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Essays on Optimal Fiscal and Monetary Policies

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Résumé

Cette thèse se compose de trois articles sur les politiques budgétaires et monétaires optimales. Dans le premier article, J'étudie la détermination conjointe de la politique budgétaire et monétaire optimale dans un cadre néo-keynésien avec les marchés du travail frictionnels, de la monnaie et avec distortion des taux d'imposition du revenu du travail. Dans le premier article, je trouve que lorsque le pouvoir de négociation des travailleurs est faible, la politique Ramsey-optimale appelle à un taux optimal d'inflation annuel significativement plus élevé, au-delà de 9.5%, qui est aussi très volatile, au-delà de 7.4%. Le gouvernement Ramsey utilise l'inflation pour induire des fluctuations efficaces dans les marchés du travail, malgré le fait que l'évolution des prix est coûteuse et malgré la présence de la fiscalité du travail variant dans le temps. Les résultats quantitatifs montrent clairement que le planificateur s'appuie plus fortement sur l'inflation, pas sur l'impôts, pour lisser les distorsions dans l'économie au cours du cycle économique. En effet, il ya un compromis tout à fait clair entre le taux optimal de l'inflation et sa volatilité et le taux d'impôt sur le revenu optimal et sa variabilité. Le plus faible est le degré de rigidité des prix, le plus élevé sont le taux d'inflation optimal et la volatilité de l'inflation et le plus faible sont le taux d'impôt optimal sur le revenu et la volatilité de l'impôt sur le revenu. Pour dix fois plus petit degré de rigidité des prix, le taux d'inflation optimal et sa volatilité augmentent remarquablement, plus de 58% et 10%, respectivement, et le taux d'impôt optimal sur le revenu et sa volatilité déclinent de façon spectaculaire. Ces résultats sont d'une grande importance étant donné que dans les modèles frictionnels du marché du travail sans politique budgétaire et monnaie, ou dans les Nouveaux cadres keynésien même avec un riche éventail de rigidités réelles et nominales et un minuscule degré de rigidité des prix, la stabilité des prix semble être l'objectif central de la politique monétaire optimale. En l'absence de politique budgétaire et la demande de monnaie, le taux d'inflation optimal tombe très proche de zéro, avec une volatilité environ 97 pour cent moins, compatible avec la littérature. Dans le deuxième article, je montre comment les résultats quantitatifs impliquent que le pouvoir de négociation des travailleurs et les coûts de l'aide sociale de règles monétaires sont liées négativement. Autrement dit, le plus faible est le pouvoir de négociation des travailleurs, le plus grand sont les coûts sociaux des règles de politique monétaire. Toutefois, dans un contraste saisissant par rapport à la littérature, les règles qui régissent à la production et à l'étroitesse du marché du travail entraînent des coûts de bien-être considérablement plus faible que la règle de ciblage de l'inflation. C'est en particulier le cas pour la règle qui répond à l'étroitesse du marché du travail. Les coûts de l'aide sociale aussi baisse remarquablement en augmentant la taille du coefficient de production dans les règles monétaires. Mes résultats indiquent qu'en augmentant le pouvoir de négociation du travailleur au niveau Hosios ou plus, les coûts de l'aide sociale des trois règles monétaires diminuent significativement et la réponse à la production ou à la étroitesse du marché du travail n'entraîne plus une baisse des coûts de bien-être moindre que la règle de ciblage de l'inflation, qui est en ligne avec la littérature existante. Dans le troisième article, je montre d'abord que la règle Friedman dans un modèle monétaire avec une contrainte de type cash-in-advance pour les entreprises n'est pas optimale lorsque le gouvernement pour financer ses dépenses a accès à des taxes à distorsion sur la consommation. Je soutiens donc que, la règle Friedman en présence de ces taxes à distorsion est optimale si nous supposons un modèle avec travaie raw-efficace où seule le travaie raw est soumis à la contrainte de type cash-in-advance et la fonction d'utilité est homothétique dans deux types de main-d'oeuvre et séparable dans la consommation. Lorsque la fonction de production présente des rendements constants à l'échelle, contrairement au modèle des produits de trésorerie de crédit que les prix de ces deux produits sont les mêmes, la règle Friedman est optimal même lorsque les taux de salaire sont différents. Si la fonction de production des rendements d'échelle croissant ou decroissant, pour avoir l'optimalité de la règle Friedman, les taux de salaire doivent être égales.

Mots clés: Frictions de marché du travail; La rigidité des prix; La stabilité des prix; Taux d'inflation optimal et sa volatilité; Les coûts de l'aide sociale de règles monétaires; La règle de Friedman

Abstract

This dissertation consists of three essays on optimal fiscal and monetary policies. In the first two essays, I consider New Keynesian frameworks with frictional labor markets, money and distortionary income tax rates. In the first one, I study the joint determination of optimal fiscal and monetary policy and the role of worker's bargaining power on this determination. In the second one, I study the effects of worker's bargaining power on the welfare costs of three monetary policy rules, which are: strict inflation targeting and simple monetary rules that respond to output and labor market tightness, with and without interest-rate smoothing. In the third essay, I study the optimality of the Friedman rule in monetary economies where demand for money is motivated by firms, originated in a cash-in-advance constraint.

In the first essay, I find that when the worker's bargaining power is low, the Ramsey-optimal policy calls for a significantly high optimal annual rate of inflation, in excess of 9.5%, that is also highly volatile, in excess of 7.4%. The Ramsey government uses inflation to induce efficient fluctuations in labor markets, despite the fact that changing prices is costly and despite the presence of time-varying labor taxes. The quantitative results clearly show that the planner relies more heavily on inflation, not taxes, in smoothing distortions in the economy over the business cycle. Indeed, there is a quite clear trade-off between the optimal inflation rate and its volatility and the optimal income tax rate and its variability. The smaller is the degree of price stickiness, the higher are the optimal inflation rate and inflation volatility and the lower are the optimal income tax rate and income tax volatility. For a ten times smaller degree of price stickiness, the optimal rate of inflation and its volatility rise remarkably, over 58% and 10%, respectively, and the optimal income tax rate and its volatility decline dramatically. These results are significant given that in the frictional labor market models without fiscal policy and money, or in the Walrasian-based New Keynesian frameworks with even a rich array of real and nominal rigidities and for even a miniscule degree of price stickiness, price stability appears to be the central goal of optimal monetary policy. Absent fiscal policy and money demand frictions, optimal rate of inflation falls to very near zero, with a volatility about 97 percent lesser, consistent with the literature.

In the second essay, I show how the quantitative results imply that worker's bargaining weight and welfare costs of monetary rules are related negatively. That is, the lower the bargaining power of workers, the larger the welfare losses of monetary rules. However, in a sharp contrast to the literature, the rules that respond to output and labor market tightness feature considerably lower welfare costs than the strict inflation targeting rule. This is specifically the case for the rule that responds to labor market tightness. The welfare costs also remarkably decline by increasing the size of the output coefficient in the monetary rules. My findings indicate that by raising the worker's bargaining power to the Hosios level and higher, welfare losses of the three monetary rules drop significantly and response to output or market tightness does not, anymore, imply lower welfare costs than the strict inflation targeting rule, which is in line with the existing literature.

In the third essay, I first show that the Friedman rule in a monetary model with a cash-in-advance constraint for firms is not optimal when the government to finance its expenditures has access to distortionary taxes on consumption. I then argue that, the Friedman rule in the presence of these distorting taxes is optimal if we assume a model with raw-efficient labors where only the raw labor is subject to the cash-in-advance constraint and the utility function is homothetic in two types of labor and separable in consumption. Once the production function exhibits constant-returns-to-scale, unlike the cash-credit goods model that the prices of both goods are the same, the Friedman is optimal even when wage rates are different. If the production function has decreasing or increasing-returns-to-scale, then to have the optimality of the Friedman rule, wage rates should be equal.

Keywords: **Labor Market Frictions; Price Rigidity; Price Stability; Optimal Inflation Rate and Volatility; Welfare Costs of Monetary Rules; The Friedman Rule**

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Introduction

Monetary and fiscal policies are central tools of macroeconomic management. Over the past two decades, there has been a very large literature on optimal fiscal and monetary policies in the context of New Keynesian models, which have become the workhorse for the analysis of the business cycles, monetary policy, fiscal policy, and inflation. The common finding of all these studies implies an optimal inflation volatility that is zero or close to zero, due to the presence of price adjustment costs, when the fiscal authorities raise revenue either by lump sum taxes or by distorting taxes. In this literature, even for a miniscule degree of price stickiness that is for example ten times below available empirical estimates, the optimal volatility of inflation remains still near zero. What is, however, absent in most of these models is the existence of involuntary unemployment which is, perhaps, the most unpleasant feature of modern advanced economies. This has been particularly the case since the onset of the Great Recession in 2008. To be sure, recently, there has been an outburst of papers studying optimal monetary policy in the context of DSGE frameworks with frictional labor markets and sticky prices. But a central characteristic of all those papers is that optimal policy is derived in environments where fiscal policy is ignored and the government is assumed to have a fiscal budget constraint that is balanced at all times due to the presence of lump-sum taxation. However, assuming such an assumption not only is empirically unrealistic but also undermines a potentially significant role of monetary policy in stabilization of costly aggregate fluctuations around a distorted steady-state equilibrium. And also as the recent global financial crisis and its aftermath rocked the advanced economies, the tenability of ignoring fiscal policy has been strained.

Therefore, in the first two essays, I extend the Canonical New Keynesian model and allow for search and matching frictions, money, and distortionary labor income taxes and then study Ramsey-optimal policy and simple monetary policy rules. The general equilibrium search and matching model incorporates a labor force participation decision and uses the "instantaneous hiring" view of transitions between search unemployment and employment, such that newly hired workers start to work right away without any delay. Several studies have recently confirmed that this type of timing is consistent with the U.S. labor market flows at a quarterly frequency. It also has recently become common in models with frictional labor markets (see, e.g., Blanchard and

Gali (2010) and Arseneau and Chugh (2012) among many others). My motivation behind considering distorting labor income taxes comes from the fact that several researchers find that adding tax-style wedges to the business cycle models enable them to fit the U.S. business cycle data well. For example, Chari et al. (2007) find that the efficiency and labor wedges together account for essentially all of the fluctuations in the U.S. data. Ohanian (2010) also shows that, even during the recent great recession, the role of the labor wedge was greater than normal. Price adjustment costs are introduced a la Rotemberg (1982), by assuming that firms face a convex cost of price adjustment. Money friction demands are introduced into the model via cash-in-advance constraints in such a way that holding liquidity balances facilitates the household's ability to purchase consumption goods and the firm's ability to pay for the wage bill. Motivating a working capital constraint for firms comes from the facts that more than 60 percent of M1 in industrialized economies is held by firms. The models' fluctuations are conditional on exogenous government expenditure and productivity processes, each of which is calibrated to US data. The key mechanism underlying the main results in the first two essays stems from the interaction between the existence of a fiscal policy, in fact the absence of lump-sum taxation, and low bargaining power on the part of workers.

To ascertain the roles of labor market frictions and of fiscal policy in inducing optimal Ramsey dynamics, in the first essay, I simulate four different economies: the baseline model with money and with search and matching frictions and labor income taxes (baseline monetary model); the baseline monetary model without money and fiscal policy; the baseline monetary model without labor market frictions (New-Keynesian monetary model), and the Canonical New-Keynesian model. The main result is that in the baseline monetary model and once the worker's bargaining power is low, the Ramsey-optimal inflation rate is very high and very volatile over the business cycle, orders of magnitude more volatile and higher than the optimal inflation rate in the other three models. The labor market dynamics induced by optimal policy in the baseline model are vastly different from their counterparts in the no fiscal-policy model. More specifically, for the baseline calibration, the optimal policy features an inflation rate that is 9.6 percent per year with a volatility of 7.4 percent. On the fiscal part, optimal fiscal policy is characterized by a highly volatile income tax rate, 30%, with a volatility of 5.5%. Once I reduce the degree of price stickiness, I find a clear trade off between the optimal rate of inflation and its volatility and the optimal rate of labor income tax and its fluctuations. The smaller is the degree of price stickiness, the higher are the optimal inflation rate and inflation volatility and the lower are the optimal income tax rate and income tax volatility. The Ramsey government can thus be understood as using inflation volatility to ensure efficient labor market fluctuations, despite the fact that prices are sticky and changing them are costly. Another important result is that even in the presence of labor tax rates and in spite of the costly price adjustments, the Ramsey government finds it optimal to rely on inflation, not tax volatility, in order to induce efficient fluctuations in the labor market.

In the second essay, and in the context of the same macroeconomy model as in the first essay, I show that, in contrast to the conventional wisdom, despite the presence of price adjustment costs, once workers bargaining weight is low, strict inflation targeting is remarkably welfare detrimental. At the same time the monetary rule that responds to output or labor market tightness yields significantly lower welfare costs than the monetary rule that just targets inflation. I first compute the welfare costs of strict inflation targeting and a rule that responds to output in the context of the baseline monetary model without search and matching frictions. In line with the existing literature, I find that strict inflation targeting delivers a welfare level that is virtually identical to the one obtained under the Ramsey-optimal policy and response to output is always welfare detrimental. I then show that in the presence of labor market frictions and once the worker's bargaining power is low, while strict inflation targeting is significantly welfare detrimental, responding to labor market tightness or output can be considerably welfare improving compared to responding only to inflation. This is specifically the case for the market tightness targeting. The numerical results indicate that welfare losses associated with the rule that responds to the labor market tightness are more than 95% lower than the welfare losses associated with the strict inflation targeting rule. I also show that by raising the worker's bargaining power to the Hosios level and higher, welfare losses of the monetary rules drop significantly and response to output or market tightness does not, anymore, imply lower welfare costs than the strict inflation targeting rule, which is in line with the existing literature.

The third essay (revision requested by the International Journal of Central Banking) deals with the optimality of the Friedman rule, which is one of the most celebrated propositions in modern monetary economics, in a DSGE model where a money demand by firms is motivated. Based on this rule, the nominal interest rate should be zero. Studying the optimality of the Friedman rule has become more important, recently, due to the situation that the central banks around the world are confronted with. There have been many papers on the optimality of the Friedman rule under different situations and assumptions. However, almost all of them has restricted their attention to the case that it is only households that obtain a service flow from holding money. While, based on the evidence, two-thirds of M1 in industrialized economies are held by firms. Therefore, I study the optimality of the Friedman rule in monetary economies with distorting taxes on consumption and where firms must borrow in order to finance some fraction of their wage bill. Introducing such a constraint on wages has received a big boost from the evidence that firms were hurt during the financial crisis, when they could not get access to credit to pay for working capital (see, e.g., Gilchrist et al. (2015)).

I first show that, irrespective of the form of the utility function, the Friedman rule ceases to be optimal. This non-optimality is in line with the Phelps's criticism that Friedman's first best argument ignores the second best fact that inflation produces seigniorage incomes for the fiscal authority and all forms of taxation produce distortions of some kind. I then follow Jones et al. (1997), and consider a model where households sell two types of labor, raw and effective labors, to the market where only the raw labor wages are subject to a cash-in-advance constraint. I demonstrate that, in this setup, the optimality of the Friedman rule with distorting consumption taxes reemerged if the production function exhibits constant-returns-to-scale and the utility function is a homothetic function of the mentioned two types of labor and separable in consumption.

Chapter 1

Frictional Labor Markets and the Optimal Inflation Rate and its Variability

1.1 Introduction

Several papers, recently, have combined the search and matching paradigm into the DSGE frameworks with sticky prices aim to explore the implications for optimal monetary policy. Almost all of these studies are conducted in the context of theoretical frameworks which are cashless and abstract from fiscal policy.[1] In this paper, I show that two important drawbacks due to these unrealistic assumptions and simplifications arise: first, considering a cashless economy leaves untouched a very important policy problem, that is, the optimal rate of inflation. Indeed, the existing literature on optimal monetary policy in the models with matching frictions is completely silent on this and only focuses on the optimal inflation volatility. Second, treating the government budget constraint as a residual object due to the presence of a lump-sum tax, significantly underestimates the optimal inflation volatility and undermines the role of monetary policy-in particular, inflation-in stabilizing the inefficient fluctuations in labor markets.

I develop a general equilibrium matching model with sticky prices, money and distortionary labor income taxes, where it is possible to analyze the interactions between optimal fiscal and monetary policies and have clear policy recommendations on optimal rate of inflation and its volatility. The model is an extension of the DSGE labor search-and-matching and perfectly competitive model of Arseneau and Chugh (2012). Arseneau and Chugh consider a real model that is abstract from any nominal aspects. They show that their model generates reasonable business cycle fluctuations of several key labor market outcomes. In their model, the government finances

[1] Arseneau and Chugh (2008) study optimal fiscal and monetary policy in a frictional labor market model with costly nominal wage adjustments but flexible prices. Their model and results are different and in most cases in contrast to this study. These differences and contrasts are discussed in detail below.

exogenous expenditures with revenue from distortionary labor income taxes, from dividend income taxes and from issuing real state contingent debt. They also assume that, the government provides vacancy subsidies and unemployment benefits. Arseneau and Chugh (2012) in their paper, which is calibrated to the U.S. economy, find that the Ramsey-optimal policy calls for extreme labor tax rate volatility. I depart from them by introducing market power, price rigidities and money demands into their theoretical framework. Money is introduced into the model via cash-in-advance constraints in such a way that holding liquidity balances facilitates the household's ability to purchase consumption goods and the firm's ability to pay for the wage bill. Motivating a working capital constraint for firms comes from the fact that more than 50 percent of M1 in industrialized economies is held by firms. Unlike Arseneau and Chugh, in my model the government debt is non-contingent nominal debt, which is more realistic, and there is no subsidy tax.

