OPTIMAL MONETARY POLICY UNDER THE PRESENCE OF INFORMALITY

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OPTIMAL MONETARY POLICY UNDER THE PRESENCE OF INFORMALITY

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Thesis Abstract

Salim Ergene, " Optimal Monetary Policy Under The Presence of Informality"

This thesis studies the optimal monetary policy in an informal sector framework in the presence of nominal price stickiness. We study the optimal policy as a Ramsey plan in which the policy makers maximizes the agent's welfare subject to equilibrium conditions and the assumed monetary policy rule, nominal interest rate rule. Optimality conditions imply positive rate of inflation in the long run. In the presence of nominal rigidities, we showed that positive rate of inflation facilitates price adjustments and affects the efficiency of the price system. Each firm may reset its price in any given period. The optimal price for a firm depends on mark-up, real marginal cost, money stock and real marginal adjustment cost. Moreover, in each period, a firm observes its technology shock and decides in which sector to produce. In such an environment, we show that there exists a threshold technology level such that firms having a productivity below(above) this level chose to operate in the informal(formal) sector. In this setting, the monetary authority has incentives to use monetary policy to induce firms into the formal sector. The positive rate of inflation might increase the number of firms in the formal sector which leads to higher aggregate activity, but eventually the effect dies out, because positive inflation, at the same time, decreases the labor demand and gives firm an incentive to adjust their prices that is, however, a costly process.

Tez Özeti

Salim Ergene, "Kayıtdışı Ekonominin Varlığı Altında Optimal Para Politikası"

Bu tezde, yapışkan fiyatlar ve kayıtdışılık altnda optimal para politikası çalışılmaktadır. Optimal para politikası denge denklemleri ve varsayılan para politikası denklemi altında bireylerin refahını yükselten bir Ramsey planı olarak belirlenmektedir. Uzun dönemde pozitif bir enflasyon oranının optimal olduğu belirlenmiştir. Yapışkan fiyatlar altında, pozitif enflasyon oranının fiyatlama mekanizmasının verimliliğini arttırdığı gösterilmiştir. Her firma herhangi bir dönemde fiyatlarını değiştirebilir. Bir firmanın optimal fiyatı marjinal maliyetine, para arzına ve reel marjinal fiyat değiştirme maliyetine bağlıdır. Ayrıca her dönemde bir firma teknoloji şokunu gözlemledikten sonra hangi sektörde üretim yapacağına da karar verebilir. Böyle bir ortamda, eşik bir teknoloji seviyesinin olduğu gösterildi, öyle ki, bu eşik teknoloji seviyesinden daha yüksek bir seviyeyle üretim yapabilen firmalar formel sektörde üretirken diğerlerinin informel sektörde üretim yapıcağı belirlenmiştir. Bu durumda para politikacıları firmaları formel sektörde üretime teşvik etmek için para politikasını kullanabilir. Pozitif enflasyon oranının formel sektördeki firmaların sayısını arttırdığını, bunun da makro düzeyde ekonomik aktiviteyi hızlandırdığını, ancak bir süre sonra bu etkinin azaldığını, çünkü pozitif enflasyon oranı aynı zamanda firmaların işçi talebini de azalttığı gösterilmiştir.

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CHAPTER 1

INTRODUCTION

Optimal monetary policy and welfare implications of different policies in the presence of an informal sector and nominal price stickiness are important questions for the monetary policy makers. Our analysis is relevant to the developing economies where the effects of an informal sector on aggregate activity is more important than the developed ones. There has been an ongoing discussion, in particular, about the optimal rate of inflation in many developing countries. This thesis focuses on the optimal rate of inflation in developing economies.

In the monetary policy literature it is commonly agreed that the optimal rate of inflation is zero. However, most central banks follow a positive inflation target. Despite the common assumption in the monetary policy literature that the optimal inflation rate is zero, there exists some controversial studies. Ascari et al.(2007), for instance, show that even low positive trend inflation has strong effects on optimal monetary policy. Moreover, Ascari(2003) reveals that a very mild level of positive inflation implies huge changes in the steady state output level. Kim et al.(2009) indicates that the optimal level of inflation for the U.S. economy is about 0.35% per year, with a 95% confidence interval ranging from 0.04% to 0.87%. Furthermore, Zaid(2013) reveals that optimal monetary policy features positive inflation in the long run; the optimal annual long run inflation rate for the U.S. economy is slightly below 1% with a money demand motive and around 2% percent otherwise. Arseneau et al.(2008) show that the optimal rate of inflation is quite volatile. Faia(2009) supports that optimal policy features deviations from price stability in response to both productivity and government expenditure shocks. These recent studies support that models log linearized around a zero inflation steady state are quite misleading even for developed economies.

In this thesis we study optimal monetary policy under the presence of informality in a context where firms are heterogeneous in their productivity. Each firm might chose to operate either in the formal sector, thereby enjoying public capital in production at the cost of paying taxes, or in the informal sector where it only pays a fraction (depending on tax enforcement) of taxes levied on the formal sector. We develop a general equilibrium model that includes rigidities in price decisions. Each firm may reset its price in any given period. The optimal price for a firm depends on mark-up, real marginal cost, money stock and real marginal price adjustment cost. In each period, a firm observes its technology shock and then decides in which sector to produce. It is obvious that technology shocks affects firms' marginal cost which will affect their price decisions. On the other hand, we use the money stock as the nominal anchor. Therefore, unexpected changes in money stock or changes after the price adjustment affects firms' formal/informal sector decisions. There exists two channels in our model to give firms an incentive for the price adjustment: the first one is real marginal cost shocks due to the productivity shocks and the second one is the nominal shocks due to the unexpected changes in money stock. When monetary authority change the money stock unexpectedly, this gives the incentive to change nominal prices, since unexpected changes in money stock requires the adjustment of relative prices. Consideration of two channels for the incentive to adjust prices allows us to compare the relative importance of different policies for understanding the economic effects of real shocks and nominal shocks. In this paper, we focus on the effects of nominal shocks. Moreover, firm heterogeneity in terms of their productivity allows us to determine the threshold technology level such that firms having a productivity below (above) this level chose to operate in the informal (formal) sector. Cerda et al.(2013) studies the optimal taxation in context with firm heterogeneity. Our model extends their fiscal policy approach to monetary policy with nominal price frictions. This extension allows us to test several macroeconomic relationships regarding inflation, aggregate output, informal sector size and nominal rigidities.

