan, Argentina, Bangladesh and Russia they are at the right regime (regime 1). However, many other emerging economies in regime 2 such as Greece, Columbia, Mexico, Brazil, Chile, South Africa and Turkey, they need to reconsider their policy regime choice. Having financial integration is like "putting a new engine in an old car" (Stigliz, 2010). It will make the car go faster, but when it crashes, it crashes hard (Kaminsky et al, 2005). Once currency crisis hits those economies, they would lose a lot more. The economies such as Romania, Israel, Peru and Philippines have high reserve ratio (more than 0.2) and they are at the right regime according to analyze of the paper.

It seems that too many emerging economies with low reserve ratio are in regime 2. It is almost a trend that more and more emerging economies are opening up capital market. However, many financially stable emerging economies[10] hold large international reserves as means to self-insuring their growing exposure to financial turbulences (Aizenman, 2010). It would be too risky for economies with low reserve ratio to be in regime 2. Although economies can accumulate reserve ratio in a long run, given a period, one can think of reserve ratio as a fixed variable at least in a short run. That is, if a large negative shock (such as foreign demand shock) hits the economy before they accumulate enough reserve ratio,

[10] As noted by Lee et al (2010), Advanced economies such as United States do not need to hold large amount of reserves because in many cases, they have international currency. When currency crisis hits those economies, they can simply print out money to escape such crisis (e.g., 2006 Financial crisis in the U.S).

they are going to experience currency crisis. This is actually what happened for East Asian economies in 1997. Many East Asian economies such as South Korea, Taiwan did not understand the importance of having reserve in the time of crisis and it was too late when they realized it.

Chapter 6. Conclusion

The paper presents an open economy agent based model that reproduces a wide ensemble of macro-stylized facts and distributions of micro characteristics. The model entails feature of open economy where foreign entities play an important role in the formation of adaptive demand expectation and investment plan by domestic firms which are heterogeneous in technology and demand condition. They face microeconomic technology disturbances that are different among firms and a macroeconomic foreign demand shock which propagates through the entire economy in each period.

The model is able to analyze aggregate economic variables such as GDP or investment in different regimes in the presence of shocks. In this respect, we can compare the economic growth rate for different regimes given different value of country specific characteristics: openness and reserve ratio. The paper runs two different experiment depending on the assumption regarding regime 1.

In experiment 1, the paper compares average GDP growth rate for different regimes by varying both export ratio and reserve ratio in different macro demand shocks assuming that economies are able to set up the target exchange rate depreciated in regime 1 at the initial stage. When there is no shock, the best regime choice that yield highest economic growth depends on the export/GDP ratio. Given the model design, there is a threshold point when export/GDP ratio is around 0.41. Economies with higher than export ratio .41 the optimal policy choice would be regime 1 and vice versa. We have seen the changes in optimal regime in the presence of different macro demand shocks. When there are both negative and positive shocks, economies with low reserve ratio ($\boldsymbol{\omega} = \mathbf{0.05}$), it is better for them to avoid regime 2 due to the high frequency of crisis and the best regime choice for them is regime 1. For economies with higher reserve ratio ($\boldsymbol{\omega} = \mathbf{0.20}$ and $\mathbf{0.35}$), it is better for them to choose regime 2 when the export ratio

is less than the threshold export ratio ($\boldsymbol{\gamma = 0.20}$ and $\mathbf{0.41}$ respectively) and choose regime 1 when the export ratio is above it.

In experiment 2, the paper attempts to find the optimal amount of capital control that provides highest average GDP growth rate for regime 1. In this experiment economies are unable to maintain exchange rate at the depreciated level but able to set amount of capital control in regime 1. When there is no foreign demand shock, regime 2 provides highest GDP growth rate for economies regardless of the export ratio which is very different from experiment 1. However, in the presence of both shock the best regime choice becomes similar to that of experiment 1. It is also shown that the optimal amount of capital control rises as both export ratio and reserve ratio rises. For high value of reserve ratio, regardless of export ratio, 0 capital control provides highest GDP growth (regime 2). For reserve ratio less than that, the optimal capital control is greater than 0 and for economies with higher export ratio, they need to have much stronger capital control than those with lower export ratio.

The policy implication for trilemma choice can be summarized as follow. Emerging economies are diversified in both openness (export/GDP ratio) and reserve (reserve/GDP). For economies with low reserve ratio, the optimal policy choice would be regime 1. For economies with middle and high level of reserve ratio, their optimal regime choice depends on the export ratio and the ability to set depreciated level of target exchange rate. The paper also finds optimal amount of capital control which would depends on the reserve ratio and export ratio. The paper also the provide policy suggestions for variety of emerging economies and question whether they are at the right regime.