In this context, the crucial parameter for the results is the bargaining power of workers. This parameter is also the key parameter for Arseneau and Chugh (2012), that they choose based on the work of Hagedorn and Manovskii (2008). Hagedorn and Manovskii find that a reasonably calibration of the parameters of the Mortensen-Pissarides model is consistent with the key business cycle facts for the U.S. economy. Their calibration delivers the worker's bargaining weight at a relatively low value, 0.05. I pick this value as the baseline calibration as Arseneau and Chugh did. For the other search and matching parameters, because the two models have the same labor market structure, I also adopt the Arseneau and Chugh (2012) calibration.[2] I then simulate four different economies: the baseline monetary economy with distortionary taxes and labor market frictions, the cashless form of the baseline monetary model with lump-sum taxes, the baseline monetary economy with Walrasian wages (New Keynesian monetary model) and the traditional cashless New Keynesian economy. The main results can be summarized as follows: In the baseline model, the Ramsey-optimal rate of inflation is 9.6 percent per year with a volatility of 7.4 percent. On the fiscal part, optimal fiscal policy is characterized by a highly volatile income tax rate, although two percentage points less volatile than inflation. The labor income tax rate is on average equal to 30% points with a volatility of 5.5%. The optimality of an extremely high inflation rate which is also extremely volatile is a remarkable and striking result in two ways: first, once we compare it with the results of the existing literature on Ramsey-optimal policy under sticky prices in the Walrasian-based DSGE models with money and taxes or with the results of the cashless models with frictional labor markets and lump-sum taxes. Indeed, the key finding of the New Keynesian frameworks with Walrasian labor markets is that, once changing prices is costly, price stability appears to be the central goal of optimal monetary policy, even when the model features a rich array of real and nominal rigidities.[3] Compared to the results of the papers with

[2]Different calibrations qualitatively deliver exactly the same results, but of course quantitatively different.
[3]See for example Schmitt-Grohé and Uribe (2005b,a).

labor market frictions that are abstract from money and tax, although it is true that a short-run unemployment/inflation trade-off arises in these papers which makes the full price stability no longer optimal, however, in most of them the trade-off resolves in favor of full price stability and in all of them the optimal rate of inflation is zero and the optimal volatility of inflation is very low.[4]

Second and more strikingly, even in the presence of labor tax rates and in spite of the costly price adjustments, the Ramsey planner relies more heavily on inflation than tax volatility to induce efficient fluctuations in the labor market and to stabilize the economy over the business cycle. While one might expect that in this context monetary policy is the most appropriate instrument to deal with the sticky price distortion and the labor tax rate is the most appropriate instrument to deal with distortions in the labor market, the quantitative results, however, run against this prior and make it quite clear that it is the inflation, not the labor tax, that plays the crucial role in inducing optimal labor market fluctuations. Indeed, in this environment for a degree of price stickiness that is three times smaller than the benchmark estimate, the optimal fiscal/monetary policy regime features a labor income tax on average two percentage points lower (28%) and three percentage points less volatile (2.5%) and an inflation that is on average 15% points higher (24.3%) and one and a half percentage points more volatile (8.8%) than in the case with the benchmark calibration. These findings are vastly different from their counterparts in the cashless economy with lump-sum taxes and also the monetary and cashless Wlrasian-based New Keynesian models with sticky prices. Moving to the cashless model with lump-sum taxes, the optimal policy features an optimal rate of inflation near zero with a volatility of only 0.34 percent per year, which is even less than the optimal inflation volatility in the New Keynesian monetary model without matching frictions (0.5%), in line with the existing literature. In the standard New-Keynesian literature, even for a miniscule degree of price stickiness (i.e., ten times below available empirical estimates) the optimal volatility of inflation is very low (see for example, Schmitt-Grohé and Uribe (2004b) and Siu (2004)). While, this is even remarkably the case for the cashless economy with labor market frictions, but in the monetary model with distortionary labor taxes and matching frictions, on the one hand, once the degree of price stickiness is ten times smaller than the benchmark and the bargaining power is at 0.05 level, then the optimal rate of inflation rises to about 58% and becomes extremely volatile (10.1%). On the other hand, the average rate of income tax and its volatility fall to 24% and 1.8%, respectively. In this case, if the whole consumption expenditures and wage payments must be backed with cash, then the optimal labor income tax rate drops to just 10%.

These results are also comparable to the Arseneau and Chugh (2012) results. They find that the Ramsey government uses purposeful tax volatility, orders of magnitude larger than the cornerstone

[4] See for example Thomas (2008), Faia (2009), Blanchard and Gali (2010) and Ravenna and Walsh (2011, 2012) among many others.

tax-smoothing result of the standard Ramsey literature, to induce efficient fluctuations in labor markets, by keeping distortions constant over the business cycle. In contrast, in the context of this framework, the main burden of inducing efficient fluctuations in labor markets falls on inflation not taxes. Indeed, the smaller is the degree of price stickiness, the higher are the optimal inflation rate and its variations and the lower are the income tax rate and its volatility. The point is not that because taxes are distortionary the Ramsey planner finds it optimal to use inflation; since in almost all of the existing literature on optimal fiscal and monetary policy in the Walrasian-based New Keynesian frameworks the trade-off is overwhelmingly resolved in favor of price stability even for very small degrees of price stickiness. The point is that in the context of a monetary New Keynesian model with frictional labor markets, when the bargaining power on the part of workers is low, which results in inefficiently-time-varying components of static and intertemporal wedges, using inflation to induce efficient fluctuations in the wedges is more efficient than variations in taxes, even if changing prices is costly. Put another way, the benefits of purposeful high inflation rate and high inflation volatility in inducing small and efficient fluctuations in labor markets by keeping intertemporal distortions low over the business cycle outweigh the inflation costs.

It is important to note that the reason behind the optimality of a high inflation rate is the presence of a cash-in-advance constraint on purchases of the consumption good. Optimal inflation volatility dramatically rises from 7.4% to 12.3% per year and average inflation sharply drops from 9.6% to -0.73% per year in the absence of this constraint. In fact, the inflation rate is positive and high only if households hold cash balances, otherwise it falls to below zero. Indeed, there is also a trade-off between the average inflation and inflation volatility in the case of a cash constraint for households. The reason behind it lies in two facts: first, money demand friction on the part of households, on the one hand, enters directly into the Phillips curve and so has a direct effect on inflation. On the other hand, such a friction also enters into the optimal vacancy creation condition and the static and intertemporal wedges, which are due to the matching frictions. Taken together all, not only the existence of the money demand friction by households per se induces the Ramsey planner to use inflation to minimize intertemporal distortions to ensure efficient labor market fluctuations, but also the fraction of the consumption expenditures that must be backed with monetary assets has direct impact on the average rate of inflation. This is not, however, the case for the firm's capital constraint, since it doesn't impact the Phillips curve directly, although the presence of this constraint, due to the its negative impact on Nash-bargained real wages, induces, to some extent, lower income tax rates.

By raising worker's bargaining power to the Hosios level (0.4), the Ramsey-optimal policy in the baseline model delivers an optimal inflation rate on average negative and close to zero (-0.4%) with a very low variability (0.4%). In this case, in contrast to the baseline calibration of bargaining parameter, even for a ten times smaller degree of price rigidity parameter, inflation stability remains optimal. By deviating from the Hosios efficiency condition and increasing worker's bargaining power more, optimal inflation rate and its volatility decline more. This is also significantly the case for the optimal income tax rate. Indeed, once the bargaining power is set to 0.9, the optimal inflation rate and its variability fall to very near zero and the average income tax rate declines by about 10 percentage points to 21% with an optimal volatility about 80% lesser (1%).

Taking these points together leads us to the implication that, the main reasons behind the optimality of an extremely high inflation rate which is also very volatile in the baseline calibrated model are low bargaining power on the part of workers and the nonexistence of lump-sum taxes. The mechanism of wedge-smoothing in Arseneau and Chugh (2012) applies here too. As they mentioned and showed carefully, non-tax components of wedges are very important in determining the mapping from wedge-smoothing to the dynamics of taxes in their framework, but in this context, also to the dynamics of inflation and nominal interest rates. In the baseline calibrated model, because worker's bargaining power is inefficiently low, the optimal policy features variations in inflation to offset inefficient fluctuations in the wedges. More precisely, the Ramsey planner uses inflation to ensure efficient labor market fluctuations by minimizing static and intertemporal distortions over the business cycle despite the fact that changing prices is costly. In other words, because of low employment rate and inefficient and very large movements in labor market tightness, that can be thought of as the summary statistic of period t labor market outcomes, due to the worker's low bargaining power, and the fact that the government has no access to lump-sum taxes but only distorting income taxes, it is optimal to use an appropriate combination of average inflation and inflation volatility and to some extent tax variations to stabilize the labor market over the business cycle.

While the results to some extent are in line with Arseneau and Chugh (2012), they are also comparable but to some extent in contrast to Arseneau and Chugh (2008) results, the only paper on the joint determination of optimal fiscal and monetary policy in frictional labor markets with nominal rigidities. Arseneau and Chugh (2008) study optimal fiscal and monetary policy in a cash-credit goods model with labor market frictions and costly nominal wage adjustments. In their model, there is no imperfect competition and product prices are flexible. The main result of their paper is that, in spite of the nominal wage rigidities, the optimal policy implies a highly volatile price inflation. However, Arseneau and Chugh (2008) study differs from this work in three very important dimensions: first, Arseneau and Chugh (2008) assume flexible product prices, while price adjustment costs are at the center stage of my paper. Due to the flexibility of product prices in their setup, therefore, the optimality of high inflation volatility is not surprising. Second, they assume that the bargaining parameter is at its efficient level, while focusing on the role of worker's bargaining power is another central part of this work. Third, they do not address the welfare costs of price stability and also do not provide quantitative results for the case that fiscal policy is absent, thus it is not clear how much important is the role of distortionary income taxes and the absence of lump-sum taxation. On the other hand, my results, that are derived under the presence of price adjustment costs and flexible real wages not nominal wage adjustment costs, from two very important aspects, among many other aspects, are qualitatively in contrast to what Arseneau and Chugh report: first, in Arseneau and Chugh (2008) paper, with increasing the period of nominal wage adjustment costs, the optimal price inflation volatility rises substantially and optimal nominal wage inflation volatility doesn't show a clear trade-off. Because as table (2) of their paper shows, the nominal wage volatility rises again for four quarters of nominal wage stickiness in comparison with the three quarters of nominal wage stickiness. While in my paper and under the presence of nominal price adjustment costs, the inverse of their findings, in fact, happens and the relation between optimal price inflation volatility and price adjustment costs parameter is negative. In other words, as the degree of price stickiness rises, the optimal price inflation volatility declines substantially, which is very reasonable. Second, Arseneau and Chugh (2008) results on the optimality of high inflation volatility are obtained under the Hosios efficiency level, while at that level my results quite clearly show that price stability is the optimal policy. This is the case even for a small degree of price rigidity.

Another central focus of the paper is to show how the welfare losses of inflation targeting are remarkably high for low levels of workers bargaining power. Specifically, my results suggest that there is a direct link between the welfare losses of price stability and bargaining power of workers. For the baseline calibration, the welfare cost of price stability is extremely large and more than 20% of the consumption stream under the Ramsey policy. This cost is about 50 times of the price stability cost in the cashless economy, that is 0.4% of the consumption stream under the optimal policy. In both economies, by raising worker's bargaining power toward the Hosios efficiency level, the welfare cost of strict inflation targeting reduces substantially such that for the monetary economy it drops to about 0.11% and for the cashless economy to 0.08%. These results are new in the literature in the sense that the existing literature focused only on the welfare casts of price stability for the cases that either bargaining power is at the efficient level or higher than that level. At the same time, the results are also at a sharp contrast to that part of the existing literature that report a negligible welfare cost for strict inflation targeting. For example, Ravenna and Walsh (2012) find that price stability delivers a level of welfare close to the level achieves under an optimal monetary policy. They show this result in a cashless economy with lump-sum taxes and for values of bargaining power at the Hosios efficient level (0.5) and higher (0.7). The cashless part of my model with lump sum taxes confirms Ravenna and Walsh results and implies a very low welfare cost once the workers bargaining power is for example 0.7, despite the fact that unlike Ravenna and Walsh I do not assume an efficient steady state.

Literature Review: There is a vast literature on the optimal monetary policy in New Keynesian models with frictional labor markets. This literature, that incorporated nominal rigidities in the form of price sluggishness, has focused only on monetary policy and has completely ignored fiscal policy.[5].

Regarding the role of worker's bargaining parameter in determination of optimal inflation volatility, my findings on the dynamic properties of the Ramsey economy with different values for bargaining power, ω, are in a sharp contrast to what Faia (2009) reports. Faia (2009) in a model with sticky prices a la Rotemberg and matching frictions finds that optimal monetary policy in response to both productivity and government expenditure shocks deviates from price stability. In her framework, which abstracts from money demand friction and fiscal policy regime, in response to both shocks the optimal inflation volatility increases with the worker's bargaining power. However, as is explained below, this sharp contrast goes back to the facts that her framework abstracts from distortionary taxes and unemployment transfers.

Another related work to this study is Ravenna and Walsh (2012). Ravenna and Walsh (2012) address the question of why price stability remains optimal even in the presence of labor market distortions in standard New Keynesian models. They assume a government that has access to non distorting revenue sources and always able to replicate the first best allocation. In contrast to the present paper, they do not solve a constrained optimal taxation problem. By assuming a tax policy that corrects the inefficiency wedges in the first order conditions of competitive equilibrium, Ravenna and Walsh (2012) find that the welfare gains of optimal monetary policy that allows for deviating from price stability is negligible, compared to the welfare that price stability policy delivers when wages are Nash-bargained and the Hosios efficiency condition is met. But once wages are fixed at a norm far from the related efficient steady-state, optimal monetary policy by deviating from price stability delivers not negligible welfare gains. Comparing their results with my results in the cashless and no-fiscal policy case (which is a specific part of the paper and not the main focus), some points which are important to note are discussed below.

Regarding a highly positive steady-state optimal inflation rate in the presence of labor market friction and CIA constraint for households, my findings are in line with WANG and XIE (2013). WANG and XIE (2013) in a monetary growth model with cash constraint for both households and firms and in the absence of distortionary taxes show that labor market frictions play a crucial role through which the steady inflation influences the long-run real activities. The key elements in their analysis are costly vacancy creation, job search and imperfect job matches. WANG and XIE (2013) conduct their analysis in the context of a model with perfect competition and flexible prices where in the absence of labor market frictions the optimal inflation rate is on average negative due

[5] See for example Chéron and Langot (2000), Walsh (2003), Thomas (2008), Faia (2008), Blanchard and Gali (2010) and Ravenna and Walsh (2011) among many others.

to the optimality of the Friedman rule. They do not study the business-cycle properties of the Ramsey-optimal policy which is in fact the central piece of this study. In my model also because of nominal rigidities and in the absence of matching and monetary frictions the optimal inflation rate is close to zero even with distorting taxes. Introducing frictional labor markets makes the intertemporal and static wedges highly inefficiently volatile, and so one tool of the Planner is to use high inflation rate to lower these inefficient volatilities.

1.2 Model

The theoretical framework embeds nominal rigidities in the form of sluggish price adjustment a la Rotemberg (1982), demands for money by households and firms and the ability of government to issue only nominal non state-contingent debt into the simple DSGE economy model with labor search and matching frictions of Arseneau and Chugh (2012). In contrast to Arseneau and Chugh, I do not allow for vacancy subsidy and state-contingent real debt. Because I want to consider firms which are price setters, final consumption is assumed to be a composite good, aggregated over a continuum of goods with Dixit-Stiglitz aggregator. Each good is produced by a monopolist, and all producers produce output using only labor and are subject to an aggregate productivity shock. The matching frictional part of the model features agents in three labor market states. They are either employed, searching for a job or are outside of the labor force and enjoy their leisure.

I assume that there is a representative household with preferences described over consumption C_t, search activity S_t, and the desired stock of employment H_t^h,

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, S_t, H_t^h\right) \tag{1.1}$$

with

$$U\left(C_t, S_t, H_t^h\right) = u\left(C_t\right) - N\left[H_t^h + \left(1 - pp_t\right) S_t\right], \tag{1.2}$$

and

$$C_t = \left[\int_0^1 c_{it}^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}}, \tag{1.3}$$

where pp_t denotes probability of job-finding, taken as given by households, c_{it} is private consumption of variety $i \in [0,1]$ and $\xi > 1$ is the elasticity of substitution between varieties. The function $N(.)$ is a function of the measured labor force, defines as

$$LFP_t = H_t^h + (1 - pp_t)\,S_t, \tag{1.4}$$

which is strictly increasing and strictly convex in the size of the labor force LFP_t. In each period t, LFP_t agents participate in the labor force and $1 - LFP_t$ do not participate. In the measured labor force definition, $(1 - pp_t)\,S_t$ represents the measure of individuals who turn out to be unsuccessful in finding a job. The measure H_t^h that is the fraction of household members who are employed is defined as

$$H_t^h = (1 - \rho)\,H_{t-1}^h + S_t pp_t, \tag{1.5}$$

where ρ stands for a constant rate of exogenous separations. More precisely, at the beginning of each period t a fraction ρ of employment relationships that produced output and were active in period $t-1$ breaks up.