The main implication of our model is that the optimal inflation rate is positive which induces firms to produce in the formal sector, because the change in money supply, especially unexpected change, gives firms an incentive to adjust their prices. However, the price adjustment is a costly process. In this environment firms in the informal sector can not enjoy public capital in the production to increase their productivity which, at the same time, decreases their marginal cost, as a result, they may not compensate the costs of unexpected nominal shocks. On the other hand, the government expenditure can be increased by seigniorage revenue which gives rise to increase the productivity of firms in the formal sector. Under the presence of informality, due to the existence of tax evasion in the economy, the government has to rely on indirect taxation through seigniorage revenues.(See Roubini and Sala-i Martin, 1992, 1995 and Elgin and Uras, 2013). Although governments benefit from the seigniorage revenue, someone has to pay the costs of inflation in the economy. Therefore, several papers attempt to compare the costs and benefits of inflation. In this thesis, we follow a different approach. In this thesis, not only the government, but also firms in the formal sector might benefit from seigniorage revenue. In other words, firms in the formal sector might compensate the costs of inflation by enjoying public capital. In contrast to several studies in the literature which reveals a positive relationship between the size of the informal sector and the inflation rate, however, in our model the size of the informal sector declines with positive rate of inflation. Koreshkova(2006), for instance, study the interaction between the size of the underground economy and the inflation rate. Koreshkova(2006) reveals that the size of the underground economy is positively associated with the inflation rate.

Despite the possible importance of the existence of an informal sector and nominal stickiness for the determination of optimal policy and optimal rate of inflation, a few works examines these features in concert. Our paper might contribute to this part of the literature.

The rest of the thesis is organized as follows. Chapter 2 describes the model economy which introduces the optimality conditions of firms and households. Chapter 3 sets up the relationship between different variables in our model. In our model, there exist infinite number of firms and households. Thus, chapter 4 presents the aggregate activity after observing the decisions of each firm and household. Chapter 5 sets up and solves the Ramsey problem. Chapter 6 concludes the thesis.

CHAPTER 2

THE MODEL ECONOMY

The model economy is characterized by monopolistic competition, adjustment costs on pricing and endogenous formal/informal decision. There is a continuum of agents whose total measure is normalized to one. Households consume different varieties of goods. In this environment, households save in not time contingent securities which allow them to smooth their income fluctuations due to technology shocks. Each agent either work in formal sector or in informal sector. We suppose a perfect labor market without any friction. Nominal wages adjust proportionally to money stock in the economy. We suppose that households supply labor inelastically. Moreover, there exists monopolistic competition in the production sector. Each firm produces a different variety of good by using labor and public capital if they operates in the formal sector. However, a firm in the informal sector produces its different good by only using labor.

Households

We use $c_t \equiv \int_0^1 [c_{it}^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ as a Dixit-Stiglitz aggregator of different varieties of goods. Households consume all different varieties of goods unless the price of that good is equal to zero. Households' optimal allocation of expenditure on different varieties of goods is given by $c_t(i) = (\frac{p_{it}}{p_t})^{-\epsilon} c_t$. In this environment, we use the $p_t \equiv \int_0^1 [(p_{it})^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ as the price index. Households might also invest in nominal bonds, b_t which pays a gross nominal interest rate $(1+r_t)$ one period later. There is a continuum of agents who choose a consumption path $(c_t)_{t=0}^{\infty}$ to maximize their following expected life time utility:

$$E_t\{\sum_{t=0}^{\infty}\beta^t\frac{c_t^{1-\sigma}}{1-\sigma}\}$$

where σ is the curvature parameter of the period utility function of consumption.

It is supposed that households supply labor inelastically h (which is normalized to 1). Each agent might benefit from the profits of the monopolistic sector which they own, Θ_t. Therefore, the following nominal budget constraint can be written:

$$p_tc_t+\frac{b_t}{1+r_t}\leq b_{t-1}+w_t^fn_t^f+w_t^in_t^i+p_t\Theta_t$$

In this environment households choose the set of processes $\{c_t,b_t\}_{t=0}^{\infty}$ taking as given the set of processes $\{p_t,w_t^f,w_t^i,r_t\}_{t=0}^{\infty}$ and the initial wealth b_0, in order to maximize their expected lifetime utility subject to nominal budget constraint. We define λ_t is the Langrange multiplier on nominal budget constraint.

The Households' Optimality Conditions

Households' expected maximization problem is subject to nominal budget constraints. Thus, we write the following Langrange problem in order to solve the optimal consumption level.

$$L=E_0\{\sum_{t=0}^{\infty}\beta^t\frac{c_t^{1-\sigma}}{1-\sigma}\}+E_0\{\sum_{t=0}^{\infty}\lambda_t\{b_{t-1}+w_t^fn_t^f+w_t^in_t^i-p_tc_t-\frac{b_t}{1+r_t}\}\}$$

Then, we get the following optimality conditions:

$$\beta^tc_t^{-\sigma}-\lambda_tp_t=0$$

$$-\lambda_t \frac{1}{1+r_t} + \lambda_{t+1} = 0$$

$$\beta^{t+1} c_{t+1}^{-\sigma} - \lambda_{t+1} p_{t+1} = 0$$

After some manipulation, we get the intertemporal Euler Equation. According to the optimality condition, households' consumption decision depends on the expectations of next period's price index. In other words, the change in the price index affects the consumption decision very substantially.

$$c_t^{-\sigma} = \beta(1+r_t) E_t\{c_{t+1}^{-\sigma} \frac{p_t}{p_{t+1}}\}$$

Optimality conditions imply that No-Ponzi condition on wealth is also satisfied.

Firms

In our model, we suppose that there are infinite number of heterogeneous firms. It is supposed that heterogeneous firms indexed by i are distributed on the unit interval and have a mass of 1.

The production sector acts as a monopolistic competitive sector which produces a differentiated good using labor as input and faces adjustment costs. In this model, we develop the optimization decision of firms choosing prices, p_{it}, number of employees, n_{it} and in which sector to produce. Moreover, in this model there are two sectors of production. Informal sector uses only labor to produce as a factor of production, while the formal sector uses public capital and labor to produce their differentiated good. In each period t, a firm decides whether to produce in a formal sector where the government raises taxes or an informal sector where it cannot do so.

Firms may have different nominal profits in each sector. That's why, they might compare their profits in order to decide whether to operate in the formal or in the informal sector.