The methodology given by the paper has some limitations. Firstly, the counterfactual standard that the model creates comes from the two hypotheses regarding export/GDP ratio and reserve ratio. Although the logic of hypotheses comes from existing literature and data, the paper cannot deny the fact that it is

only pseudo. It is true that pseudo analysis is widely used methodology in many fields of social science but further studies might be needed to test whether the counterfactual standard is not just coincidental. Secondly, when it comes to varying parameter of interest, the paper only considers few points (high, middle and low). Although there is no problem with the range of parameter values since the range of export ratio and reserve ratio are calibrated from the data, having more grid points of parameter of interest would enhance the analysis. Primary reason for only considering three different parameter changes for each (9 cases total) is to reduce the computational time. However, considering more parameter changes given the same range would make the paper be able to calculated more accurate threshold value. Thirdly, the paper only considers one macro shock (a foreign demand shock). One can impose variety of other shocks such as a foreign supply shock to see how it affects the GDP growth rate in different regimes.

An economy needs to choose a macroeconomic regime that suits the economic structure the best. The paper only regards openness and reserve that are diversified in actual data as key country specific characteristics in choosing regimes. There could be many others (financial development, technology capability or etc.,) which could influence macroeconomic dynamics in difference regimes. I hope that this study would provide a good starting ground for analyzing the optimal macroeconomic policy choice in the presence of country specific variables that are diversified.

Appendix : Balance of Payment Crisis and Reserve Ratio

In the appendix, we will see the relationship between frequency of balance of payment crisis and reserve ratio when there are negative foreign demand shocks. The export ratio is assumed to be 0.41 and vary reserve/GDP ratio from 0.05 to 0.35. The purpose of this experiment is compare the frequency of balance of payment crisis in the absence of capital control for different value of reserve ratio.

Figure A-1. Output Growth Rate for Three Different Regimes (ω=0.2)

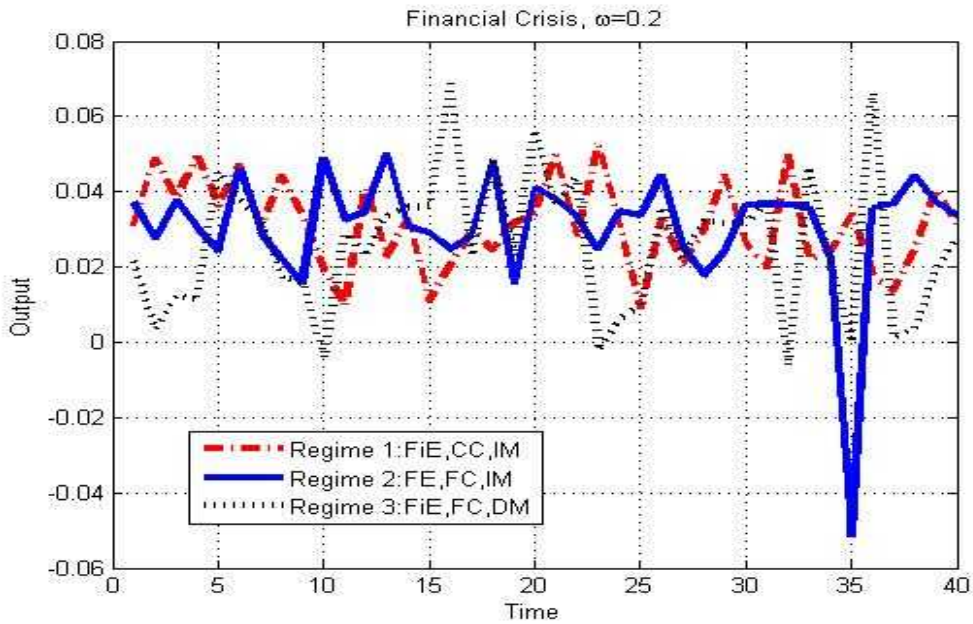


Figure A-1 shows the output growth rate when reserve ratio is 0.2 in a single simulation. One can see that there is an occurrence of balance of payment crisis at period 35. Figure A-2, on the other hand, shows the output growth rate with 0.05 reserve ratio. With lower value of reserve ratio, there is more frequent occurrence of crisis (four times). Table A-1 shows the average frequency of financial crisis for 1000 run simulation for different value of reserve/GDP ratio.