The production function of each intermediate good i uses labor, H_{it}^f, according to

$$c_{it} = Z_t H_{it}^f, \tag{1.6}$$

where Z_t is an aggregate productivity shock. Total measure of workers H_t^f is

$$H_t^f = \int_0^1 H_{it}^f di. \tag{1.7}$$

The law of motion of Z_t is given by

$$LnZ_t = \rho^z LnZ_{t-1} + \varepsilon_t^z, \tag{1.8}$$

where $\rho^z \in (-1,1)$ and ε_t^z is an i.i.d. innovation with mean zero and standard deviation σ^z.

1.2.1 Government

The government each period levies distorting labor income taxes, τ_t^h, prints money, M_t, and issues one-period nominally risk-free bonds, B_t, to finance a stream of spending G_t that is exogenous, stochastic and unproductive. It also pays unemployment benefits, $(1 - pp_t)\,S_t\chi$, to households. It's period-by-period budget constraint is given by

$$M_t + B_t + P_t\tau_t^h W_t H_t^h = R_{t-1}B_{t-1} + M_{t-1} + P_t G_t + (1 - pp_t)\,P_t S_t \chi, \tag{1.9}$$

where $P_t = \left[\int_0^1 p_{it}^{1-\xi}\right]^{\frac{1}{1-\xi}}$ is a nominal price index, R_t denotes the gross one-period nominal interest rate and W_t is the real wage. $\frac{R_{t-1}B_{t-1}+M_{t-1}}{P_{t-1}} \equiv A_t$ denotes total real government liabilities in units of period $t-1$ goods at the end of period $t-1$.

I assume that the logarithm of variable G_t follows a first-order autoregressive process of the form

$$lnG_t = (1-\rho^g)\,lnG + \rho^g lnG_{t-1} + \varepsilon_t^g, \tag{1.10}$$

where $\rho^g \in (-1,1)$ and $G > 0$ are parameters, and ε_t^g is an i.i.d. innovation with mean zero and standard deviation σ^g. The parameter G represents the non-stochastic steady-state level of government expenditures.

1.2.2 Firms

Each good's variety is produced by a monopolist which faces quadratic costs of adjusting prices and has to hold money to satisfy a working-capital constraint. The demand for money by firms is rationalized by imposing that wage payments be subject to a cash-in-advance constraint of the form:

$$BP_tW_tH_{it}^f \leq M_{it}^f, \tag{1.11}$$

where B is a parameter indicating the fraction of the wage bill that must be backed with cash. Real wages, W_t, as described below, are determined through the Nash bargaining mechanism. The wage-setting protocol is taken as given when firms maximize profits. M_{it}^f denotes the demand for nominal money balances by firm i in period t. The firm i also posts ϑ_{it} vacancies with the per-vacancy posting cost γ.

The sequence of budget constraints that firm i faces is:

$$M_{it}^f = M_{it-1}^f + P_{it}Y_{it} - P_tW_tH_{it}^f - P_t\Phi_{it} - \frac{\theta}{2}\left(\frac{p_t^i}{p_{t-1}^i} - 1\right)Z_tP_tH_{it}^f - P_t\gamma\vartheta_{it}. \tag{1.12}$$

where $\frac{\theta}{2}\left(\frac{p_t^i}{p_{t-1}^i} - 1\right)Z_tH_{it}^f$ represents price adjustment costs, p_i^t is the price of good's variety i, θ measures the degree of price stickiness, $\gamma\vartheta_{it}$ represents costs of posted vacancies and Φ_{it} is distributed profits.

Following Arseneau and Chugh (2012) I assume that each firm i begins period t with employment stock H_{t-1}^f and the productive employment stock of such a firm in period t, H_t^f, depends on its vacancy postings at that period and the random matching process. Let qq_t denotes the probability that a given vacancy is filled by a worker which is taken as given by the firm. This probability like the matching probability for households, pp_t, is assumed to depend only on aggregate labor market conditions.

The representative firm discounts profits period-t using $\beta^t \frac{\lambda_t}{\lambda_0}$, which is the value to the households of receiving profits, and chooses $\left\{p_t^i, H_{it}^f, m_{it}^f, \vartheta_{it}\right\}$ to solve the following maximization problem in real terms:

$$Max\ \ \Pi_{it} = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{p_t^i}{P_t} y_{it} - W_t H_{it}^f + \frac{m_{it-1}^f}{\pi_{t-1}} - m_{it}^f - \gamma \vartheta_{it} - \frac{\varphi}{2} \left(\frac{p_t^i}{p_{t-1}^i} - 1 \right)^2 y_{it} \right\}, \tag{1.13}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the gross consumer price inflation rate.

Output $y_{it} = c_{it}$ must satisfy the technology constraint (1.6) and the demand function

$$y_{it} = \left(\frac{p_t^i}{P_t} \right)^{-\xi} Y_t, \tag{1.14}$$

where $Y_t = Z_t H_t^f$.

The maximization is also subject to eq. (1.11) and the following sequence of perceived laws of motion for employment level

$$H_{it}^f = (1-\rho) H_{i,t-1}^f + q q_t \vartheta_{it}. \tag{1.15}$$

Let the Lagrange multiplier on the production constraint (1.14) be MC_t, which is the marginal cost of the representative firm.

As is common in the literature, I restrict attention to symmetric equilibria where all firms charge the same price for the goods they produce. As a result $p_t^i = P_t$ for all t. But if they all choose the same price, they face exactly the same demand. This in turn means that they will each produce an equal amount and will hire an equal amount of labor (since they all face the same aggregate TFP). So we drop the index i. Then the first-order conditions of the above maximization problem yields the following equations

$$\frac{\gamma}{q q_t} = Z_t MC_t - W_t \left[1 + B\left(1 - R_t^{-1}\right)\right] + \beta (1-\rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\gamma}{q q_{t+1}}, \tag{1.16}$$

$$1 - \theta \pi_t (\pi_t - 1) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[\theta \pi_{t+1} (\pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} \right] = (1 - MC_t) \xi, \tag{1.17}$$

In deriving eq. (1.16) I used in advance from the fact that the Euler equation (1.25) is satisfied. Equation (1.16) is the job creation condition and equation (1.17) is the expectations augmented Phillips curve. As equation (1.16) shows, the presence of a working-capital requirement introduces a financial cost of labor that is increasing in the nominal interest rate in addition to the labor market frictions costs. The left side of (1.16) is the search costs associated with hiring $\left(\frac{\gamma}{qq_t}\right)$. The right side is the discounted expected value of profits from a match.

1.2.3 Households

The representative household minimizes spending on aggregate C_t by choosing the consumption of different goods varieties according to

$$\frac{c_{it}}{C_t} = \left(\frac{p_{it}}{P_t}\right)^{-\xi}.$$

The budget constraint in terms of aggregates is written as

$$P_t C_t + B_{t+1} + M_t^h = \left(1 - \tau_t^h\right) P_t W_t H_t^h + R_{t-1} B_t + M_{t-1}^h + (1 - pp_t) S_t \chi + \Pi_t, \ t > 0 \tag{1.18}$$

together with a no-Ponzi games condition.

The perceived laws of motion for the employment stock is

$$H_t^h = (1-\rho) H_{t-1}^h + pp_t S_t, \tag{1.19}$$

And the demand for money originated in a cash-in-advance constraint takes the following form

$$AP_t C_t \leq M_t^h, \tag{1.20}$$

B_{t+1} represent risk-free nominal bonds that the representative household holds, M_t^h is the money holdings by the household in period t and A is a parameter. Also $\Pi_t = \int_0^1 \Phi_{it} di$ are total profits.

Denote by $\left\{\frac{\lambda_t}{P_t}\right\}$, $\{\mu_t\}$ and $\left\{\frac{\psi_t}{P_t}\right\}$ the sequence of Lagrange multipliers on the constraints (1.18), (1.19) and (1.20), respectively. The first order conditions of the household problem that maximizes utility (1.1) subject to the above constraints with respect to the aggregates C_t, M_t^h, S_t, H_t^h and B_{t+1} are

$$u'(C_t) = \lambda_t + \psi_t, \tag{1.21}$$

$$\frac{\lambda_t}{P_t} = \beta \frac{\lambda_{t+1}}{P_{t+1}} + A\frac{\psi_t}{P_t}, \tag{1.22}$$

$$\lambda_t (1 - pp_t) \chi + \mu_t pp_t = (1 - pp_t) N' \left[(1 - pp_t) S_t + H_t^h\right], \tag{1.23}$$

$$\lambda_t \left(1-\tau_t^h\right) W_t + \beta \left(1-\rho\right) E_t \mu_{t+1} = \mu_t + N^{'} \left[\left(1-pp_t\right) S_t + H_t^h\right], \tag{1.24}$$

$$\frac{\lambda_t}{P_t} = \beta R_t \frac{\lambda_{t+1}}{P_{t+1}}. \tag{1.25}$$

Eq. (1.25) represents the standard pricing equation for nominal bonds. Conditions (1.21) and (1.22) imply that

$$u^{'}\left(C_t\right) = \lambda_t \left[1 + A\left(1 - R_t^{-1}\right)\right], \tag{1.26}$$

this equation states that the cash-in-advance constraint introduces a wedge between the marginal utility of consumption and the marginal utility of wealth.

From eq. (1.23) solve for the multiplier μ_t

$$\mu_t = \left(\frac{1-pp_t}{pp_t}\right) \left[N^{'} \left[\left(1-pp_t\right) S_t + H_t^h\right] - \lambda_t \chi\right]. \tag{1.27}$$

Combining eqs. (1.24) and (1.27) with eq. (1.4) that $LFP_t = H_t + (1-pp_t) S_t$, gives the household's optimal labor force participation condition,

$$\begin{array}{c} \frac{N^{'}(LFP_t)}{pp_t \lambda_t} = \left(1-\tau_t^h\right) W_t - \chi + \frac{\beta(1-\rho)}{\lambda_t} E_t \{\lambda_{t+1} \\ * \left(\frac{1-pp_{t+1}}{pp_{t+1}}\right) [\frac{N^{'}(LFP_{t+1})}{pp_{t+1}\lambda_{t+1}} - \chi]\} + \left(\frac{1-pp_t}{pp_t}\right)\chi \end{array}, \tag{1.28}$$

which is equivalent to

$$\begin{array}{c} \frac{N^{'}(LFP_t) - \chi\lambda_t}{pp_t} = \lambda_t [\left(1-\tau_t^h\right) W_t - \chi] + \\ \beta\left(1-\rho\right) E_t \left\{\left(\frac{1-pp_{t+1}}{pp_{t+1}}\right) \left[N^{'}\left(LFP_{t+1}\right) - \chi\lambda_{t+1}\right]\right\}. \end{array}$$

The participation condition asserts that, the fraction of agents searching for jobs is determined in such a way that at the optimum, the expected payoff of searching will be equal to the marginal rate of substitution between consumption and participation.

1.2.4 Nash-Bargained Wages

Following much of the literature I assume that wages are determined through Nash bargaining.

Like Arseneau and Chugh (2012), let define $V\left(H_{t-1}^h\right)$ as the value function associated with the household problem. Then envelope condition by using eq. (1.27) gives

$$V^{'}\left(H_{t-1}^{h}\right)=(1-\rho)\,\mu_{t}$$
$$=(1-\rho)\left(\tfrac{1-pp_{t}}{pp_{t}}\right)\left[N^{'}\left(LFP_{t}\right)-\chi\lambda_{t}\right]. \tag{1.29}$$

Let V_t^E denote the value of an employed member to a household. This value is defined after labor matching has taken place and so the labor market status of each member's measured is known in period t. Let also define V_t^U as the value of an unemployed member to a household. This value is defined before labor matching takes place. Thus, in contrast to the former case, the participation decisions of household about how many members to be sent to search for jobs occur before matching has taken place. [6]

For a member who is employed, the valuation equation for being in a match that produces in period t is

$$V_{t}^{E}=\left(1-\tau_{t}^{h}\right)W_{t}+\frac{\beta}{\lambda_{t}}E_{t}\left(\lambda_{t+1}\frac{V^{'}\left(H_{t}^{h}\right)}{\lambda_{t}}\right), \tag{1.30}$$

the first term on the right hand side of eq. (1.30) denotes real wages net of tax and the second term which is based on envelope condition (1.29), stands for the marginal value of entering period $t+1$ with another preexisting employment relationship. The value of an unsuccessful member in finding a job is given in turn by

$$V_{t}^{U}=\chi. \tag{1.31}$$

Because a household re-optimizes participation at the beginning of period $t+1$ and at this time $(1-pp_t)\,S_t$ is not a state variable, there is zero continuation payoff of an unemployed member to the household. It follows that the household's surplus from an employment can be written as

$$V_{t}^{E}-V_{t}^{U}=\left(1-\tau_{t}^{h}\right)W_{t}-\chi+\tfrac{\beta(1-\rho)}{\lambda_{t}}$$
$$*E_{t}\left\{\lambda_{t+1}\left(1-pp_{t+1}\right)\tfrac{N^{'}\left(LFP_{t+1}\right)-\chi\lambda_{t+1}}{pp_{t+1}\lambda_{t+1}}\right\}, \tag{1.32}$$

where I used eq. (1.29) to get rid of $V^{'}\left(H_t^h\right)$. Comparing eqs. (1.32) and (1.28) reveals that

$$V_{t}^{E}-V_{t}^{U}=\frac{N^{'}\left(LFP_{t}\right)-\chi\lambda_{t}}{pp_{t}\lambda_{t}}, \tag{1.33}$$

update this expression one period and substitute it in eq. (1.32) gives

$$V_{t}^{E}-V_{t}^{U}=\left(1-\tau_{t}^{h}\right)W_{t}-\chi+\tfrac{\beta(1-\rho)}{\lambda_{t}}$$
$$*E_{t}\left\{\lambda_{t+1}\left(1-pp_{t+1}\right)\left(V_{t+1}^{E}-V_{t+1}^{U}\right)\right\}, \tag{1.34}$$

[6] For a precise image of the timing of events see page 932 of Arseneau and Chugh (2012).

Note also that the firm's surplus from an established employment relationship, denoted by Υ_t, is given by

$$\Upsilon_t = Z_t MC_t - W_t\left[1+B\left(1-R_t^{-1}\right)\right] + \frac{\beta\left(1-\rho\right)}{\lambda_t}E_t\left(\lambda_{t+1}\Upsilon_{t+1}\right), \tag{1.35}$$

where $\Upsilon_t = \frac{\gamma}{qq_t}$.

I assume a constant-return-to-scale matching function of the form

$$m\left(S_t,\vartheta_t\right) = \zeta S_t^{\kappa}\vartheta_t^{1-\kappa}, \tag{1.36}$$

Here S_t and ϑ_t denote aggregate variables, because I assume that we are in equilibrium. From eq. (1.36) we get $qq_t = \zeta Q_t^{-\kappa}$ and $pp_t = \zeta Q_t^{1-\kappa}$, where $Q_t = \frac{\vartheta_t}{S_t}$ is the measure of labor market tightness.

Because of the equilibrium $H_t = H_t^f = H_t^h$, hence the aggregate employment is given by

$$H_t = \left(1-\rho\right)H_{t-1} + m\left(S_t,\vartheta_t\right). \tag{1.37}$$

Let denotes by $\omega \in (0,1)$ the worker's bargaining power. Naturally, the firm's bargaining power will be $1-\omega$. Under Nash bargaining, workers and firms choose W_t to maximize

$$\left(V_t^E - V_t^U\right)^{\omega}\Upsilon_t^{1-\omega}.$$

This maximization problem implies the following sharing rule

$$\frac{V_t^E - V_t^U}{\Upsilon_t} = \frac{\omega}{1-\omega}\frac{\left(1-\tau_t^h\right)}{\left[1+B\left(1-R_t^{-1}\right)\right]}, \tag{1.38}$$

Now by using eqs. (1.16), (1.34) and (1.38) we get the following wage equation

$$\begin{gathered} W_t = \frac{\omega Z_t MC_t}{\left[1+B\left(1-R_t^{-1}\right)\right]} + \frac{(1-\omega)}{\left(1-\tau_t^h\right)}\chi + \beta\omega\left(1-\rho\right) \\ *\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{\gamma}{qq_{t+1}}\left[\frac{1}{\left[1+B\left(1-R_t^{-1}\right)\right]} - \left(1-pp_{t+1}\right)\frac{\left(1-\tau_{t+1}^h\right)}{\left(1-\tau_t^h\right)}\frac{1}{\left[1+B\left(1-R_{t+1}^{-1}\right)\right]}\right]\right\} \end{gathered} \tag{1.39}$$

As the first term of real wage equation (1.39) shows, the presence of the working capital constraint distorts and decreases the value of the marginal product of a new worker $Z_t MC_t$ to the firm. This is also the case for the forward-looking aspect of employment, which is captured in the last term of eq. (1.39). $\frac{(1-\omega)}{\left(1-\tau_t^h\right)}\chi$ shows the part of wage payments that goes to the household.

1.3 Ramsey Problem

I follow the form of policy commitment that in the literature is known as the "optimal from the timeless perspective". This means that, in choosing optimal policy, the government is assumed to honor its commitments made in the past. The problem of the Ramsey planner is to raise revenue to finance exogenous government expenditures through issuance of one-period nominally risk-free government debt, labor income taxes and money creation, in such a way that maximizes the welfare of the representative household, subject to the equilibrium conditions of the economy.