In this model, heterogeneous firms produce different varieties of goods under monopolistic competitive sector. Firm heterogeneity comes from a productivity parameter, A_{it}, which is distributed across firms with cumulative distribution $G(i)$ with support $[A_l, A_u]$, where $0 < A_l < A_u < \infty$ in each period. A firm i observes its technology shock A_{it} and then decides in which sector to produce.

We suppose that $A_{it} g_t^{\alpha} (n_{it}^{f})^{1-\alpha}$ be the production function of a firm in the formal sector and $B(n_{it}^{i})^{1-\gamma}$ be the production function in the informal sector. Production functions in both sectors present decreasing returns to scale and are strictly increasing, strictly concave and satisfy Inada conditions on the factors of production.

In each period, after observing its shock A_{it}, firm i might decide optimal price to adjust and it compares the after tax profits obtained in the formal sector with the profits that would be obtained in the informal sector.

There exist infinite number of firms. In this thesis, we enforce the most productive firm to operate in the formal sector. In other words, we suppose that the most productive firm would always prefer the formal sector to the informal sector.

The Optimal Price Setting Problem

In monetary policy literature, optimal price maximizes the current market value of the profits generated while that price remains effective. Firms adjust an optimal price which maximizes the nominal profits while that price stay effective k periods. We adopt the similar logic, but follow a different approach. We allow firms to determine their optimal price in each period. In other words, we change the dynamic price setting problem as a static problem. In the following sections, firms' endogenous price adjustment decision is introduced. A firm i will choose the price p^*_{it} that maximizes the value of the profit. Formally, it solves the following problem (in nominal terms):

$$max_{p^*_{it}} \Pi_{it} = p^*_{it} y_{it} - \Psi_t(y_{it})$$

subject to the sequence of demand constraints

$$y_{it} = (\frac{p^*_{it}}{p_t})^{-\varepsilon} y_t$$

In the limiting case of no price rigidity, the dynamic optimal price decision collapses to the very familiar pricing equation, specifically, under flexible price case. The first order condition associated with the problem above takes the form:

$$p^*_{it} = \omega \psi_t$$

which can be interpreted as optimal price is equal to desired mark-up, $\omega \equiv \frac{\varepsilon}{\varepsilon - 1}$, and nominal marginal cost, $\psi_t \equiv \Psi'_t(y_{it})$. In our model, in production sector there exists a monopolistic competition which allows firms to adjust a price which is higher than nominal marginal cost. As expected, we find that optimal price is higher than the nominal marginal cost as mark-up times. In our model, mark-up is determined according to the elasticity of substitution between different varieties of goods. Elasticity of substitution, ε, determines the mark-up level.

Price Adjustment

In monetary policy literature, the existence of nominal stickiness requires the nominal variables to make real by using some index variables. In general terms, the aggregate price index, $p_t \equiv \int_0^1 [(p_{it})^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$, is used as a nominal anchor in New-Keynesian models. However, in this thesis we follow Andersen (2002). He uses the money stock as a nominal anchor in his striking model. By adding money stock as a nominal anchor in his model, Andersen allows policy makers to use an indirect channel to induce firms to operate in the formal sector. An indirect channel is required, since the implications of this thesis are much more related with emerging market economies. In developing economies policy makers' enforcement is a problematic issue to force firms into to the formal sector. For this reason, the importance of indirect channels in these economies can not be ignored. As a result, in this thesis, we use the money stock as the nominal anchor for optimal price setting. It is assumed that there is a fixed real cost of adjusting the price, c, due to the need for nominal price adjustment created by inflation and total factor productivity. After using the money stock as a nominal anchor, the real profit to firm i can be written as:

$$max_{p_{it}^*} \Pi_{it} = (\frac{p_{it}}{m_t} - \frac{w_t}{\mu_{it} m_t} - c) y_{it}$$

subject to the sequence of demand constraints

$$y_{it} = (\frac{p_{it}^*}{m_t})^{-\varepsilon} y_t$$

Then, we solve the optimal price setting problem. The following first order conditions present the optimal price:

$$(\varepsilon - 1)(\frac{1}{m_t})^{1-\varepsilon} p_{it}^{-\varepsilon} = (\frac{w_t}{\mu_{it} m_t} + c)\varepsilon(\frac{1}{m_t})^{-\varepsilon} p_{it}^{-\varepsilon-1}$$

The optimal price:

$$p_{it}^* = \frac{\varepsilon}{\varepsilon - 1}(\frac{w_t}{\mu_{it} m_t} + c)m_t$$

In this model, we focus on the nominal price stickiness and ignore the labor market frictions. Furthermore, in our model there exist two sectors of production and households can earn two different wages. We suppose that there are rational households, thus, two wages must be equal in two sectors. Otherwise, rational households do not supply labor to lower wage sector. For this reason, in two sectors it is assumed that nominal wages are proportional to the money stock to eliminate the nominal wage rigidity. It follows that $\frac{w_t}{m_t}$ is a constant, χ variable.

The optimal price for firm i is readily found to be

$$p_{it}^* = \frac{\varepsilon}{\varepsilon - 1}(\frac{\chi}{\mu_{it}} + c)m_t$$

where $\frac{\varepsilon}{\varepsilon - 1} > 1$ and μ_{it} is marginal productivity of a firm i. Therefore, optimal price depends on mark-up, the inverse of real marginal productivity times χ, constant real adjustment cost and money stock in the economy. The following sections present the role of money stock. Policy makers are motivated to use money stock tool to gives rise to direct firms to produce in the formal sector.

Static Problem

At each period a firm decides to produce its output either in formal sector or in informal sector. A firm faces a trade off between two sectors. Specifically, a firm might benefit from public capital at the cost of paying higher taxes in the formal sector. On the other hand, a firm might evade from paying high level taxes in informal sector. Hence, at each period a firm compares its profit formally and then decide to produce either in formal sector or in informal sector. Price adjustment decision is endogenous in formal sector. Each firm might decide either adjust its price or not after comparing the loss of having a nonoptimal price and the adjustment cost. However, we followed the formalism proposed by Calvo(1983), since firms in informal sector are homogeneous in terms of their productivity. Therefore, we suppose that some fraction of the firms may reset their price. In other words, each firm may reset its price with probability $1-\theta$, however, the other fraction keeps their prices unchanged.