Figure A-2 Output Growth Rate for Three Different Regimes (ω=0.2)

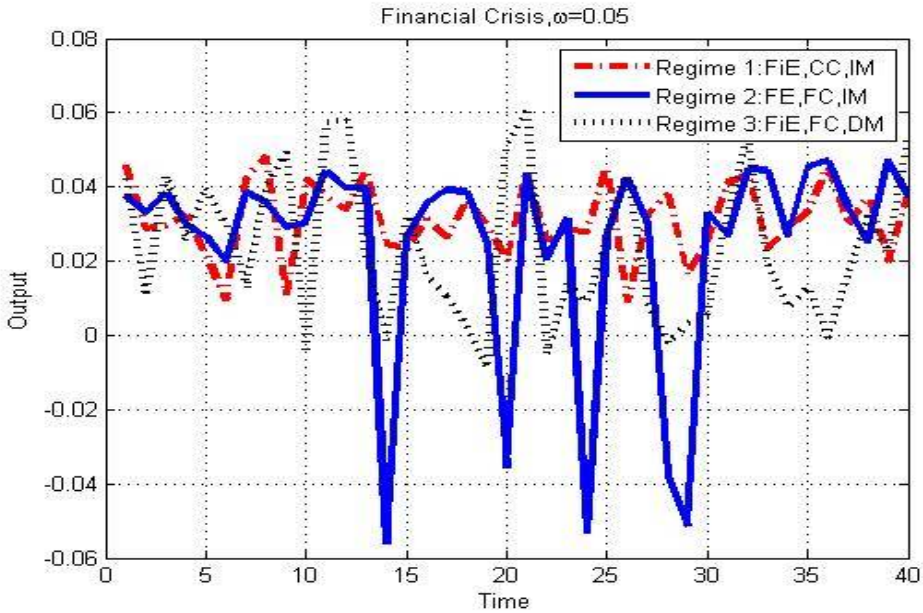


Table A-1. Reserve/GDP and Average Frequency of Balance of Payment Crisis

Reserve/GDP	Average Frequency of Balance of Payment Crisis
0.05	**4.46**
0.1	**3.45**
0.2	**2.07**
0.25	**1.011**
0.3	**0.87**
0.35	**0.05**

As one expected, as economies have more reserve/GDP ratio, the frequency of having financial crisis gets lower (from 4.46 to 0.05 in 40 periods). It tells us that economies with low reserve/GDP ratio need to have capital control to prevent the crisis from occurring.

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국문초록

신흥국 거시경제에서 삼위일체 불가능성에 대한 해법:

진화경제학적 시뮬레이션에 의한 거시 모델 분석과 정책시사

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경제학부

한 준 희

경제 삼위일체 불가능이론 (Impossible Trilemma)에 따르면 고정환율제도, 자유로운 자본의 이동 그리고 독립적 통화정책을 모두 추구하는 것은 불가능하다고 한다. 이에 따라 가장 올바른 정책선택은 무엇이냐 에대한 것은 신흥국에 경우 커다란 질문이 되었다. 본 논문에서는 이 질문에 답하기 위하여 개방도(수출 대비 GDP)와 외화 준비금 (외화준비금/GDP)이 국가 마다 다름을 상정하고 이에 따라 가장 높은 경제 성장률을 도출하는 최적의 정책 체제를 찾는 것을 목표로 삼는다. 이를 위하여 본 논문에서는 개방 경제를 상정한 행위자기반모형(Agent Based Model)을 사용하여 두가지 시뮬레이션 실험을 통해 각 정책 체제의 거시경제의 역학적 움직임을

분석한다. 본 논문의 주요한 결과는 다음과 같다. 1) 외화준비금이 낮은 국가에서의 최적 정책 체제는 개방도에 상관없이 자본을 통제하고 환율을 고정시키는 체제이다. 2) 외화준비금이 이보다 많을 경우 최적정책은 개방도에 따라 달라진다. 논문에서는 최적 정책 체제를 변화시키는 개방도의 임계점을 도출해낸다. 개방도가 이 임계점보다 적은 국가는 자본을 통제하고 환율을 고정시키는 체제가 최적의 체제이며 반대일 경우 자본을 통제하지 않고 환율이 자유롭게 움직이는 체제가 최적의 최제가 된다. 본 논문에서는 자본의 정책 선택 상 자본의 자유이동을 포기한 국가에서 가장 높은 성장률을 내는 최적의 자본 통제의 정도 또한 도출한다.

주요 용어: 고정환율제, 자본이동, 외환위기, 행위자기반모형, 경제 삼위일체 불가능이론

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