The Ramsey problem in this economy, given A_t, the fixed parameter χ and exogenous stochastic processes $\{G_t, Z_t\}_{t=0}^{\infty}$ is a set of endogenous processes

$$\left\{C_t, H_t, S_t, B_t, M_t^h, M_t, M_t^f, W_t, R_t, \vartheta_t, P_t, \tau_t^h, \lambda_t, MC_t\right\}_{t=0}^{\infty}$$

that maximizes eq. (1.1) subject to the eqs. (1.9), (1.16), (1.17), (1.25), (1.28), (1.39), the aggregate resource constraint

$$Y_t = C_t + G_t + \frac{\theta}{2}(\pi_t - 1)^2 Y_t + \gamma\vartheta_t \tag{1.40}$$

the total aggregate nominal balances constraint

$$M_t = M_t^h + M_t^f = AP_tC_t + BP_tW_tH_t \tag{1.41}$$

In principle, the constraint $R_t \geq 1$ that ensures the chosen allocation can be supported as a monetary equilibrium must also be imposed. However, because in the steady-state of this model R_t is always greater than one and the lower bound $R_t = 1$ was never reached in any of the simulations of the model without this constraint, I therefore proceed from here on dropping it from the Ramsey problem.[7]

1.4 Calibration

I take a period to be a quarter. The structural parameter values implied by the calibration are summarized in table (1.1) . I adopt utilities

$$u(C_t) = lnC_t \quad and \quad N(LFP_t) = \frac{\upsilon}{1+1/\phi} LFP_t^{1+1/\phi},$$

[7] Although focus of my study is not the role of unemployment transfers and their absence which is empirically an unrealistic assumption, it is worth pointing out the only case that the lower bound was violated most of the time was when the unemployment transfers were absent in the baseline monetary economy with distortionary taxes.

where I set the parameter scaling the disutility of labor market effort $\upsilon = 7.7$ to deliver a steady-state participation rate of 66 percent. I set $\phi = 1$, which is a very common value in the literature. The discount factor is set to be $\beta = 0.99$, which implies that in the steady-state real interest rate is about four percent. Following Basu and Fernald (1997), I assume that the value added mark-up of prices over marginal cost is equal to 0.25. To calibrate the degree of price stickiness, I follow Chugh (2006) and derive the mapping between the parameter θ in the Rotemberg quadratic price adjustment cost and the probability f of receiving a signal to change prices in the price-stickiness of Calvo apparatus. This mapping delivers the following relationship between θ and f

$$\theta = \frac{1-f}{f}\frac{1}{1-\beta(1-f)},$$

If we assume that the average duration of a price is four quarters, then we get a value for f equal to $\frac{1}{4}$. Therefore, in the present model which is a quarterly model since $\beta = 0.99$, the corresponding Rotemberg parameter is thus $\theta = 13.5$. Chugh (2006) sets this value equal to 5.88 because he assumes that on average 1/3 of firms set price in a given period.

Using postwar U.S. data, I measure the average money-to-output ratio as the ratio of M1 to GDP, that implies a value equal to 18.3 percent per year. I then use this calibration and calibrate parameters of cash constraints A and B and set them equal to 0.38 and 0.52, respectively.

Because the structure of the presented matching model is precisely the same as the framework of Arseneau and Chugh (2012), I rely on their calibration for all of the matching parameters.[8] However, it's worth mentioning that except for the bargaining power, the calibration of all other parameters are in line with the literature. The bargaining parameter, ω, the unemployment benefits χ, the quarterly probability of separation ρ and vacancy elasticity of matches $1-\kappa$ are set to 0.05, 0.76, 0.1 and 0.6, respectively. I set the values of matching rate for a searching individual pp_t, the fixed cost of opening a vacancy γ, and the job-filling rate of a vacancy qq_t and the matching parameter ζ equal to $pp_t = 0.61$, $\gamma = 0.27$, $qq_t = 0.9$, $\zeta = 0.77$. The fraction of searching workers S_t in the steady-state is set to 0.08. I set the persistence parameters and the standard deviations of the exogenous processes of the government expenditure shock and the productivity shock such that $\left(\rho^g, \varepsilon_t^g\right) = (0.95, 0.027)$ and $\left(\rho^z, \varepsilon_t^z\right) = (0.95, 0.006)$. These values are very in line with Arseneau and Chugh (2012) and the related literature. Following Schmitt-Grohé and Uribe (2007) and Arseneau and Chugh (2012), I also choose G to be 17% of output.

Concerning the numerical accuracy and sensitivity of the results to the calibration, although not reported here, I find qualitatively precisely the same results once I adopt different forms of utility functions or different calibrations for the search and matching frictions. However, different

[8]For a very detailed explanation on how the parameters are calibrated please see Arseneau and Chugh (2012).

calibrations do matter for precise quantitative policy predictions.

Table 1.1: Baseline Calibration

Calibrated Parameters		Value
β	Discount factor	0.99
θ	Price stickiness parameter	13.5
ξ	The value added mark-up of prices	0.25
υ	Preference Parameter	7.7
ϕ	Elasticity of participation w.r.t wages	1
A	Fraction of consumption held in money	0.38
B	Fraction of wage payments held in money	0.52
z	Steady state productivity shock	1
ρ^g	Serial correlation of $ln\, g_t$	0.95
σ^z	Std. dev of innovation to $ln\, z_t$	0.006
σ^g	Std. dev of innovation to $ln\, g_t$	0.027
ρ^z	Serial correlation of $ln\, z_t$	0.95
γ	Fixed cost of posting vacancy	0.27
ζ	Matching function parameter	0.77
ω	Worker's bargaining power	0.05
χ	Unemployment benefits	0.76
κ	Elasticity of aggregate matches	0.4
ρ	Job separation rate	0.1

1.5 Optimal Ramsey Policy

To study the business-cycle properties of Ramsey-optimality policy I approximate the Ramsey equilibrium dynamics by solving a second-order approximation to the Ramsey equilibrium conditions around the non-stochastic steady-state of these conditions. My numerical method is the perturbation algorithm described by Schmitt-Grohe and Uribe (2004) which has been implemented by them for example in Schmitt-Grohé and Uribe (2007, 2004b, 2005b). In computing the sample moments of interested variables, all structural parameters of the model take the values shown in table 1. Second moments are calculated using Monte Carlo simulations. I conduct 500 simulations, each 100 periods long. For each simulation, I compute sample moments and then average these figures over the 500 simulations.

1.5.1 Results

Table (1.2) presents simulation results for the four-mentioned economies in the introduction and for different values of the price stickiness parameter. The first economy and the more interested one is the baseline search and matching monetary economy with distortionary labor taxes and cash-in-advance constraints for households and firms. The dynamics of this economy are presented in the first column of table (1.2). The second economy, which its dynamics are shown in the second column, is the cashless economy with lump-sum taxes and labor market frictions. This economy is the same as the common economy in the existing literature on optimal monetary policy with sticky prices and frictional labor markets. The third economy, presented in the third column, is the baseline monetary economy without frictional labor markets. The last column presents dynamics of the cashless economy with lump-sum taxes and Walrasian labor markets (Canonical New Keynesian model). Panel A presents results for the baseline structural parameters, Panel B presents results for a degree of price stickiness 3 times smaller than the baseline calibration, and Panel C presents dynamics for a degree of price stickiness 10 times smaller than the baseline structural value. Each of these experiments is conducted keeping all other structural parameters fixed at their baseline settings.

The most striking feature of the Ramsey allocations that emerges from table 2 is that, in the baseline monetary model and with the baseline calibration for the price stickiness parameter θ, under the optimal policy regime inflation rate is remarkably high and volatile over the business cycle, as Panel A shows. A two-standard deviation band on each side of the mean features an inflation rate of 2.2 percent at the lower end and an inflation rate of 17.1 percent at the upper end. On the other hand, labor income taxes are also far from zero and very volatile. The average value of the labor income tax rate in the baseline model is 30% with a standard deviation that is 5.5 percentage points. The Ramsey planner uses variations in inflation as a tool to induce efficient labor market fluctuations despite the fact that changing prices is costly. The high volatility and high average rate of the inflation in the context of the baseline model stands in sharp contrast to the near zero and smooth behavior of the inflation rate in the other three models, as the second, third and fourth columns display. More precisely, in the case of cashless frictional labor market model with lump sum taxes, the optimal rate of inflation is close to zero with a volatility about only 0.34%. The 0.34% is even less than the optimal inflation volatility in the standard New Keynesian monetary economy, presented in the third column of Panel A, where the optimal rate of inflation and its volatility are also low and equal to 0.74% and 0.54%, respectively. The fourth column represents the standard results in the standard New-Keynesian models that the optimal inflation rate is zero in a cashless economy with no-fiscal policy. The reason that the optimal volatility is not exactly zero, although still very near zero, is that I do not assume the government can subsidize production to undo imperfect competition distortions.

Another remarkable result that emerges from inspection of Table 2 is that, unlike the other three models, in the baseline model there is a tradeoff between the optimal rate of inflation and its variability and the optimal income tax rate and its volatility. When θ is reduced by a factor of 3, Panel B, the optimal rate of inflation sharply increases by a factor of 2.5 and its volatility rises to 8.8%. On the other hand, the mean and standard deviation of the labor tax rate decline significantly. The average value of the income tax rate falls to 28% with a volatility about 55% lesser. The second column of Panel B shows that this is, however, not the case in the cashless economy with lump-sum taxation where there is almost no change in the optimal inflation rate and its volatility. This is also the case in the Walrasian-based models, as the last two columns present. These columns show that despite the reduction of the price stickiness parameter the optimal inflation variability remains virtually unchanged, in line with the existing literature. There is also no significant change in the optimal inflation and labor income tax rates in the monetary economy with frictionless labor markets and the standard New-Keynesian framework.

Once I reduce the price stickiness parameter by a factor of 10, in the baseline model, on the one hand the optimal rate of inflation dramatically rises to more than 58% per year with an extreme volatility of 10.1% and on the other hand, the income tax rate drops to 24% with a much lower volatility about just 1.8%.[9] It is important to note that, in this case, if the whole consumption expenditures and wage payments be subject to the cash constraints ($A = B = 1$), then the optimal income tax is just 10%. These results are all the more striking when we compare them to the cashless economy with Nash-bargained wages and lump-sum taxes and the monetary economy with Walrasian wages and the benchmark New-Keynesian model. As columns 2, 3 & 4 clearly show there are very small changes in the optimal inflation volatility in these cases even with a degree of price stickiness 10 times smaller. While the optimal inflation rate remains zero regardless of the price stickiness parameter in the Canonical New-Keynesian model, it rises to just 3.4% in the standard New-Keynesian model added with monetary frictions and distortionary income taxes.

[9] I deliberately chose 10 because as I mentioned in the introduction and I also showed it clearly in the third and fourth columns of table 2, it is a very well known result in the standard New-Keynesian literature that even for a miniscule degree of price stickiness 10 times smaller than the existing calibration the optimal inflation rate and its volatility remain close to zero.

Table 1.2: Ramsey-optimal policy

variable	baseline monetary economy			no-fiscal cashless economy			frictionless labor-monetary economy			frictionless labor-cashless economy		
	mean	Std.dev	Autocorrelation	mean	Std.dev	Autocorrelation	mean	Std.dev	Autocorrelation	mean	Std.dev	Autocorrelation
A. $\theta = 68$ (baseline Calibration)												
τ^h	30	5.5	0.1285	-	-	-	20.6	0.44	0.6778	-	-	-
π	9.6	7.4	0.1735	0.01	0.34	0.8652	0.74	0.54	0.6988	0.000	0.04	0.2805
R	13.9	4.3	0.5734	4.6	7.7	0.8905	4.8	0.2	0.7394	4.4	6.8	0.9034
$output$	0.49	0.009	0.7519	0.49	0.008	0.8848	0.31	0.005	09032	0.34	0.005	0.9082
B. $\theta = 22.5$ (three times smaller)												
τ^h	28	2.5	0.3477	-	-	-	20.3	0.4	0.9160	-	-	-
π	24.3	8.8	0.3203	0.01	0.39	0.8531	2.3	0.55	0.5790	0.000	0.05	0.1012
R	29.2	6.01	0.7149	4.5	8.2	0.8862	6.5	0.16	0.7683	4.7	6.6	0.8981
$output$	0.49	0.009	0.7486	0.49	0.0083	0.7683	0.31	0.005	0.8992	0.4	0.0058	0.9034
C. $\theta = 6.8$ (ten times smaller)												
τ^h	24.1	1.8	0.7923	-	-	-	19.2	0.36	0.9736	-	-	-
π	58.1	10.1	0.4511	0.01	0.48	0.8441	3.4	0.7	0.3681	0.000	0.06	0.0187
R	64.3	7.4	0.7941	4.3	8.1	0.8911	11.8	0.13	0.9177	4.8	6.7	0.8996
$output$	0.49	0.008	0.7884	0.49	0.0084	0.9009	0.31	0.0047	0.8982	0.38	0.006	0.9107

Note: τ^h, π and R are expressed in percentage points and $output$ in level.

1.5.2 Equilibrium Wedges

In this subsection, I try to briefly shed light on the inefficiencies that arise in the allocations of labor market, due to the several assumed distortions, and then use them to explain why the optimal policy, when the worker's bargaining power is low, features a high inflation rate which is also highly volatile, in the monetary economy with frictional labor markets. In doing so, it is useful to relate my model to the simple DSGE labor search and matching model of Arseneau and Chugh (2012). In their paper, they nicely provide a welfare-relevant concept of efficiency that makes it clear under what conditions tax smoothing is optimal and is not. Applying their welfare-relevant notion of efficiency and labor wedges to the monetary and fiscal policy questions of my model allows me to pinpoint the conditions under which a high inflation rate with high volatility is optimal.

The two following conditions are the efficient "zero wedge" conditions for Ramsey allocation which both are related to the labor market:

$$\frac{N^{'}(LFP_t)}{u^{'}(C_t)} = \gamma \frac{\kappa}{1-\kappa} Q_t, \tag{1.42}$$

$$\frac{\gamma Q_t^{\kappa}}{\zeta(1-\kappa)} - Z_t = (1-\rho)\, E_t\{ \frac{\beta u'(C_{t+1})}{u'(C_t)} \\ * \left[1-\zeta\kappa Q_{t+1}^{1-\kappa}\right] \frac{\gamma Q_{t+1}^{\kappa}}{\zeta(1-\kappa)} \quad , \tag{1.43}$$

$$\frac{N'(LFP_t)}{u'(C_t)} \frac{Q_t^{(\kappa-1)}}{\zeta\kappa} - Z_t = (1-\rho)\, E_t\{ \frac{\beta u'(C_{t+1})}{u'(C_t)} \frac{N'(LFP_{t+1})}{u'(C_{t+1})} \\ * \frac{Q_{t+1}^{(\kappa-1)}}{\zeta\kappa} \left[1 - \frac{\zeta\kappa}{Q_{t+1}^{(1-\kappa)}}\right] \tag{1.44}$$

These conditions obtained by maximizing eq. (1.1) subject to the eqs. (1.37) and (1.40). The first equation (1.42) is the static marginal rate of transformation between consumption and labor force participation and the second and third equations (1.43) and (1.44) are the intertemporal marginal rate of transformation between consumption and LFP which state that if the economy consumes one unit less in period t then how many additional units it can achieve in period $t+1$. The last two equations are equivalent if the first one holds.

The equilibrium wedges that arise in the decentralized monetary economy change the above efficient conditions as follows:

$$\frac{N'(LFP_t)}{u'(C_t)} = \frac{1}{\left[1+A\left(1-R_t^{-1}\right)\right]}\{\chi + \left(1-\tau_t^h\right)\gamma\frac{\omega}{1-\omega} Q_t \frac{1}{\left[1+B\left(1-R_t^{-1}\right)\right]}\} \\ = \gamma\frac{\kappa}{1-\kappa} Q_t \{ \frac{\chi(1-\kappa)}{\gamma\kappa Q_t} \frac{1}{\left[1+A\left(1-R_t^{-1}\right)\right]} \\ + \left(1-\tau_t^h\right) \frac{\omega(1-\kappa)}{(1-\omega)\kappa} \frac{1}{\left[1+B\left(1-R_t^{-1}\right)\right]} \frac{1}{\left[1+A\left(1-R_t^{-1}\right)\right]}\} \quad , \tag{1.45}$$

$$\frac{\gamma Q_t^{\kappa}}{\zeta} = Z_t MC_t \left(1 - \frac{\omega}{\left[1+B\left(1-R_t^{-1}\right)\right]}\right) - \frac{(1-\omega)}{(1-\tau_t^h)}\chi \\ + \frac{(1-\rho)\beta\left[1+A\left(1-R_t^{-1}\right)\right]}{u'(C_t)} E_t\{ \frac{\gamma Q_{t+1}^{\kappa}}{\zeta} \frac{u'(C_{t+1})}{\left[1+A\left(1-R_{t+1}^{-1}\right)\right]} [1 - \frac{\omega}{\left[1+B\left(1-R_t^{-1}\right)\right]} \\ + \frac{\omega\left(1-\tau_{t+1}^h\right)}{\left(1-\tau_t^h\right)} \frac{1}{\left[1+B\left(1-R_{t+1}^{-1}\right)\right]} \left(1-\zeta Q_{t+1}^{1-\kappa}\right)]\} \tag{1.46}$$

Condition (1.45) obtained by using eqs. (1.16), (1.28) and (1.34). Condition (1.46) obtained by substituting the Nash wage outcome (1.39) into the vacancy creation condition (1.16). Comparison of (1.45) with (1.42) and (1.46) with (1.43) and (1.44) reveal the within-period and intertemporal wedges. The wage determination mechanism, the imperfect competition which makes MC_t different from 1, distorting labor taxes, and the two cash constraints are the four features that create inefficiencies in the above listed conditions. Important to note from eq. (1.45) is that, if worker's bargaining power ω were zero, then neither tax rate nor firm's working capital constraint would have any effect on the within period wedge. This is not true for the cash constraint for households. This condition also makes it clear that sufficient conditions to achieve within-period (static) efficiency are that the decentralized economy features $A = B = \chi = \tau^h = 0$ and $\kappa = \omega$. The mentioned conditions are not necessary conditions because for example for any value for χ, κ, A, B and ω different from zero, a suitable setting of nominal interest rate R_t and labor tax rate τ_t^h can achieve efficiency.