A firm solves the following static problem in period t:

$$max\{V_{it}^f, V_{it}^i\}$$

where

$$V_{it}^f = max_{n_{it}^f}[(1-\tau)p_{it}A_{it}g_t^{\alpha}(n_{it}^f)^{1-\alpha} - w_t^f n_{it}^f]$$

and

$$V_{it}^i = max_{n_{it}^i}[(1-\rho\tau)p_{it}B(n_{it}^i)^{1-\gamma} - w_t^i n_{it}^i]$$

where V_{it}^f is the profit in formal sector and V_{it}^i is the profit in the informal sector.

Formal output is taxed by the government at an exogenous rate $\tau \in [0,1]$ which can only be partially enforced for informal output. Here ρ denotes the tax enforcement parameter measuring how well taxes are enforced in the informal sector.

In our model, firm heterogeneity comes from the productivity parameter, A_{it}. After observing their productivity parameter A_{it} firms decide in each period either to produce in formal sector or in informal sector. By solving the formal problem, we showed that it is possible to find out a threshold productivity level which determines the size of the formal/informal sector. By Envelope Theorem, we showed the existence of this threshold technology level.

Lemma 1: There exists a threshold technology level A_t^* such that firms endowed with technology $A_{it} \geq A_t^*$ enter into the formal sector, while firms endowed with $A_{it} \leq A_t^*$ do not enter into the formal sector.

There are heterogeneous firms in our model. Some firms are more productive than others. By $Lemma$ 1 we know that if the most productive firm produce in the informal sector, then all of the remaining firms will produce in the informal sector, however, that is not an interesting case for our model. We aim to increase the size of the formal sector by using monetary policy tools. In the extreme case, when the most productive firm produce in the informal sector, policy makers cannot induce firms to produce in the formal sector. For this reason, we suppose that the most productive firm in the economy would always prefer the formal to the informal sector. In other words, we enforce the most productive firm to produce in the formal sector. This is not an unrealistic assumption, because although this thesis is much more related with emerging market economies, it is not easy for the most productive firms to evade completely from taxes and to produce in the informal sector.

Flexible Prices

In this thesis, firms either adjust their prices or not. It depends on the comparison of profit loss when they do not adjust optimal price with the real adjustment cost. In this limiting case, we suppose that firms can adjust their prices without any frictions. In other words, firms immediately adjust their price when there exist a change either in real marginal cost or money stock at the cost of paying real adjustment cost. In this case, some of the aggregate output is wasted due to the real adjustment cost.

In this case, firms can adjust their prices after they observe the money stock perfectly. Therefore, optimal nominal price for firm i is

$$p_{it} = \omega(k_{it} + c)m_t.$$

where $\omega = \frac{\varepsilon}{\varepsilon - 1}$, $k_{it} = \frac{\chi}{\mu_{it}}$.

After determining their optimal price, firms might have to decide either to produce in the formal sector or in the informal sector. A firms sets up its nominal profit when it produces in the formal sector or in the informal sector and solves the maximization problem, $max\{V_{it}^f, V_{it}^i\}$, in order to decide in which sector to operate. In this limiting case, firms might adjust their prices without any constraint.

After adjusting its price, a firm determines its nominal profit in both sector. A firm might choose its labor. Labor demand is the second decision of a firm. The following equations represents the labor demand in both sector after observing its technology shock and adjusting its price. The following equation is the labor demand in the formal sector, n_{it}^f.

$$n_{it}^f = \left(\frac{(1-\alpha)(1-\tau)\omega c m_t A_{it} g_t^\alpha}{w_t^f - \frac{(1-\tau)\omega\chi m_t}{1-\alpha}}\right)^{\frac{1}{\alpha}}$$

The following equation represents the labor demand in the informal sector, n_{it}^i.

$$n_{it}^i = \left(\frac{(1-\gamma)(1-\rho\tau)\omega c m_t B}{w_t^i - \frac{(1-\rho\tau)\omega\chi m_t}{1-\gamma}}\right)^{\frac{1}{\gamma}}$$

Threshold Technology Level

After determining its labor demand in both sectors, a firms might set up and solve the maximization problem, $max\{V_{it}^{f}, V_{it}^{i}\}$. By Lemma 1, we represent that there exists always a threshold technology level A_t^* such that firms endowed with technology level $A_{it} \geq A_t^*$ enter into the formal sector, while firms endowed with technology level $A_{it} < A_t^*$ might operate in the informal sector. The unique solution of the maximization problem represents the threshold technology level.

$$A_t^* = \left(\frac{(1-\gamma)(1-\rho\tau)\omega cB}{\chi - \frac{(1-\rho\tau)\omega\chi}{1-\gamma}}\right)^{\frac{\alpha}{\gamma}}\left(\frac{\chi - \frac{(1-\tau)\omega\chi}{1-\alpha}}{(1-\alpha)(1-\tau)\omega c g_t^{\alpha}}\right)$$

Under the flexible price case, the threshold technology level only depends on the real parameters, nominal variables can not play an important role. Therefore, when there exists no nominal rigidity, as expected, policy makers might not induce or force firms to operate in the formal sector. However, the role of frictions in this environment is represented in the following section, but in this limiting case there exists no role for nominal variables. The findings in this thesis are consistent with the classical models when all firms are able to adjust their prices, the effects of nominal variables can be ignored.

Sticky Prices

In this thesis, the effects of nominal stickiness are investigated. If there exists a nominal stickiness, the policy makers might influence the aggregate activity in the economy. A firm might adjust its price, after observing the total factor productivity and money stock at each period. In this thesis, some of the firms might not adjust its price at any period. If a firm can not adjust its price, then monetary authority might affect the formal/informal decision of these firms by giving public capital incentive to formal firms at the cost of paying taxes.

Now, a firm i solves the following static problem in period t:

$$max\{V_{it}^{f}, V_{it}^{i}\}$$

where

$$V_{it}^{f} = max_{n_{it}^{f}}[(1-\tau)p_{it}A_{it}g_{t}^{\alpha}(n_{it}^{f})^{1-\alpha} - w_{t}^{f}n_{it}^{f}]$$

and

$$V_{it}^{i} = max_{n_{it}^{i}}[(1-\rho\tau)p_{it}B(n_{it}^{i})^{1-\gamma} - w_{t}^{i}n_{it}^{i}]$$

where $p_{it} = \omega(k_{it}+c)m_{t-1}$ and $m_t = (1+\pi_t)m_{t-1}$

The following equations represents the labor demand in both sectors after observing technology shocks. The following equation is the labor demand in the formal sector, n_{it}^{f}.

$$n_{it}^{f} = (\tfrac{(1-\alpha)(1-\tau)\omega(k_{it}+c)A_{it}g_{t}^{\alpha}}{\chi(1+\pi_t)})^{\frac{1}{\alpha}}$$

The following equation represents the labor demand in the informal sector, n_{it}^{i}.

$$n_{it}^{i} = (\tfrac{(1-\gamma)(1-\rho\tau)\omega(k_{it}+c)B}{\chi(1+\pi_t)})^{\frac{1}{\gamma}}$$

Threshold Technology Level

After determining its labor demand in both sectors, a firm might set up and solve the maximization problem, $max\{V_{it}^{f}, V_{it}^{i}\}$. By Lemma 1, we represent that there exists always a threshold technology level A_t^* such that firms endowed with technology level $A_{it} \geq A_t^*$ enter into the formal sector, while firms endowed with technology level $A_{it} < A_t^*$ might operate in the informal sector. The unique solution of the maximization problem represents the threshold technology level.

$$A_t^* = (\tfrac{(1-\gamma)(1-\rho\tau)\omega(k_{it}+c)B}{\chi(1+\pi_t)})^{\frac{\alpha}{\gamma}}(\tfrac{\chi(1+\pi_t)}{(1-\alpha)(1-\tau)\omega(k_{it}+c)g_t^{\alpha}})$$

Under the sticky price case, the threshold technology level depends on both the real and nominal parameters, nominal variables might play a very important role. Therefore, when there exists nominal rigidity, as expected, policy makers might induce or force firms to operate in the formal sector directly or indirectly. Many empirical studies imply that labor share in the informal sector is higher than the labor share in the formal sector, specifically $\alpha \geq \gamma$. Therefore, the positive rate of inflation starts to decrease the threshold technology level very substantially. It seems that very high level of positive inflation might be great for this economic environment, but it is not the case that since very high level of inflation decreases the labor demand which decreases the productivity of firms. In other words, there is a trade off between the producing in the formal sector by benefiting public capital and the cost of paying taxes.

Adjustment Cost

In our model adjusting prices is a costly process. At each period, after observing their technology shocks and money stock firms might determine their optimal price which depends on the mark-up, real marginal cost and money stock. On the other hand, in our model there exists a real adjustment cost. For this reason, firms have to decide either to have an optimal price at the cost of real adjustment cost or not. In other words, firms have to compare the cost of having a non optimal nominal price relative to the cost of adjusting the price.

Second Order Approximation

We use the second order approximation to compare the profit loss of a firm when it does not have an optimal price. We use the p_i to show the previous price and p_i^* to show the optimal price. In this case, k_i represents real marginal cost of the firm. We write profit as a function of the $\frac{p_i}{m}$ and k_i. Formally, we solve the following second order approximation. By this method, we determine which firms might reset their price and which firms might not. Firms might weight of setting non optimal price relative to real adjustment cost.

$$V(\tfrac{p_i}{m}, k_i) = V(\tfrac{p_i^*}{m}, k_i) + V'(\tfrac{p_i^*}{m})(\tfrac{p_i}{m} - \tfrac{p_i^*}{m}) + \tfrac{1}{2}V''(\tfrac{p_i}{m})(\tfrac{p_i}{m} - \tfrac{p_i^*}{m})^2$$

Hence;

$$V(\tfrac{p_i^*}{m}, k_i) - V(\tfrac{p_i}{m}, k_i) = -\tfrac{1}{2}V''(\tfrac{p_i}{m})(\tfrac{p_i}{m} - \tfrac{p_i^*}{m})^2 = \phi(\tfrac{p_i}{m} - \tfrac{p_i^*}{m})^2 < c$$

The firm decides not to change its price if its profit loss less than the real adjustment cost. Otherwise, it is more profitable for firms to adjust their prices. By analysing second order approximation, we determine the fraction of firms which might reset their prices and which not.

$$\phi(\frac{p_i}{m} - \frac{p_i^*}{m})^2 < c$$

In the informal sector, we suppose that firms have common productivity. Firms in the informal sector are homogeneous. Therefore, we suppose that θ fractions of the firms have sticky prices, and they might not adjust their prices. On the other hand, $1-\theta$ fraction of the firms might adjust their prices. Therefore, the optimal price setting problem for a firm which might operate in the informal sector can be written in the following way:

$$max_{p_{it}^*}\Pi_{it} = \sum_{t=0}^{\infty} \theta^k E_t\{Q_{t,t+k}(p_{it}^* y_{it,t+k} - \Psi_{t+k}(y_{t+kIt})\}$$

subject to the sequence of demand constraints

$$y_{it} = (\frac{p_{it}^*}{p_t})^{-\varepsilon} y_t$$

The optimal price for a firm in the informal sector represented in the following way:

$$p_{it}^* = \omega\psi_t$$

where $Q_{t,t+k} \equiv \beta^k(\frac{c_{t+k}}{c_t})^{-\sigma}(\frac{p_t}{p_{t+k}})$ is the stochastic discount factor, $\omega \equiv \frac{\varepsilon}{\varepsilon-1}$ and $\psi_t \equiv \Psi_t'(y_{it})$ denotes the nominal marginal cost in period t.

There is a randomness in the price adjustment mechanism of informal sector. However, formal firms might decide to adjust their prices or not by comparing their profit loss with the adjustment cost. Therefore, informal firms might formally find the optimal price which maximizes the expected profit while that price remains effective.

Monetary Policy

We suppose that monetary policy is conducted as a nominal interest rate reaction function. Several monetary policy reaction functions consider the deviations from target levels. We also define reaction function as deviations from steady state levels of inflation and aggregate output level. Moreover, for the aggregate output level we also consider the deviations from the potential output level which is computed when the economy uses its all resources in the formal sector. In other words, potential output is the maximum level which can be found out when all the resources are operated in the formal sector. It is extremely important for the policy makers to induce firms to operate in the formal sector which is a more productive sector. Thus, policy makers should react to deviations from the potential output level.

We suppose an interest rate rule of the form:

$$log(\frac{r_t}{r}) = \phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{y_t}{y})$$

with undated variables denoting the steady state values of the corresponding variables, ϕ_π is the coefficient of inflation and ϕ_y is the smoothing coefficient of output.

Numerically, we search for the specification of $\{\phi_y, \phi_\pi\}$ that maximizes household's welfare.