Achieving intertemporal efficiency (zero intertemporal distortions) is not, however, possible once we look at it through the lens of condition (1.46). The reason behind it is that even if all the above mentioned parameters were zero, still because of the nominal rigidities in the form of price stickiness and the imperfect competition $MC_t \neq 1$.

1.5.3 Analysis and Intuition

The most important policy implication of the models featuring a New Keynesian Phillips curve and Walrasian labor markets (as the third and fourth columns of table (1.2) display) is the optimality of price stability. This policy implication is also the case and survives in a cashless economy with lump-sum taxes and matching frictions (as the second column of the table shows), for the whole range of bargaining weight on the workers part and even a price stickiness parameter 10 times smaller than the baseline calibration. The reason for this optimality is that it eliminates the inefficiencies brought about by the presence of price-adjustment costs. This optimality insight, however, doesn't apply to the present monetary model with distorting taxes and frictional labor markets, as these frictions generate an unemployment/inflation trade-off. The trade-off is overwhelmingly resolved in favor of unemployment once worker's bargaining weight is low enough. As I mentioned before and the condition (1.46) clearly shows, the decentralized economy not only doesn't achieve efficient fluctuations in the long run but also along the business cycles, hence, the optimal policy would be to minimize distortions as much as possible over the business cycles.

With low worker bargaining power, not only surplus sharing that goes to workers is very low but more importantly it makes the static and intertemporal wedges to fluctuate very inefficiently that in turn lead to highly inefficient fluctuations in employment and labor market tightness, which is in fact a good summary statistic for labor market outcomes. And since the intertemporal efficiency or in my model minimizing intertemporal inefficiencies is the paramount concern of the social planner, it uses an appropriate combination of time-varying inflation, nominal interest rate and labor taxes to take care of the concern and reduces the inefficient fluctuations in the wedges. However, the results presented above make it quite clear that it is the inflation rate that plays the major role in inducing efficient fluctuations in the labor markets. By raising the bargaining power ω, surplus sharing shifts toward workers and leads to substantial reductions in the inefficient fluctuations in labor market tightness Q_t.[10] Therefore, the Ramsey planner finds it optimal to keep volatilities of inflation and tax rates very low since changing the former is costly and the later is distortionary and inefficient.

Table 1.3: Ramsey-optimal policy with different values for ω

variable	baseline monetary economy			no-fiscal cashless economy		
	mean	Std.dev	Autocorrelation	mean	Std.dev	Autocorrelation
			A. $w = 0.1$			
τ^h	30.6	4.7	0.1819	-	-	-
π	2.5	6.1	0.1472	0.005	0.23	0.8540
R	6.6	2.5	0.8034	3.8	7.7	0.8957
$output$	0.49	0.012	0.8448	0.49	0.008	0.8984
			B. $\omega = 0.2$			
τ^h	30.7	2.2	0.4045	-	-	-
π	0.76	2.8	0.1321	0.002	0.12	0.7217
R	4.8	1.08	0.8567	4.2	7.7	0.8883
$output$	0.49	0.01	0.9050	0.49	0.008	0.8995
			C. $\omega = 0.4$			
τ^h	27.8	1.05	0.9401	-	-	-
π	-0.39	0.44	0.0403	0.002	0.04	-0.0866
R	3.7	0.41	0.7313	4.6	7.3	0.8946
$output$	0.49	0.009	0.9087	0.49	0.0075	0.9038
			D. $\omega = 0.9$			
τ^h	21.4	1.01	0.8767	-	-	-
π	-0.1	0.13	0.0066	0.0000	0.01	-0.1130
R	3.9	0.44	0.4810	4.5	6.3	0.8790
$output$	0.49	0.007	0.9042	0.48	0.006	0.9025

Note: τ^h, π_t and R_t are expressed in percentage points and $output$ in level.

Table (1.3) reports Ramsey optimal policy for the baseline monetary economy with distorting taxes and the cashless counterpart with lump-sum taxes for different values of ω. Both columns of the table quite clearly show that worker's bargaining weight and the optimal inflation rate and its volatility are related negatively. This negative relationship is also the case between the bargaining power and the optimal income tax rate and its volatility in the baseline model. Panel C shows how in the baseline model the optimal rate of inflation and its variability decline remarkably to near zero once the Hosios efficiency condition is satisfied. In this case, the optimal volatility of tax rate also drops by more than 80%. In fact, in both economies by increasing workers bargaining power ω both the optimal fluctuations in inflation π_t and the optimal rate of inflation substantially decline. This is also the case for the nominal interest rate R_t and labor taxes τ_t^h. Figure (1.1) shows

[10] Although not reported here, the simulation results evidently show that the standard deviations of labor market tightness, employment and the fraction of searching people drop remarkably by raising worker's bargaining power.

the negative relationship between the standard deviation of inflation and the worker's bargaining power ω in a more clear way.

This negative relationship contrasts sharply with the conclusions from a related analysis in Faia (2009). Faia derives optimal monetary policy in a model with matching frictions, monopolistic and sticky prices. More precisely, she finds that in response to government expenditure and technology shocks the optimal inflation volatility increases with the worker's bargaining power. There are, however, several contrasts between her framework and analysis and mine. First, she doesn't explicitly focus on sample moments of Ramsey-optimal policy and doesn't report them, while at the center stage of this paper is the calculation of the moments using Monte Carlo simulations.[11] Second, Faia assumes lump sum taxes and so no fiscal policy. Third, she doesn't incorporate a labor force participation decision in her model and households utility function is a function of only consumption. Fourth, in Faia model, the steady state inflation rate is zero. Fifth, the standard deviation of inflation in her model for different values of bargaining power is also extremely low and in the range of (0.02-0.12) which in the present framework are accounted as near zero.

Nevertheless, for different versions and different calibrations of the model I get qualitatively exactly the same results. This, as we saw above in table (1.3), is also the case with lump-sum taxation. However, if in the model with lump-sum taxes, in order to make my model as close as possible to Faia model, the unemployment transfers are assumed to be zero ($\chi = 0$) and households are assumed to derive no direct utility from leisure ($\upsilon = 0$), then I get qualitatively the same results as Faia, but of course quantitatively the results are different.

Important to note is that, as the second column of Panel B shows, the optimal inflation volatility is not exactly zero in the cashless economy with lump-sum taxes once the Hosios efficiency is met. There are two reasons for this. First, as is mentioned in the introduction, I do not assume the government subsidizes the economy to undo imperfect competition distortion. Second, χ is different from zero.

The reason behind a very high and positive optimal inflation rate in the baseline monetary economy, is the presence of a money demand for households. To understand this, we should analyze the impacts of such a demand on the New Keynesian Phillips curve. By merging eqs. (1.17) and (1.26), the New Keynesian Phillips curve takes the following form

$$\pi_t(\pi_t - 1) = \beta E_t \left(\frac{u'(C_{t+1})}{u'(C_t)} \frac{\left[1 + A\left(1 - R_t^{-1}\right)\right]}{\left[1 + A\left(1 - R_{t+1}^{-1}\right)\right]} \right) \left[\pi_{t+1}(\pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} \right] + \left[1 - (1 - MC_t)\,\xi\right]/\theta, \tag{1.47}$$

[11] This is the method that has been used by Arseneau and Chugh (2012, 2008); Schmitt-Grohé and Uribe (2005b, 2004,b, 2007); Siu (2004) among many others.

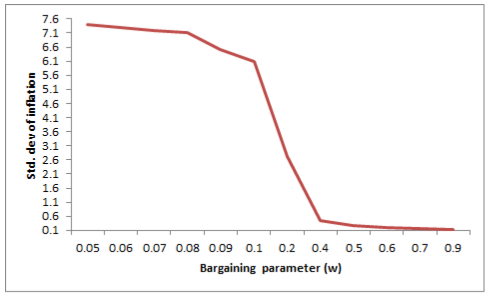

Figure 1.1: Degree of Bargaining Power and Optimal Inflation Volatility. The Standard Deviation of Inflation Is Measured in Percent per year.

This optimal price-setting behavior makes it quite clear that the current and expected inflation are functions of household's money demand friction. Because of the presence of both current and future nominal interest rate, finding an explicit relation between inflation rate and money demand friction is not possible and the mapping is a complicated endogenous object than can be approximated only quantitatively. Table (1.4) presents simulation results for different pairs of (A, B) for the baseline monetary economy with matching frictions and the baseline monetary economy with Walrasian-based wages.

In the economy with Walrasian-based wages there is no significant change in the optimal inflation volatility and the optimal rate of inflation also remains very low. Only for $A = 1$ the optimal inflation rate rises to 1.6 percent per year. But in the case of baseline model when wages are Nash-bargained and households have motivations to hold money, then the optimal inflation rate is very high and for the baseline calibration is as high as 9.6% per year. Once the fraction of consumption expenditures for households that must be backed by money rises to 100% ($A = 1$), as the first column of Panel C shows, on the one hand the optimal inflation rate rises to 16.4% and its optimal volatility drops to 3% and on the other hand significantly lesser labor tax volatility becomes optimal. This is not, however, the case once only firms have motivations for holding cash balances. As Panel A shows, in this case, whilst the optimal rate of inflation is on average negative and low, both the optimal inflation and income tax variabilities are about 4% higher than the case of cash constraint only for households.

These results, along with the results presented in table 2, make it again quite clear that the optimal inflation rate and its volatility and the optimal income tax rate and its variability are related negatively. Indeed, this is also the case between the optimal rate of inflation and the optimal inflation volatility. An inspection of table 3 shows that when the optimal inflation rate is quite high the optimal inflation volatility is significantly lower than the cases where the optimal inflation rate is on average low and negative. To understand the intuition behind these results, we should consider the New-Keynesian Phillips curve with monetary friction (1.47) along with static and intertemporal wedges conditions (1.45) and (1.46) and the Nash-bargained wage condition (1.39) together and as a system. Once workers bargaining power is low, inefficient labor market fluctuations are high and very costly. Hence, due to the presence of money demand friction for households, the Ramsey government finds it optimal to use a very high inflation rate which is not very volatile to ensure efficient fluctuations and also to stabilize the labor market over the business cycle. In the absence of the household's money demand friction, however, the Ramsey-optimal policy calls for an extremely volatile inflation rate along with high variations in income taxes to achieve efficient fluctuations.

Table 1.4: Ramsey-optimal policy for different values of (A, B)

variable	monetary economy with matching frictions			frictionless labor-monetary economy		
	mean	Std.dev	Autocorrelation	mean	Std.dev	Autocorrelation
A. $(A, B) = (0, 0.52)$						
τ^h	30.7	9.4	0.2036	20.7	0.41	0.6663
π	-0.73	12.3	0.0261	-0.04	0.55	0.7138
R	2.9	7.3	0.1563	3.9	0.3	0.3967
$output$	0.49	0.013	0.5512	0.31	0.005	0.8999
B. $(A, B) = (0.38, 0)$						
τ^h	30.6	6.2	0.0837	20.5	0.42	0.6577
π	9.1	7.1	0.1653	0.75	0.54	0.7187
R	13.4	4.8	0.5858	4.8	0.2	0.8205
$output$	0.49	0.0098	0.6563	0.31	0.005	0.9005
C. $(A, B) = (1, 0)$						
τ^h	28.5	2.5	0.2371	20.03	0.43	0.6591
π	16.4	3.04	0.3499	1.6	0.5	0.6815
R	21.1	2.7	0.6711	6.1	0.15	0.9044
$output$	0.49	0.008	0.7959	0.31	0.005	0.9009
D. $(A, B) = (0, 0)$						
τ^h	30	11.1	0.1568	20.6	0.4	0.6297
π	-0.17	12.7	0.0416	-0.03	0.5	0.7196
R	3.5	8.1	0.2077	4	0.22	0.4836
$output$	0.49	0.015	0.5600	0.31	0.005	0.9005
E. $(A, B) = (1, 1)$						
τ^h	25.7	2.3	0.3962	19.9	0.45	0.7164
π	16.7	3.3	0.3381	1.9	0.5	0.6512
R	21.4	2.7	0.6625	6.02	0.14	0.8803
$output$	0.49	0.0075	0.8439	0.31	0.005	0.9031

Note: τ^h, π_t and R_t are expressed in percentage points and $output$ in level.

1.6 Welfare Measuring

Like some of the recent widespread application of DSGE models with matching frictions, I conduct policy evaluations by computing the welfare cost of a particular monetary/fiscal policy regime relative to the time-invariant equilibrium process associated with the Ramsey policy. The particular policy regime that I focus on is the strict inflation targeting policy which is a standard comparison in the matching literature. To measure the welfare costs I follow Schmitt-Grohé and Uribe (2007, 2005b) and use their procedure to conduct policy evaluations by computing the welfare losses of strict inflation targeting regime relative to the time-invariant equilibrium process associated with the Ramsey policy. I estimate the welfare conditional on a particular state in period 0 where all state variables of the economy equal their respective Ramsey-steady-state values and the policy regime has the same steady state. Schmitt-Grohé and Uribe (2007) find that conducting policy evaluations conditional on an initial state different from the Ramsey steady state deliver similar results. Let the Ramsey-optimal policy and the strict inflation targeting policy be denoted by RP and IP, respectively. Let also the equilibrium processes for consumption and labor force participation associated with a particular policy be $\{C_t, LFP_t\}$. Then welfare is measured as the conditional expectation of lifetime utility as of time zero evaluated at $\{C_t, LFP_t\}$ and is denoted by V_0

$$V_0 = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, LFP_t\right) \tag{1.48}$$

where at time 0 all state variables take the associated Ramsey-steady-state values. Let $V_0^{RP}$and V_0^{IP} define the welfare levels associated with the Ramsey-optimal and strict inflation targeting policies. If Θ be the welfare cost of adopting price stability policy instead of the Ramsey-optimal policy conditional on a particular state in period 0, then a second order approximation of it around the deterministic Ramsey steady state of the state vector yields

$$\Theta \approx (V^{RP}_{\sigma_\varepsilon\sigma_\varepsilon} - V^{IP}_{\sigma_\varepsilon\sigma_\varepsilon})(1-\beta).\frac{\sigma_\varepsilon^2}{2}, \tag{1.49}$$

where σ_ε is a parameter scaling the standard deviation of the exogenous shocks. Θ measures, in fact, the fraction of the Ramsey-optimal policy consumption process that a household would be willing to give up to be as well off under price stability policy as under the Ramsey-optimal policy.

Table (1.5) reports welfare costs associated with strict inflation targeting, interpreted to be any monetary policy capable of bringing about zero inflation at all times, for the baseline monetary economy with labor taxes and the cashless economy with lump sum taxes for different values of bargaining power ω, by keeping fixed the other structural parameters at their baseline values. The point of comparison for the policy evaluation is the time-invariant stochastic real allocation associated with the Ramsey policy. The table reports conditional welfare cost as defined in eq. (1.49).

Table 1.5: Welfare costs of price stability for different values of ω

ω	monetary economy welfare cost ($\Theta \times 100$)	cashless economy welfare cost ($\Theta \times 100$)
0.05	20.8366	0.3995
0.06	12.4711	0.3669
0.07	8.2319	0.3382
0.08	5.8063	0.3127
0.09	4.2883	0.2901
0.1	3.2764	0.2699
0.11	2.5698	0.2519
0.4	0.1173	0.0819
0.5	0.0794	0.0713
0.6	0.0629	0.0661
0.7	0.0552	0.0636
0.9	0.0500	0.0624

In table 5, ($\Theta \times 100$) is defined as the percentage decrease in the Ramsey-optimal consumption process necessary to make the level of welfare under the Ramsey policy identical to that under the strict inflation targeting rule. The first row of table 5 shows the welfare cost consequences of price stability for the baseline value of ω. It shows that the welfare cost of strict inflation targeting for the monetary economy is huge. For the monetary economy it is about 21 percent and for the cashless economy is about 0.4 percent of the consumption stream associated with the Ramsey policy. These results imply that the welfare cost of price stability in the monetary economy is 50 times more than the welfare cost of price stability in the cashless economy once $\omega = 0.05$. I then do the same exercise for different and higher values of ω. As the next rows of the table show, the welfare costs are monotonically decreasing in ω. By raising the bargaining share by only one percentage point, the welfare cost of strict inflation targeting for the baseline model reduces by more than 30%. Once the bargaining share is only 5% points higher and $\omega = 0.1$, it decreases by about 80% and is equal to 3.28. Although, the welfare cost for the case $\omega = 0.1$ is significantly lower than the case $\omega = 0.05$ but still is very high compared to the welfare cost of price stability for the same value of ω in the cashless economy. These findings demonstrate how the slope of the welfare is extremely sensitive to the bargaining power of workers in the monetary model in the presence of distorting taxes, specifically for the low values of the bargaining power. The reason that the welfare cost of strict inflation targeting for the monetary economy is so high goes back to the high desirability of the Ramsey planner to use inflation to minimize inefficiently high static and intertemporal wedges fluctuations, when the bargaining share of workers is low. In the

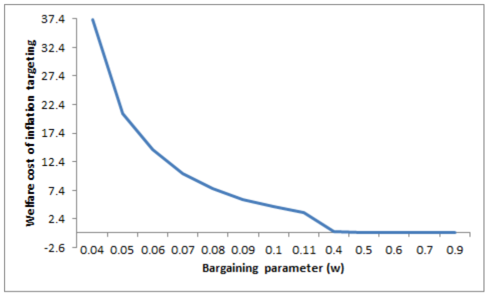

Figure 1.2: Degree of Worker's Bargaining Power and the Welfare Costs of Price Stability

cashless economy, because the several intertemporal distortions present in the monetary economy are absent, the cost of price stability is much lower.

To make it more clear, figure (1.2) illustrates the impact of raising the bargaining power ω on the welfare costs of price stability in the baseline monetary model. Once ω is high enough the model implies that the welfare costs of strict inflation targeting are negligible and close to zero.

Now, it is useful to relate my results on the welfare costs of strict inflation targeting in the cashless economy to what Ravenna and Walsh (2012) report. They report welfare gains or losses under parametrization which is either implying efficient labor matching in the sense of Hosios ($\omega = \kappa = 0.5$) or if not, the worker's bargaining power is higher than the associated efficient level. They find in several calibrated versions of their model that the level of welfare obtained under the optimal policy is very close to the one obtained under a policy of price stability. Indeed, I also find for high values of ω welfare cost is remarkably low and close to zero compared to the low values of ω. But I also find that what is crucial for the size of welfare gains or losses is how much low or high is the worker's bargaining power not it is at the efficient level or not. More precisely, in Ravenna and Walsh (2012) because they subsidize factor inputs to eliminate the distortion introduced by monopolistic competition in product markets, when wages are Nash-bargained and the Hosios efficiency condition holds the first best allocation or 'divine coincidence' occurs. But since I do not follow this practice, automatically we are away from the first best and unable to replicate it and so in the presence of inefficiency of wage setting in the spirit of Hosios, the optimal way is to deal with both distortions simultaneously. In other words, the optimal way to deal with a distortion depends on other existing distortions. Also since Ravenna and Walsh do not report welfare costs for low values of bargaining power, one cannot know whether welfare costs still remain negligible for that cases. Once I adopt their calibration of parameters and apply it to my model for the case that they have report on relative optimal inflation volatility (the case with Nash bargaining wages where $\omega = 0.7$ in table 5 of their paper), I find an optimal inflation volatility (about 0.05%) much lower than their report (0.22%) that implies a very low welfare cost for inflation strict targeting policy. These similar results obtained despite the differences in

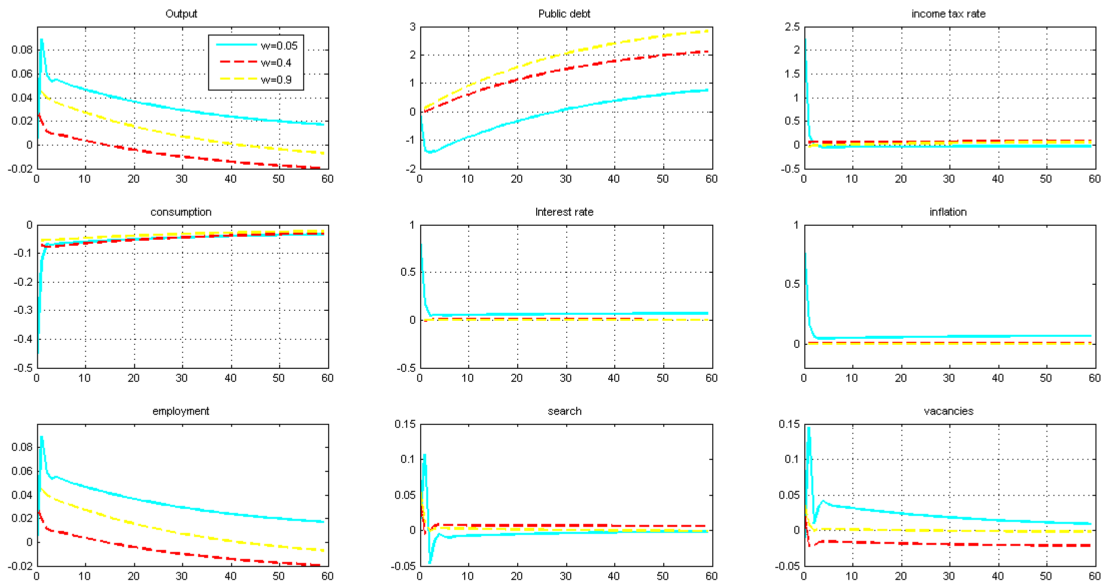

Figure 1.3: Dynamic Path for the Baseline Monetary Economy with Matching Frictions in Response to a 1 Percent Positive Shock to G_t for Three Different Values of ω.

the models frameworks and different solution methods and also the fact that Ravenna and Walsh subsidize factor inputs and assume an efficient steady state.

1.7 Impulse Responses

In this section, I first study impulse responses of the baseline monetary economy to government expenditures and TFP shocks for three different values of bargaining weight (0.05, 0.4 and 0.9), and then for the case $\omega = 0.05$, I compare the responses of the baseline model economy with the responses of the cashless economy with lump-sum taxes and matching frictions. Specifically, I first investigate the extent to which the introduction of matching frictions changes the Ramsey allocation behavior, compared to the one arising in the standard New-Keynesian economy with sticky prices and without real state contingent debt. In other words, I wish to find out whether with labor market frictions the result that under sticky prices the Ramsey planner replaces front-loading revenue via surprise changes in the price level with standard debt and tax instruments and in response to an unexpected increase in government spending the planner does not generate a surprise increase in the price level and instead prefers to finance the increase in expenditures through an increase in taxes and public debt can be obtained.

Fig. (1.3) displays the impulse responses to a one-percent increase in government spending

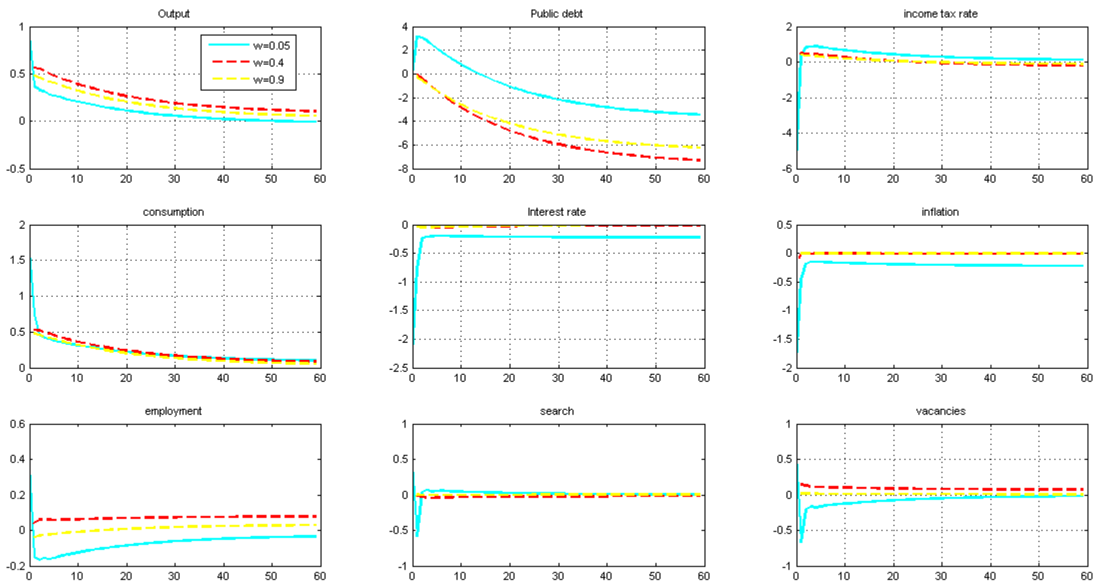

Figure 1.4: Dynamic Path for the Baseline Monetary Economy with Matching Frictions in Response to a 1 Percent Positive Shock to Z_t for Three Different Values of ω.

predicted by the baseline model. We see that, once the bargaining power is low, the model economy has a significant response to the shock in comparison with the other two cases which the economy response is very mild. The baseline model predictions about inflation, public debt and taxes for the baseline value of bargaining power $\omega = 0.05$ (shown with the cyan line) are in a sharp contrast to the predictions of standard New-Keynesian model with Walrasian-based wages. The shock leads to a substantial rise in inflation and labor taxes and a sharp drop in public debt in this case. While the increase in labor tax is in line with the standard New-Keynesian framework, but its inheritance of the stochastic process of the underlying exogenous shock is in contrast to that framework, which predicts a unit root behavior in public debt and taxes. Despite the fact that prices are sticky and changing them are costly, the government finds it optimal to increase the price level which leads to a sharp decline in real public debt. The model also predicts a rise in output, employment, the number of people searching for jobs and vacancies. Output and employment responses are approximately the same and go in the same direction. The model also implies that, consistent with the preceding analysis, by increasing ω the Ramsey planner doesn't inflate away because price increases are costly and instead finances its spending partly by increasing taxes and partly by increasing public debt. Although it's not very clear in the figure for the labor tax due to the large response in the case $\omega = 0.05$, but both taxes and the stock of public debt display persistent increases and display random walk behavior for $\omega = 0.4, 0.9$, consistent with the standard result.

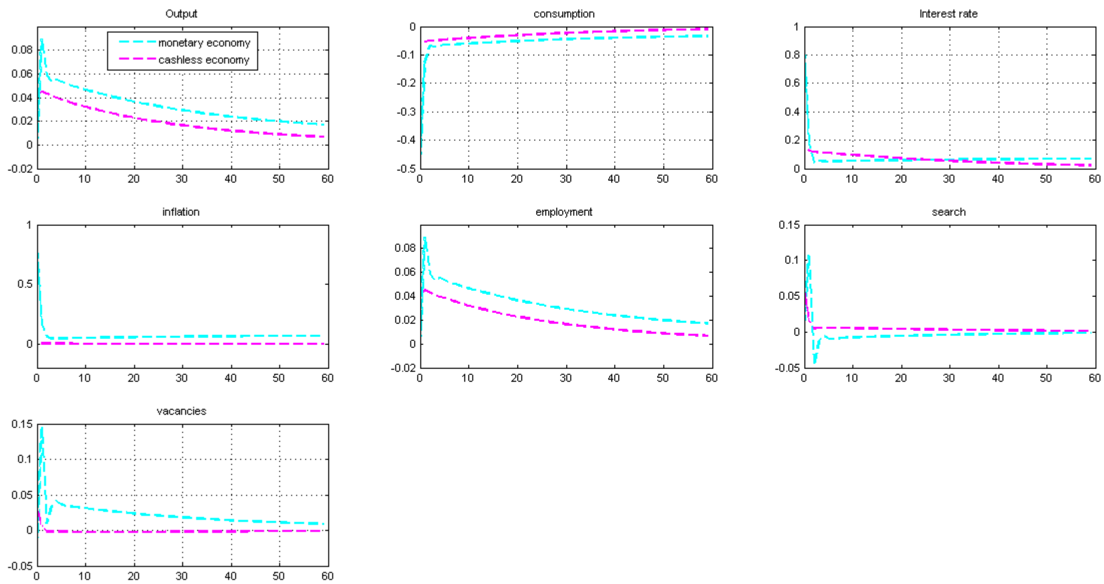

Figure 1.5: Dynamic Path for the Baseline Monetary Economy and the Cashless Economy in Response to a 1 Percent Positive Shock to G_t for $\omega = 0.05$.

Fig. (1.4) displays the path of the economy in response to positive TFP shocks. Again, like the response to the government spending shock, the responses of the case $\omega = 0.05$ are very larger than the responses of the cases $\omega = 0.4, 0.9$. The increase in total factor productivity leads to an increase in output and consumption that is greatly amplified for the case $\omega = 0.05$. The shock also induces a remarkable drop in inflation once the bargaining power is low. Due to the sharp and large falls in taxes the real wages (not shown here) decrease substantially. Taken together the decreases in inflation and real wages, unitary profits of firms increase and as a result firms post more vacancies and employment increase for $\omega = 0.05$ on impact. However this doesn't last and after a while due to the rise in inflation vacancy postings drop substantially and leads to a significant decrease in employment and an increase in search activity. Compared to this case, once the bargaining power rises, on the one hand the drop in inflation and the increases in output and consumption are greatly mitigated. On the other hand, tax rates, vacancy postings and employment increase. The response of public debt is also intuitive. for the case $\omega = 0.05$ that the drops in inflation and tax rates are high, the stock of public debt increases substantially on impact. when the bargaining power rises and income taxes increase and the drop in inflation is mitigated, then as a result the public debt decreases.

To ascertain the role played by the low bargaining power on the part of workers in the monetary economy and in the presence of distorting taxes, Figures (1.5) and (1.6) display the responses of the baseline economy without lump-sum taxes and the cashless economy with lump-sum taxes

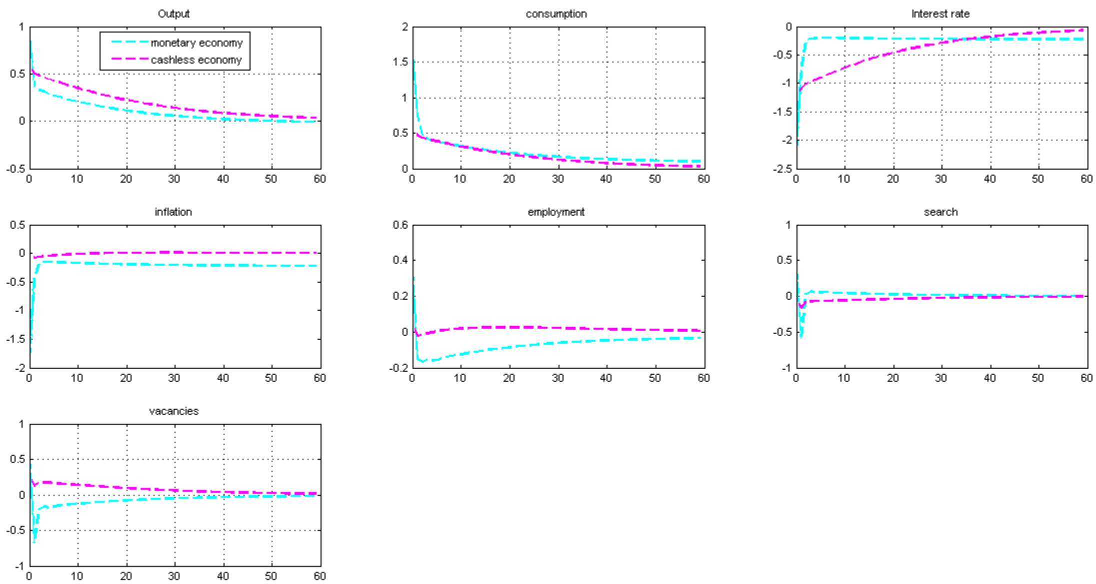

Figure 1.6: Dynamic Path for the Baseline Monetary Economy and the Cashless Economy in Response to a 1 Percent Positive Shock to Z_t for $\omega = 0.05$.

to government expenditures and technology shocks for seven macro variables. First, we see that the responses of the monetary model to both shocks are very significant and very larger than the responses of the cashless economy. For example, in response to the government expenditure shock, inflation jumps up sharply and has a strong response in the monetary economy, the response of inflation in the cashless economy is much more limited and is approximately zero. This remains also the case for the other macro variables.

In response to a positive technology shock (Figure 6), the cashless economy's response, like its response to the government expenditures shock, is much more smaller than the monetary economy's response to that shock, for all the interested macro variables. In particular, the negative response of inflation is significantly smaller than the responses of the same variable in the case of monetary economy. On the other hand, the responses of employment and vacancy postings to the TFP shock in the both economies are very different and in contrast to each other. As I explained before, after a while vacancy posting and employment fall below the steady state in the monetary economy, but this is not the case in the cashless economy. Both variables rise on impact and do not display any decrease relative to the their steady state values. The response of the fraction of search workers in the cashless economy is much smaller than the monetary economy and also displays a different manner. While the number of workers searching for a job jumps down on impact and then converges to zero in the cashless economy, in the monetary economy, in contrast, it jumps up on impact and then declines substantially and rises again above the steady state. Important to emphasize is that, in response to the government spending shock, the fraction of searching workers has a large positive response and then converges to zero in the cashless economy, while it jumps up and then down and then converges to below zero in the monetary economy.

1.8 Conclusion

In this paper, I study the Ramsey-optimal policy in the context of a New Keynesian monetary model with labor matching frictions. I jointly characterize optimal fiscal and monetary policy. My main results are to demonstrate how the optimal policy calls for an extremely high inflation rate that is highly volatile and how the welfare costs of price stability are huge once the worker's bargaining power is low and the government has no access to lump-sum taxes but only distortionary taxes. The existing papers that study the optimal monetary policy in a DSGE model with labor market frictions and in the presence of sticky prices limit their attention to the cashless economies with lump-sum taxes, which are empirically unrealistic assumptions. In contrast, to study optimal monetary policy, I develop a general equilibrium matching model with sticky prices, money, and distortionary labor income taxes, which is an extension of the DSGE matching and perfectly competitive model of Arseneau and Chugh (2012).

I find that: first, the optimal policy implies an inflation rate that is extremely high and volatile once the bargaining share of workers is low. Second, price stability for low values of bargaining power is significantly harmful and the welfare costs in terms of consumption are very high. Third, I find a clear trade-off between the optimal rate of inflation and its volatility and the optimal income tax rate and its variations. While, in contrast to the standard New Keynesian literature and the cashless models with matching frictions, for a small degree of price stickiness parameter, the Ramsey-optimal policy, due to the presence of a cash-in-advance constraint on purchases of the consumption good, calls for a high inflation rate that is very volatile. It, at the same time, calls for a lower income tax rate that is significantly less volatile. Fourth, the results make it quite clear that, it is the inflation that plays the main role in inducing efficient fluctuations in labor markets, not taxes, despite the fact that prices are sticky and costly to change. Fifth, my results show that, by increasing bargaining power the optimal rate of inflation and its volatility drop substantially, such that once the bargaining power is set to 0.9, they fall to near zero. Sixth, with high values for the bargaining power or in the absence of distorting taxes and the presence of lump-sum taxes, my model confirms the standard results in the literature.