The Government

In this thesis, the government spending plays a very important role, since in most models government spending might be wasted. However, we use the government spending as a channel to increase the number of firms in the formal sector. Government spending compensates the cost of adjusting price. Many sectoral shocks requires the adjustment of relative prices due to the fact that firms might need to adjust their prices, but the adjustment cost decreases the incentive to adjust prices. At that time, the government can play a very important role. The government collects taxes. If tax revenue is used to increase the productivity in the formal sector, firms might compensate their adjustment costs, at the same time, choose to operate in the formal sector. We assume that the government can commit itself to a given policy so we do not analyse commitment issues.

In the model economy, the government collects tax. The government's period budget constraint is as follows:

$$g_t = \tau \int A_{it} g_t^{\alpha} (n_{it}^{f})^{1-\alpha} + \rho\tau \int B (n_{it}^{i})^{1-\gamma} + \frac{m_t - m_{t-1}}{p_t}$$

The seigniorage and formal tax revenue increase the productivity in the formal sector. That's why, inflation can not always be really bad thing for emerging market economies. In these economic environments, policy makers need indirect channels to control the firms in the formal sector.

CHAPTER 3

COMPARATIVE STATISTICS

Several variables affect the size of the formal and informal sector. In this chapter, we investigate the relationship between different variables and threshold technology level.

The Threshold Technology Level And Public Good

First of all, we looked into the effects of government spending on the threshold technology level. Government spending gives rise to trade off for firms to either produce in formal sector or in informal sector. The following equation implies that there is negative relationship between the size of the informal sector and government spending which means that when public good increases the size of the informal sector decreases. Government spending can be increased by tax revenue and seigniorage revenue which gives an incentive to monetary authority to increase the money stock.

$$\frac{dA_t^*}{dg_t} < 0$$

The Threshold Technology Level And Informal Sector Productivity

Secondly, we determine the relationship between the informal sector common productivity level and threshold technology level. As expected, we showed that there exists a positive relationship between threshold technology level and informal sector common productivity level. In other words, when the productivity of informal sector increases, the number of firms in the informal sector also increases.

$$\frac{dA_t^*}{dB} > 0$$

The Threshold Technology Level And Enforcement Rate

Thirdly, we investigate the relationship between the threshold technology level and tax enforcement rate. When the enforcement rate increases the number of the firms in the informal sector, on the other hand, decreases due to the fact that increase in tax enforcement gives firms an incentive to produce in the formal sector and to benefit from public capital.

$$\frac{dA_t^*}{d\rho} < 0$$

The following graph represents the effects of tax enforcement on the threshold technology level. When the tax enforcement starts to increase, the threshold technology level starts to decrease which implies that the number of firms in the informal sector decreases.

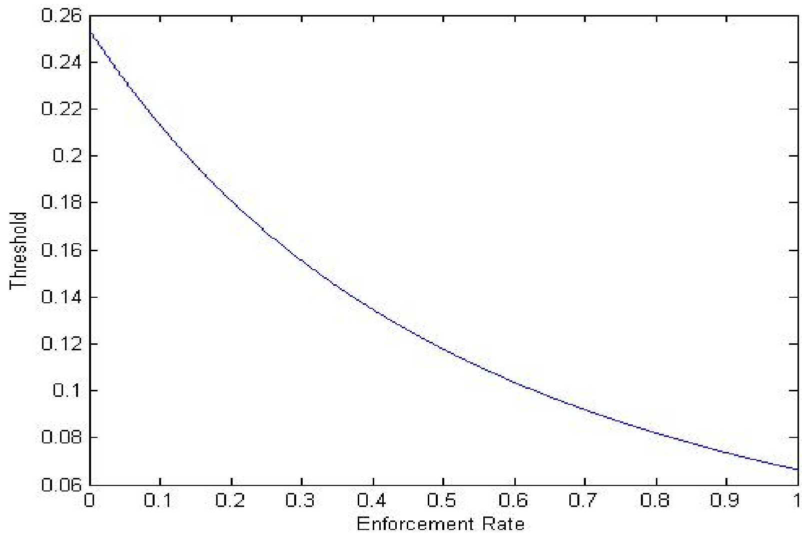

Figure 1: The relationship between the threshold technology level and enforcement rate

The Threshold Technology Level And Inflation Rate

The main aim of this thesis to create an indirect channel for policy makers which induce firms to produce in formal sector due to the fact that our thesis is much more related to emerging market economies where policy makers cannot fully enforce firms to produce in the formal sector. Therefore, policy makers need indirect channels to give firms an incentive to produce in the formal sector. The following equation represents the relationship between the threshold technology level and the inflation rate. Many empirical studies imply that α is greater than γ, which means that the share of labor in the informal sector is greater than the share of labor in the formal sector. Then, we find a negative relationship between the inflation rate and the threshold technology level. In other words, when the inflation rate increases, the size of the informal sector decreases because of the fact that high levels of inflation decreases labor demand very substantially which decreases the productivity of the firms. Therefore, positive rate of inflation gives rise to an increase in the number of firms in the formal sector.

$$\frac{dA_t^*}{d\pi_t} < 0$$

The following graph represents the relationship between the inflation rate and the threshold technology level. Positive rate of inflation increases the number of firms in the formal sector. Main contribution of this thesis is to use government spending as a way to increase the number of firms in the formal sector. Government might increase its revenue by seigniorage revenue, then use this spending to increase the productivity of firms in the formal sector.

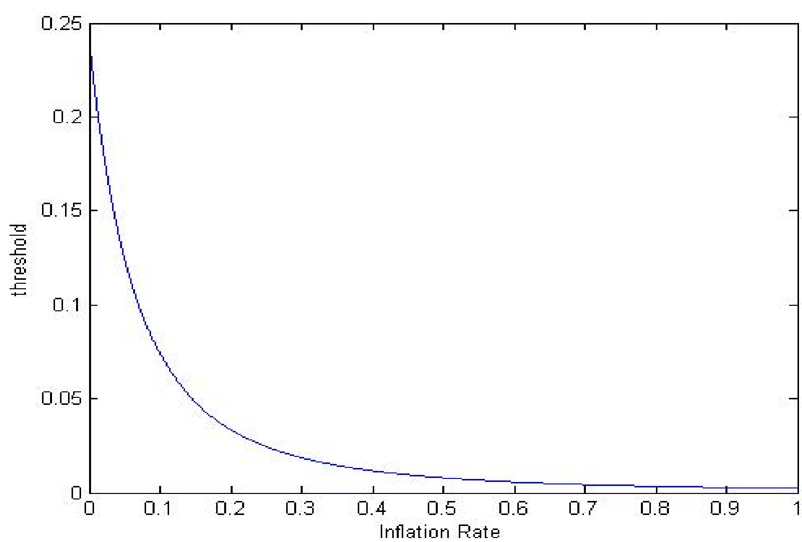

Figure 2: The relationship between the threshold technology level and inflation rate