Chapter 2

Monetary Policy Rules in a Frictional Labor Market with Distortionary Taxes

2.1 Introduction

In this paper, I consider a general equilibrium search and matching model with sticky prices and distorting labor income taxes that incorporates a labor force participation decision. I use this model to show that, in contrast to the conventional wisdom, even in the presence of price adjustment costs, inflation targeting is remarkably welfare detrimental and at the same time responding to output or labor market tightness yields significantly lower welfare costs than just responding to inflation. I analyze the policy implications of three simple monetary rules: an strict inflation targeting rule, a rule that responds to output, and a rule that responds to labor market tightness, with smoothing and no-smoothing nominal interest rates.

As a benchmark, I consider a model economy that is similar to the fully flexible price model of Arseneau and Chugh (2012), where they consider a simple DSGE labor search and matching model and calibrate it to the U.S. data in such a way that it generates business cycle fluctuations for several key labor market outcomes very close to the empirical evidence. For Arseneau and Chugh (2012) results, the bargaining parameter is very crucial. Hagedorn and Manovskii (2008) proposed a new way to calibrate the parameters of the Mortensen-Pissarides model and found that a reasonably calibrated model is consistent with the key business cycle facts. Two central parameters for their finding are the worker's value of non-market activity and the worker's bargaining weight where the first one is substantially higher and the second one is substantially lower than the values used in the standard parametrization of the Mortensen-Pissarides model. I adopt the Arseneau and Chugh (2012) calibration for these two parameters where they relied on Hagedorn and Manovskii (2008) calibration. For the other search and matching parameters, I also adopt their calibration. I depart from Arseneau and Chugh (2012) by assuming an imperfectly competitive monetary economy where price are sticky a la Rotemberg (1982) and by introducing money into the model via a cash-in-advance constraint on consumption goods. I also, in order to make my model comparable to the vast literature on the joint determination of fiscal and monetary policy in New Keynesian frameworks, assume that debt is non-contingent nominal debt. Because I want to consider firms that are price setters, I assume that final consumption is a composite good, aggregated over a continuum of goods with the Dixit-Stiglitz aggregator. Each good is produced by a monopolist, and all producers share the same labor-only linear technology. In the model, business cycles are driven by stochastic variations in the level of government expenditures and total factor productivity.

First, I compute the welfare losses of strict inflation targeting rule and a rule that responds to output in the absence of labor market frictions. In the existing literature there are two key results on the welfare costs of monetary policy rules in the context of the New Keynesian paradigm with and without frictional labor markets. First, strict inflation targeting delivers a welfare level that is virtually identical to the one obtained under the Ramsey-optimal policy. Second, response to output is always welfare detrimental. For example, Schmitt-Grohé and Uribe (2007) evaluate the stabilizing properties of simple monetary and fiscal rules in a calibrated Walrasian-based model of the business cycle with sticky prices, money and distortionary taxes. They find that welfare is virtually insensitive to changes in the inflation coefficient and responding to output is significantly harmful. Faia (2008) confirms these results in the context of the Canonical New Keynesian model but with matching frictions. In her model the government has access to lump-sum taxes and the bargaining weight is at the Hosios efficiency level. To quantify the differences in the level of welfare under the Ramsey-optimal policy and under the monetary rules, I compute the welfare costs of the monetary rules relative to the time-invariant equilibrium process associated with the Ramsey policy using the methodology of Schmitt-Grohé and Uribe (2007). Once I compute the welfare costs of strict inflation targeting and response to output rules in the absence of matching frictions, I find the same results as Schmitt-Grohe and Uribe, such that the welfare cost of strict inflation targeting is virtually zero while responding to output is welfare detrimental. Like them, I show that the welfare costs increase with varying output coefficient.

Then, I move to the frictional labor market model and I show that how the results dramatically change. For the baseline calibration, my numerical findings suggest that strict inflation targeting is significantly harmful once the bargaining parameter is low. On the other hand, responding to labor market tightness or output can be considerably welfare improving compared to responding only to inflation. This is specifically the case for the market tightness targeting. The welfare costs associated with the rule that responds to the labor market tightness are more than 95% lower than the welfare costs associated with the strict inflation targeting rule. I also show that for low values of the bargaining parameter the welfare costs associated with the simple Taylor rule, the rule that responds to both inflation and output, can substantially be reduced by increasing the output coefficient. This result is striking and in a sharp contrast to the existing literature which implies the interest-rate rules that feature a positive response to output can lead to significant welfare losses, in contrast to the strict inflation targeting rule that features virtually the same welfare as the optimal monetary policy. However, the standard result emerges once we set the bargaining weight at the Hosios level or higher. Indeed, by raising the worker's bargaining weight, the optimal inflation volatility and thus the welfare losses of strict inflation targeting remarkably decline and response to output is no longer welfare improving relative to price stability rule. My numerical results also suggest that the welfare losses of responding to output or labor market tightness are substantially smaller without interest rate smoothing than with interest rate smoothing. This is specifically the case for the response to output rule.

What explains these results? To answer this question, it is useful to relate my findings to the findings of Arseneau and Chugh (2012). In their framework, Arseneau and Chugh (2012) find that Ramsey government uses volatility of labor income tax rates to achieve smooth static wedge and zero intertemporal distortions in order to induce efficient fluctuations in labor markets. As they explained and showed carefully, while like the standard Ramsey models with Walrasian labor market the goal of Ramsey planner is to smooth wedges, the nature of wage determination in a model of labor market frictions and whether they are set efficiently or not determine the very nature of wedges and how they map into taxes. Once the Hosios condition is not met and unemployment transfers are different from zero, they find that the optimal policy features high volatility in both income tax and vacancy subsidy rates in order to keep the volatility of both static and intertemporal distortions low. In the present framework which in contrast to the Arseneau and Chugh (2012) framework is a monetary framework, it is the inflation rate and its variability that play the crucial roles, more crucial than the role of labor taxes, in inducing efficient fluctuations in static and intertemporal wedges, notwithstanding the fact that price adjustment is costly. More precisely, once the worker's bargaining power is inefficiently low, static and intertemporal distortions are very volatile and since the main concern of the Ramsey government is to minimize these distortions as much as possible over time, it uses suitable combinations of time varying inflation, nominal interest and income tax rates along with an extremely high inflation rate to achieve this aim. However, the quantitative results make it quite clear that the main burden of inducing smooth intertemporal wedges over the business cycle falls on the inflation rate and its volatility. Such a result- a substantially high inflation rate which is extremely volatile- is more stark when we recall that price stability appears as the central goal of optimal monetary policy even in the medium-scale macroeconomic models that feature a rich array of real and nominal rigidities, as for example shown by Schmitt-Grohé and Uribe (2005b,a).

Therefore, with a low value for bargaining power on the part of workers if the monetary authority follows the strict inflation targeting, it in fact sets the inflation rate and its variability at zero which produces substantial volatility in static and intertemporal wedges and labor market tightness and, therefore, large and inefficient fluctuations in labor market. By responding to labor market tightness or output along with inflation, inflation variability which is required to minimize inefficient distortions is not anymore zero, although substantially higher than the optimal level, and so welfare losses associated with these rules appear to be smaller than the strict inflation targeting rule. Remarkably, increasing the output coefficient implies lower welfare losses, because it significantly induces lower fluctuations in the wedges and labor market tightness.

When I follow the standard practice in the New Keynesian literature on optimal policy in frictional labor markets models and ignore government financing issues, due to the presence of lump-sum taxation, the results dramatically change. The welfare costs associated with the strict inflation targeting rule, for the same structural parameters from the fiscal-policy model, drop by about 99 percent and responding to output or labor market tightness doesn't anymore imply lower welfare losses. In fact, a positive response of the nominal interest rate to labor market tightness leads to significantly larger welfare losses than a positive response to inflation, even once the bargaining power is low. At the same time the welfare costs of responding to output are monotonically increasing in output coefficient, thereby underlining the importance of not responding to output. These results suggest that it is, in fact, the combination of both the low bargaining power on the part of workers and the presence of distortionary labor income taxes that derives the main findings presented in the paper.

Toward the end, I compare the impulse response functions under the Ramsey policy with the impulse response functions implied by the standard New Keynesian model (the baseline model without labor frictions), that is widely studied in the existing literature.[1]I show that how vastly different the dynamics of the model with matching frictions are from the dynamics of the model without matching frictions, once worker's bargaining weight is low enough. By raising worker's bargaining power to the Hosios efficiency level and higher, the dynamics of the two models become relatively similar.

One of the key findings in the literature on Ramsey-optimal policy in the presence of sticky prices and absence of labor market frictions is that because changing prices are costly, on the one hand, the optimal policy features price stability and on the other hand, tax rates and the real value of government debt exhibit a near random walk behavior in response to a positive fiscal shock. I show that in the frictional labor market model these are not the case when the bargaining parameter

[1]While there is a very large literature on the Canonical New Keynesian model with frictional labor markets, there has been no paper, to the best of my knowledge, that study fiscal and monetary policy jointly in a model with labor market frictions, sticky prices and distortionary taxes.

is set at a small value. Indeed, surprise changes in the price level are optimal in this case and due to these surprises real public debt declines on impact. More precisely, not only inflation jumps up on impact but also it exhibits a near random walk behavior. With increasing the bargaining weight we get similar results to the standard New Keynesian literature.

My work is more broadly related to the literature exploring the consequence of nominal rigidities in models with frictional labor markets.[2] The study most closely related to mine is Faia (2008). However the focus of her paper differs from mine in a number of dimensions. First, Faia considers a framework with lump-sum taxes and real wage rigidities, while in my framework real wages are flexible and the presence of distortionary income taxes is very important for the welfare costs of monetary rules and for the optimal policy implications. Second, she limits her attention to the cases where the Hosios (1990) efficiency condition is met, while the worker's bargaining power and the implications of different values for it are crucial for my results. Third, in terms of policy evaluations, Faia point of comparison is the optimal rule, whilst I follow Schmitt-Grohé and Uribe (2007) and consider Ramsey-optimal policy as the point of comparison. Fourth, my search and matching model incorporates a labor force participation decision, while Faia (2008) model is abstract from this and also the stock of employment is not an object of the preferences.

The rest of the paper is organized as follows. Section 2 lays out the basic search model. In Section 3, I define the Ramsey equilibrium and Section 4 presents the calibration of the model. Section 5 studies the Ramsey optimal policy and computes the welfare costs of different monetary regimes in the absence and presence of search and matching frictions. Section 6 analyzes Ramsey optimal impulse responses of the model with and without frictional labor markets. Section 7 concludes.

2.2 Model Setup

The labor market frictions of the model economy are based on the DSGE labor search and matching model of Arseneau and Chugh (2012). However, in contrast to their model which is a real economy, I consider a monetary economy that allows for imperfect competitions and nominal rigidities. More specifically, I add nominal rigidities in the form of price stickiness, a demand for money by households originated in a cash-in-advance constraint, and assume that the government issues nominal non-state contingent bonds instead of real state contingent bonds. The purpose of these assumptions is to make the framework comparable to the New Keynesian models with and without labor market frictions that focus on Ramsey-optimal policy. The matching frictional part of the model features agents in three labor market states. They are either employed, searching for

[2] For example, Chéron and Langot (2000), Walsh (2003); Thomas (2008); Ravenna and Walsh (2011, 2012); Blanchard and Gali (2010) among many others.

a job or are outside of the labor force and enjoy their leisure.

2.2.1 Preferences

The economy is populated by a continuum (measure one) of individuals with identical preferences represented by the discounted sum of utility over consumption C_t, search activity S_t, and the desired stock of employment N_t^c,

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, S_t, N_t^c\right) \tag{2.1}$$

with

$$U\left(C_t, S_t, N_t^c\right) = u\left(C_t\right) - H\left[\left(1 - pp_t\right) S_t + N_t^c\right], \tag{2.2}$$

and

$$C_t = \left[\int_0^1 c_{it}^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}}, \tag{2.3}$$

where $\beta < 1$. $u(.)$ is a strictly increasing and strictly concave function in consumption C_t that is assumed to be a composite good produced with a continuum of private consumption , c_{it}, of variety $i \in [0, 1]$, defined by Eq. (2.3). $\xi > 1$ denotes the elasticity of substitution between varieties.

The money demand for households is introduced in the form of a cash-in-advance constraint as follows

$$AP_tC_t \leq M_t^h, \tag{2.4}$$

Optimal demand for each variety i takes the familiar form:

$$\frac{c_{it}}{C_t} = \left(\frac{p_{it}}{P_t}\right)^{-\xi}, \tag{2.5}$$

where it has been obtained by minimizing total expenditure, $\int_0^1 p_{it}c_{it}di$, subject to the aggregate constraint (2.3). p_{it} is the nominal price of a good of variety i at time t and $P_t = \left[\int_0^1 p_{it}^{1-\xi}\right]^{\frac{1}{1-\xi}}$ is the nominal price index for final goods.

$H(.)$ is a strictly increasing and strictly convex function in $(1 - pp_t) S_t + N_t^c$ which is defined below. Here pp_t represents the probability of job-finding by households that is given from their point of view. Suppose that ρ denotes a constant separation rate at which the employment relationships that were active in period $t-1$, N_{t-1}^c, experience separations. A fraction of these newly unemployed household members enters the job search process at time t. Thus S_t, the fraction of searching workers, is the sum of this fraction and the fraction of household members that were nonparticipants in the labor market in period $t-1$, but are participants in period t. I now define the measured labor force in period LFP_t as

$$LFP_t = N_t^c + (1 - pp_t) S_t, \tag{2.6}$$

In each period t, LFP_t members participate in the labor force and $1 - LFP_t$ do not participate. In this definition, $(1 - pp_t) S_t$ represents the measure of individuals who turn out to be unsuccessful in finding a job. The fraction of household members who are employed, N_t^c is also defined as

$$N_t^c = (1 - \rho) N_{t-1}^c + S_t pp_t, \tag{2.7}$$

this equation implies that current hires become productive in the same period. This timing is consistent with the bulk of the business cycle literature, where employment is assumed to be a non-predetermined variable and is assumed in Blanchard and Gali (2010) and Arseneau and Chugh (2012) among some others.

The household is assumed to face a sequence of budget constraints given by

$$P_t C_t + B_{t+1} + M_t = P_t (1 - \tau_t) W_t N_t^c + R_{t-1} B_t + M_{t-1} + (1 - pp_t) S_t \chi + \Pi_t, \; t > 0 \tag{2.8}$$

where R_t denotes the gross one-period nominal interest rate, W_t is the real wage, τ_t denotes the income tax rate, B_{t+1} represent risk-free nominal bonds that the representative household holds and M_t is cash balances . χ is the level of unemployment benefits and Π_t is a lump-sum component of income that include, among other items, dividends from ownership of firms or lump-sum taxes. Eq. (2.8) is supplemented with a solvency condition which prevents the household from engaging in Ponzi schemes.

Associate the Lagrange multipliers $\left\{\frac{\lambda_t}{P_t}\right\}$ with the sequence of budget constraints and $\{\mu_t\}$ with the sequence of perceived laws of motion for the measure of family members who are employed, Eq. (2.7). The household's first-order conditions that maximize utility (2.1) subject to the mentioned constraints with respect to the aggregates C_t, B_{t+1}, M_t, S_t and N_t^c are

$$u^{'}(C_t) = \lambda_t \left[1 + A\left(1 - R_t^{-1}\right)\right] \tag{2.9}$$

$$\frac{\lambda_t}{P_t} = \beta R_t \frac{\lambda_{t+1}}{P_{t+1}}, \tag{2.10}$$

$$\lambda_t (1 - pp_t) \chi + \mu_t pp_t = (1 - pp_t) H^{'} [(1 - pp_t) S_t + N_t^c], \tag{2.11}$$

$$\lambda_t (1 - \tau_t) W_t + \beta (1 - \rho) E_t \mu_{t+1} = \mu_t + H^{'} [(1 - pp_t) S_t + N_t^c]. \tag{2.12}$$

Eq. (2.9) denotes that the equality between the marginal utility of consumption and the marginal utility of wealth is distorted by the presence of the money demand, and Eq. (2.10) represents the standard pricing equation for nominal bonds.

Solve Eq. (2.11) for μ_t

$$\mu_t = \left(\frac{1 - pp_t}{pp_t} \right) \left[H^{'} \left[(1 - pp_t) S_t + H_t^h \right] - \lambda_t \chi \right]. \tag{2.13}$$

Now from merging Eqs. (2.11) and (2.12) by eliminating μ_t we get

$$\begin{gathered} \frac{H^{'}(LFP_t) - \chi\lambda_t}{pp_t\lambda_t} = (1 - \tau_t) W_t - \chi + \\ \frac{\beta(1-\rho)}{\lambda_t} E_t \left\{ \left(\frac{1 - pp_{t+1}}{pp_{t+1}} \right) \left[H^{'} (LFP_{t+1}) - \chi \lambda_{t+1} \right] \right\}, \end{gathered} \tag{2.14}$$

where I used the definition $LFP_t = N_t^c + (1 - pp_t) S_t$. Eq. (2.14) gives the optimal labor force participation condition for households. This participation condition asserts that, the fraction of agents searching for jobs is determined in such a way that at the optimum, the expected payoff of searching will be equal to the marginal rate of substitution between consumption and participation.