The Threshold Technology Level And The Elasticity of Substitution

There exists also a relationship between the constant elasticity of substitution and the threshold technology level. We find that there is a positive relationship between the threshold and elasticity of substitution which implies that when elasticity of substitution increases, the number of firms in the formal sector decreases.

$$\frac{dA_t^*}{d\epsilon} > 0$$

CHAPTER 4

AGGREGATE ACTIVITY

In our model, there are infinite number of firms and a continuum of households. Firms determine their optimal price, labor demand, price adjustment decision and in which sector to produce. They produce different varieties of goods and households consume different goods. There is always demand for each good unless the price of that good is equal to zero. Each agent's decision affects the aggregate activity level. Firms produce according to the demand. Therefore, in this chapter we focus on the aggregate activity. Specifically, we focus on the relationship between aggregate output level and inflation rate.

Turning to aggregate activity we find a nonlinear relationship between aggregate activity and inflation.

We find two threshold technology levels, suppose that A_1^* is the threshold technology level for firm which cannot adjust its price and A_2^* is the threshold technology level form the firm which can adjust its price.

Aggregate output is obtained by aggregating production of individual firms and by subtracting the resources wasted into the cost of adjusting prices.

$$\begin{aligned} y_t = &\int_{A_l}^{A_2^*} B(n_{it}^i)^{1-\gamma} dG(A_{it}) + \int_{A_2^*}^{D} A_{it} g_t^{\alpha} (n_{it}^f)^{1-\alpha} dG(A_{it}) + \\ &\int_{D}^{A_1^*} B(n_{it}^i)^{1-\gamma} dG(A_{it}) + \int_{A_1^*}^{A_u} A_{it} g_t^{\alpha} (n_{it}^f)^{1-\alpha} dG(A_{it}) \\ &- \int_{D}^{A_u} c y_{it} dG(A_{it}) \end{aligned}$$

After determining the fraction of firms which adjust their price or not, by using the equilibrium conditions we write the demand equations instead of supply equation.

$$y_t = \frac{1}{1-\rho\tau}\{\int_{A_l}^{A_2^*}(\omega(k_{it}+c))^{-\varepsilon}dG(A_{it}) + \int_{D}^{A_1^*}(\frac{\omega(k_{it}+c)}{1+\pi_t})^{-\varepsilon}dG(A_{it})\} + \frac{1}{1-\tau}\{\int_{A_2^*}^{D}(\omega(k_{it}+c))^{-\varepsilon}dG(A_{it}) + \int_{A_1^*}^{A_u}(\frac{\omega(k_{it}+c)}{1+\pi_t})^{-\varepsilon}dG(A_{it})\} - \int_{D}^{A_u} cy_{it}dG(A_{it})$$

The following graph clarifies the relationship between aggregate output and inflation rate:

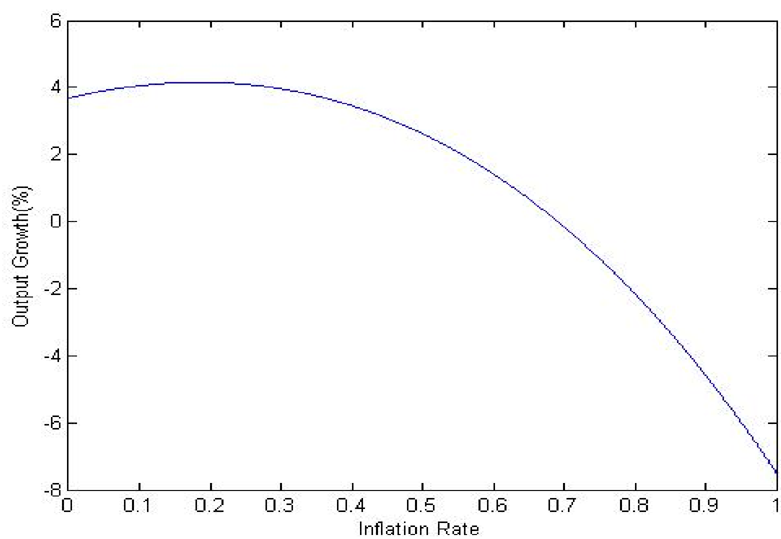

Figure 3: The relationship between the aggregate output and inflation rate

Equilibrium Conditions

1. Households maximizes lifetime utility subject to nominal budget constraint taking b_0 as given. Hence, Euler condition:

$$c_t^{-\sigma} = \beta(1+r_t)E_t\{c_{t+1}^{-\sigma}\frac{p_t}{p_{t+1}}\}$$

2. Each firm solves,

$$max\{V_{it}^f, V_{it}^i\}$$

3. The sequence of threshold technology level is determined by:

$$V_{it}^f \geq V_{it}^i, \forall_t$$

4. Each firm solves the following problem to determine its optimal price in any period,

$$max_{p_{it}^*}\Pi_{it} = (\frac{p_{it}}{m_t} - \frac{w_t}{\mu_{it}m_t} - c)y_{it}$$

subject to the sequence of demand constraints

$$y_{it} = (\frac{p_{it}^*}{m_t})^{-\varepsilon}y_t$$

5. We suppose that there is exogenous government expenditure financed through taxation. Hence, the government satisfies the following condition,

$$g_t = \tau\int A_{it}g_t^{\alpha}(n_{it}^f)^{1-\alpha} + \rho\tau\int B(n_{it}^i)^{1-\gamma} + \frac{m_t - m_{t-1}}{p_t}$$

6. The resource constraint can be written as follows:

$$y_t = c_t + g_t$$

and

$$(1-\tau)y_{it} = c_{it} = (\frac{p_{it}}{m_t})^{-\varepsilon}y_t$$

or

$$(1-\rho\tau)y_{it} = c_{it} = (\frac{p_{it}}{m_t})^{-\varepsilon} y_t$$

7. We assume zero total net supply of bonds. Hence, the bonds market clears:

$$b_t^s = b_t^d, \forall_t$$

8. The labor market clears:

$$n_t^f = \int n_{it}^f dG(A_i) + \int n_{it}^f dG(A_i)$$

$$n_t^i = n_{it}^i dG(A_i)$$

$$n_t^f + n_t^i = T$$

9. The firm has to weight the cost of having a nonoptimal nominal price relative to the cost of adjusting the price. The firm decides not to change its price if

$$\phi(\frac{p_{it}}{m_t} - \frac{p_{it}^*}{m_t})^2 < c$$

CHAPTER 5

OPTIMAL MONETARY POLICY

We constructed optimal policy by constrained Ramsey plan. In other words, the monetary authority maximizes the agents' welfare subject to supposed monetary policy rule and the equilibrium relations.

We firstly define the Ramsey problem and then we solve optimal rate of inflation which maximizes the agents' consumption level. The policy makers formally solve the following Ramsey problem.

Definition: $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}, \lambda_{6,t}\}_{t=0}^{\infty}$ represent sequence of Langrange multipliers on the constrains.

Choose $\Lambda_t = \{c_t, n_t^f, n_t^i, \pi_t\}_{t=0}^{\infty}$

$$L = max_{\{\Lambda_t\}_{t=0}^{\infty}} E_0\{\sum_{t=0}^{\infty} \beta^t \{\frac{c_t^{1-\sigma}}{1-\sigma} + \lambda_{1,t}[y_t - c_t + g_t] + \lambda_{2,t}[g_t - \tau \int A_{it} g_t {n_t^f}^{\alpha} +$$
$$\rho\tau \int B {n_t^i}^{\gamma}] + \lambda_{3,t}[c_t^{-\sigma} - \beta(1+r_t)E_t\{c_{t+1}^{-\sigma}\frac{p_t}{p_{t+1}}\}] + \lambda_{4,t}[(1-\tau)A_{it}^* f(n_t^f, g_t) -$$
$$(1-\rho\tau)B(n_t^i)] + \lambda_{5,t}[log(\frac{r_t}{r}) - \phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{y_t}{y})] +$$
$$\lambda_{6,t}[c - \phi(\frac{p_{it}}{m_t} - \frac{p_{it}^*}{m_t})^2]\}$$

Langrange multiplier $\lambda_{1,t}$ is related to resource constraint. In equilibrium, aggregate output must be equal to consumption and government spending.

The second constraint is government spending. In our model, we don't analyse any commitment issue. We suppose that government commit itself.

The constraint related to $\lambda_{3,t}$ is inter temporal Euler condition. In equilibrium, households' optimality condition must hold.

The restriction related to $\lambda_{4,t}$ indicates the sequence of threshold technology level is determined by $max\{V_{it}, V_{it}^{inf}\}$.

The restriction related to $\lambda_{5,t}$ indicates the monetary policy rule of the central bank.

$\lambda_{6,t}$ represents the endogenous price adjustment decision. Firms might compare their profit loss with the real adjustment cost. Each firm might adjust its price if its profit loss is higher than real adjustment cost.

We show that positive rate of inflation increases the aggregate economic activity under the presence of informal sector by Ramsey problem. The solution of the maximization problem implies that positive rate of inflation which is optimal increase the efficiency of the price mechanism.

CHAPTER 6

CONCLUDING REMARKS

In this thesis we study optimal monetary policy under the presence of informality in a context where firms are heterogeneous in their productivity. Each firm might chose to operate either in the formal sector, thereby enjoying public capital in production at the cost of paying taxes, or in the informal sector where it only pays a fraction (depending on tax enforcement) of taxes levied on the formal sector. We develop a general equilibrium model that includes rigidities in price decisions. Each firm may reset its price in any given period. The optimal price for a firm depends on mark-up, real marginal cost, money stock and real marginal price adjustment cost. In each period, a firm observes its technology shock and then decides in which sector to produce. It is obvious that technology shocks affects firms' marginal cost which will affect their price decisions. On the other hand, we use the money stock as the nominal anchor. Therefore, unexpected changes in money stock or changes after the price adjustment affects firms' formal/informal sector decisions.

There exists two channels in our model to give firms an incentive for the price adjustment: the first one is real marginal cost shocks due to the productivity shocks and the second one is the nominal shocks due to the unexpected changes in money stock. When monetary authority change the money stock unexpectedly, this gives the incentive to change nominal prices, since unexpected changes in money stock requires the adjustment of relative prices. Consideration of two channels for the incentive to adjust prices allows us to compare the relative importance of different policies for understanding the economic effects of real shocks and nominal shocks. In this thesis, we focus on the effects of nominal shocks. Moreover, firm heterogeneity in terms of their productivity allows us to determine the threshold technology level such that firms having a productivity below (above) this level chose to operate in the informal (formal) sector.

We have shown that inflation might increase the efficiency of price mechanism. In our model it is possible to give price adjustment incentive by real cost shocks due to productivity shock and unexpected change in money stock. Firms tries to handle real shocks by price adjustment. The government spending plays a very important role, since in most models government spending might be wasted. However, we use the government spending as a channel to increase the number of firms in the formal sector. Government spending compensates the cost of adjusting price. Many sectoral shocks requires the adjustment of relative prices due to the fact that firms might need to adjust their prices, but the adjustment cost decreases the incentive to adjust prices. At that time, the government can play a very important role. The government collects taxes. If tax revenue is used to increase the productivity in the formal sector, firms might compensate their adjustment costs, at the same, choose to operate in the formal sector. We assume that the government can commit itself to a given policy so we do not analyse commitment issues.

In this thesis, the effects of nominal stickiness are investigated. If there exists a nominal stickiness, the policy makers might influence the aggregate activity in the economy. A firm might adjust its price, after observing the total factor productivity and money stock at each period. In this thesis, some of the firms might not adjust its price at any period. If a firm can not adjust its price, then monetary authority might affect the formal/informal decision of these firms by giving public capital incentive to formal firms at the cost of paying taxes.

In our model, we suppose that there exists fixed real adjustment cost. We will extend this model by using symmetric and asymmetric adjustment cost functions. We'll adapt the Varian's(1974) function:

$$\Gamma_t^i = \Gamma(\frac{p_{it}}{p_{i,t-1}}) = \phi(\frac{exp(-\psi(\frac{p_{it}}{p_{i,t-1}}-1))+\psi(\frac{p_{it}}{p_{i,t-1}}-1)-1}{\psi^2})$$

where ϕ and ψ are cost parameters.

We will firstly try to determine the effects of different real adjustment cost functions on our model. Then, we will suppose different real adjustment cost functions for different sectors. In our model, there are two sectors. It might be interesting to determine the impacts of asymmetric real adjustment costs on our model's main implications.

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