2.2.2 Government and Monetary Policy

The government imposes distortionary income taxes at rate τ_t, issues one-period nominally risk-free bonds, B_t, and prints money, M_t, to finance a stream of spending, G_t, that is exogenous, stochastic and unproductive. The government is also assumed to pay unemployment benefits, $(1 - pp_t) S_t \chi$, to households. The period t government budget constraint is

$$P_t \tau_t W_t N_t^c + B_t + M_t = M_{t-1} + R_{t-1} B_{t-1} + P_t G_t + (1 - pp_t) P_t S_t \chi, \tag{2.15}$$

Let $A_t \equiv \frac{M_{t-1} + R_{t-1} B_{t-1}}{P_{t-1}}$ denote total real government liabilities outstanding at the end of period $t-1$ in units of period $t-1$ goods.

I assume that the logarithm of variable G_t follows a first-order autoregressive process of the form

$$lnG_t = (1 - \rho^g) lnG + \rho^g lnG_{t-1} + \varepsilon_t^g, \tag{2.16}$$

where $\rho^g \in (-1,1)$ and $G > 0$ are parameters, and ε_t^g is an i.i.d. innovation with mean zero and standard deviation σ^g. The parameter G represents the non-stochastic steady-state level of government expenditures.

I also assume that the monetary authority sets the nominal interest rate according to the following rule

$$ln(\frac{R_t}{R^*}) = \alpha_R ln\left(\frac{R_t}{R^*}\right) + \alpha_\pi ln\left(\frac{\pi_t}{\pi^*}\right) + \alpha_Y ln\left(\frac{Y_t}{Y^*}\right) + \alpha_Q ln\left(\frac{Q_t}{Q^*}\right) \tag{2.17}$$

where Y^* represents the non-stochastic Ramsey steady-state level of output, and R^*, π^*, Q^*, α_R, α_π, α_Y and α_Q are parameters. Here, Q_t denotes labor market tightness. I consider the following monetary rules. (1) a rule that responds to inflation only, strict inflation targeting, $\alpha_\pi = 1.5$, $\alpha_R = 0$, $\alpha_Q = 0$ and $\alpha_Y = 0$, (2) a rule with interest-rate smoothing that responds to output such that $\alpha_\pi = 1.5$, $\alpha_Y = 0.5/4$, $\alpha_Q = 0$ and $\alpha_R = 0.8$, (3) a rule with interest-rate smoothing that responds to labor market tightness such that $\alpha_\pi = 1.5$, $\alpha_Y = 0$, $\alpha_Q = 0.5/4$ and $\alpha_R = 0.8$. (4) I also consider the cases without interest rate smoothing $\alpha_R = 0$. These are very common parameters in the literature. Considering a monetary rule with response to labor market tightness is motivated by the fact that it is a summary statistic of period t labor market outcomes in general equilibrium matching models, as emphasized by Arseneau and Chugh (2012). Recall that the labor income tax rate τ_t is determined optimally in the model when policy is set via any of these simple monetary rules.

2.2.3 Production

The production side of the economy features firms that sell their product in a monopolistic competitive market and in order to hire workers they go to a matching market. Hiring workers is costly such that when firm i posts ϑ_{it} vacancies, it costs γ per-vacancy posting. The labor market mechanism is the same as the Mortensen-Pissarides search and matching model where wages of all workers, whether newly hired or not, are set in period-by period Nash negotiations. The wage-setting protocol is taken as given when firms maximize profits.

Each good's variety $i \in [0, 1]$ is produced by a monopolist that faces quadratic costs of adjusting prices and uses only labor as an input. The monopolist also faces a constant elasticity demand function

$$y_{it} = \left(\frac{p_t^i}{P_t}\right)^{-\xi} Y_t, \tag{2.18}$$

obtained from the demand functions for the private goods (2.5) where $Y_t = Z_t N_t^f$.

Following Arseneau and Chugh (2012) I assume that each firm i begins period t with employment stock N_{t-1}^{f} and the productive employment stock of such a firm in period t, N_t^f, depends on its vacancy postings at that period and the random matching process. Let qq_t denotes the probability that a given vacancy is filled by a worker which is taken as given by the firm. This probability like the matching probability for households, pp_t, is assumed to be dependent only on aggregate labor market conditions.

The representative firm discounts profits of period-t using $\beta^t \frac{\lambda_t}{\lambda_0}$, which is the value to the households of receiving profits, and chooses $\left\{p_t^i, N_{it}^f, \vartheta_{it}\right\}$ to solve the following maximization problem in real terms:

$$Max \;\; \Pi_{it} = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{p_t^i}{P_t} y_{it} - W_t N_{it}^f - \gamma \vartheta_{it} - \frac{\varphi}{2} \left(\frac{p_t^i}{p_{t-1}^i} - 1 \right)^2 Z_t N_{it}^f \right\}, \tag{2.19}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the gross consumer price inflation rate, $\frac{\theta}{2} \left(\frac{p_t^i}{p_{t-1}^i} - 1 \right) Z_t N_{it}^f$ represents price adjustment costs, p_i^t is the price of good's variety i, θ measures the degree of price stickiness and $\gamma \vartheta_{it}$ represents costs of posted vacancies.

The maximization problem is subject to $y_{it} = c_{it}$ that must satisfy the demand function (2.18) and the following sequence of perceived laws of motion for employment level

$$N_{it}^f = (1-\rho) N_{i,t-1}^f + qq_t \vartheta_{it}. \tag{2.20}$$

Let the Lagrange multiplier on the production constraint (2.18) be MC_t, which is, in fact, the marginal cost of the representative firm.

As is common in the literature, I restrict attention to symmetric equilibria where all firms charge the same price for the goods they produce. As a result $p_t^i = P_t$ for all t. But if they all choose the same price, they face exactly the same demand. This in turn means that they will all produce the same amount and will hire an equal amount of labor (since they all face the same aggregate TFP). So I drop the index i. Then the first-order conditions of the above maximization problem yields the following equations

$$\frac{\gamma}{qq_t} = Z_t MC_t - W_t + \beta (1-\rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\gamma}{qq_{t+1}}, \tag{2.21}$$

$$1 - \theta \pi_t (\pi_t - 1) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[\theta \pi_{t+1} (\pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} \right] = (1 - MC_t) \xi, \tag{2.22}$$

Equation (2.21) is job creation condition that is an arbitrage condition for posting of new vacancies. The left side is the search costs associated with hiring $\left(\frac{\gamma}{qq_t} \right)$. The right side is the discounted expected value of profits from a match. Equation (2.22) is the well-known expectations augmented Phillips curve.

2.2.4 Nash-Bargained Wages

Following much of the literature I assume that wages are determined through Nash bargaining.

Like Arseneau and Chugh (2012), let define $V\left(N_{t-1}^{c}\right)$ as the value function associated with the household problem. Then envelope condition by using Eq. (2.13) gives

$$\begin{aligned} V^{'}\left(N_{t-1}^{c}\right) &= (1-\rho)\,\mu_t \\ &= (1-\rho)\left(\tfrac{1-pp_t}{pp_t}\right)\left[H^{'}\left(LFP_t\right)-\chi\lambda_t\right]. \end{aligned} \tag{2.23}$$

Let V_t^E denotes the value of an employed member to a household. This value is defined after labor matching has taken place and so the labor market status of each member's measured is known in period t. Let also define V_t^U as the value of an unemployed member to a household. This value is defined before labor matching takes place. Thus, in contrast to the former case, the participation decisions of household about how many members to be sent to search for jobs occur before matching has taken place. [3]

For a member who is employed, the valuation equation for being in a match that produces in period t is

$$V_t^E = (1-\tau_t)\,W_t + \frac{\beta}{\lambda_t}E_t\left(\lambda_{t+1}\frac{V^{'}\left(N_t^c\right)}{\lambda_t}\right), \tag{2.24}$$

the first term on the right hand side of Eq. (2.24) denotes real wages net of taxes and the second term which is based on envelope condition (2.23), stands for the marginal value of entering period $t+1$ with another preexisting employment relationship. The value of an unsuccessful member in finding a job is given in turn by

$$V_t^U = \chi.$$

Because a household re-optimizes participation at the beginning of period $t+1$ and at this time $(1-pp_t)\,S_t$ is not a state variable, there is zero continuation payoff of an unemployed member to the household. It follows that the household's surplus from an employment can be written as

$$\begin{aligned} V_t^E - V_t^U &= (1-\tau_t)\,W_t - \chi + \tfrac{\beta(1-\rho)}{\lambda_t} \\ &*E_t\left\{\lambda_{t+1}\left(1-pp_{t+1}\right)\tfrac{H^{'}(LFP_{t+1})-\chi\lambda_{t+1}}{pp_{t+1}\lambda_{t+1}}\right\}, \end{aligned} \tag{2.25}$$

[3] For a precise image of the timing of events see page 932 of Arseneau and Chugh (2012).

where I used Eq. (2.23) to get rid of $V^{'}(N_t^c)$. Comparing Eqs. (2.25) and (2.14) reveals that

$$V_t^E - V_t^U = \frac{H^{'}(LFP_t) - \chi\lambda_t}{pp_t\lambda_t}, \tag{2.26}$$

update this expression one period and substitute it in Eq. (2.25)

$$\begin{gathered} V_t^E - V_t^U = W_t - \chi + \tfrac{\beta(1-\rho)}{\lambda_t} \\ *E_t\left\{\lambda_{t+1}(1-pp_{t+1})\left(V_{t+1}^E - V_{t+1}^U\right)\right\} \end{gathered}, \tag{2.27}$$

Note also that the firm's surplus from an established employment relationship, denoted by Υ_t, is given by

$$\Upsilon_t = Z_t MC_t - W_t + \frac{\beta(1-\rho)}{\lambda_t} E_t(\lambda_{t+1}\Upsilon_{t+1}), \tag{2.28}$$

where $\Upsilon_t = \frac{\gamma}{qq_t}$.

The probabilities qq_t and pp_t depend on a constant return to scale matching function which converts unemployed workers S and vacancies ϑ into matches, m:

$$m(S_t, \vartheta_t) = \zeta S_t^{\kappa} \vartheta_t^{1-\kappa}, \tag{2.29}$$

Here S_t and ϑ_t denote aggregate variables, because I assume that we are in equilibrium. Define $Q_t = \frac{\vartheta_t}{S_t}$ as the market tightness at time t. The probability for an unemployed worker to be matched with a vacancy equals $pp_t = \zeta Q_t^{1-\kappa}$ and the probability for a vacancy to be filled equals $qq_t = \zeta Q_t^{-\kappa}$.

Because of the equilibrium $N_t = N_t^f = N_t^h$, hence the aggregate employment is given by

$$N_t = (1-\rho)N_{t-1} + m(S_t, \vartheta_t). \tag{2.30}$$

Let denotes by $\omega \in (0,1)$ the worker's bargaining power. Naturally, the firm's bargaining power will be $1-\omega$. Under Nash bargaining, workers and firms choose W_t to maximize

$$\left(V_t^E - V_t^U\right)^{\omega} \Upsilon_t^{1-\omega}.$$

This maximization problem implies the following sharing rule

$$\frac{V_t^E - V_t^U}{\Upsilon_t} = \frac{\omega}{1-\omega}(1-\tau_t), \tag{2.31}$$

Now by using Eqs. (2.21), (2.27) and (2.31) we get the following wage equation

$$W_t = \omega Z_t MC_t + \tfrac{(1-\omega)}{(1-\tau_t)}\chi + \beta\omega(1-\rho) \\ *\{\tfrac{\lambda_{t+1}}{\lambda_t}\tfrac{\gamma}{qq_{t+1}}[1-(1-pp_{t+1})\tfrac{(1-\tau_{t+1})}{(1-\tau_t)}]\} \tag{2.32}$$

The first two terms of the Nash-bargained wage equation show that part of the period t wage payment is a convex combination of the contemporaneous values to the firm and the household, given by the marginal product of a new employee $Z_t MC_t$ and the value of unemployment benefits $\frac{(1-\omega)}{(1-\tau_t)}\chi$, respectively. The last term of Eq. (2.32) captures the forward-looking aspect of employment, whose value is also capitalized in the period t wage payment.

2.3 Equilibrium and the Ramsey Problem

A stationary competitive equilibrium in this economy, given A_{-1}, the fixed parameter χ and exogenous stochastic processes $\{G_t, Z_t\}_{t=0}^{\infty}$ is a set of endogenous processes

$$\{C_t, H_t, S_t, B_t, W_t, R_t, \vartheta_t, P_t, A_t, M_t, \tau_t, \lambda_t, MC_t\}_{t=0}^{\infty}$$

for $t = 0, 1, \ldots$ that remain bounded in some neighborhood around the deterministic steady-state and satisfy equations (2.10), (2.14), (2.15), (2.21), (2.22), (2.32), the aggregate resource constraint

$$Y_t = C_t + G_t + \frac{\theta}{2}(\pi_t - 1)^2 Y_t + \gamma\vartheta_t, \tag{2.33}$$

and the total aggregate nominal balances constraint $M_t = P_t C_t$.

The problem of the Ramsey planner is to raise revenue to finance exogenous government expenditures through labor income taxes, money creation, and issuance of one-period nominally risk-free government debt in such a way that maximizes the welfare of the representative household Eq. (2.1), subject to the equilibrium conditions of the economy. Put another way, the optimal fiscal and monetary policy is the process $\{\tau_t, R_t\}_{t=0}^{\infty}$ associated with the competitive equilibrium that yields the highest level of utility to the representative household.

2.4 Calibration

I take a period to be a quarter. The structural parameter values implied by the calibration are summarized in table (2.1) . I adopt logarithmic utilities

$$u(C_t) = lnC_t \quad and \quad N(LFP_t) = \frac{\upsilon}{1+1/\phi} LFP_t^{1+1/\phi}, \tag{2.34}$$

where I set $\upsilon = 5.5$ and $\phi = 1$, which are very common values in the literature. The discount factor is set to be $\beta = 0.99$ that is also a common value. Following Basu and Fernald (1997), I assume that the value added mark-up of prices over marginal cost is equal to 0.25.

To calibrate the degree of price stickiness, I follow Chugh (2006) and derive the mapping between the parameter θ in the Rotemberg quadratic price adjustment cost and the probability f of receiving a signal to change prices in the price-stickiness of Calvo apparatus. This mapping delivers the following relationship between θ and f

$$\theta = \frac{1-f}{f}\frac{1}{1-\beta(1-f)},$$

If we assume that the average duration of a price is four quarters, then we get a value for f equal to $\frac{1}{4}$. Therefore, in the present model which is a quarterly model since $\beta = 0.99$, the corresponding Rotemberg parameter is thus $\theta = 13.5$. Chugh (2006) sets this value equal to 5.88 because he assumes that on average 1/3 of firms set price in a given period. I set $A = 1$ which implies that households hold money balances equivalent to 100 percent of their quarterly consumption.

I take the calibration of all of the matching parameters from Arseneau and Chugh (2012). The bargaining parameter, ω, the unemployment benefits χ, the exogenous separation rate ρ and vacancy elasticity of matches $1-\kappa$ are set to 0.05, 0.76, 0.1 and 0.6, respectively. I set the values of matching rate for a searching individual pp_t, the fixed cost of opening a vacancy γ, and the job-filling rate of a vacancy qq_t and the matching parameter ζ equal to $pp_t = 0.61$, $\gamma = 0.27$, $qq_t = 0.9$, $\zeta = 0.77$. The fraction of searching workers S_t in the steady-state is set to 0.09. I set the persistence parameters and the standard deviations of the exogenous processes of the government expenditure shock and the productivity shock such that $\left(\rho^g, \varepsilon_t^g\right) = (0.97, 0.027)$ and $\left(\rho^z, \varepsilon_t^z\right) = (0.95, 0.006)$ following Arseneau and Chugh (2012). Following Schmitt-Grohé and Uribe (2007), I choose G to be 17% of output.

Table 2.1: Baseline Calibration

Calibrated Parameters		Value
β	Discount factor	0.99
θ	Price stickiness parameter	13.5
ξ	The value added mark-up of prices	0.25
υ	Preference Parameter	5.5
A	Fraction of consumption held in money	1
ϕ	Elasticity of participation w.r.t wages	1
z	Steady state productivity shock	1
ρ^g	Serial correlation of $ln\,g_t$	0.97
σ^z	Std. dev of innovation to $ln\,z_t$	0.006
σ^g	Std. dev of innovation to $ln\,g_t$	0.027
ρ^z	Serial correlation of $ln\,z_t$	0.95
γ	Fixed cost of posting vacancy	0.27
ζ	Matching function parameter	0.77
ω	Worker's bargaining power	0.05
χ	Unemployment benefits	0.76
κ	Elasticity of aggregate matches	0.4
ρ	Job separation rate	0.1

2.5 Ramsey-optimal policy and Welfare Measuring

To study the business-cycle properties of Ramsey-optimality policy I approximate the Ramsey equilibrium dynamics by solving a second-order approximation to the Ramsey equilibrium conditions around the non-stochastic steady-state of these conditions. My numerical method is the perturbation algorithm described by Schmitt-Grohe and Uribe (2004) which has been implemented by them for example in Schmitt-Grohé and Uribe (2007, 2004b, 2005b). In computing the sample moments of interested variables, all structural parameters of the model take the values shown in table 1. Second moments are calculated using Monte Carlo simulations. I conduct 1000 simulations, each 200 periods long. For each simulation, I compute sample moments and then average these figures over the 1000 simulations.

To measure the welfare costs of the simple monetary rules discussed above, as I mentioned in the introduction, I follow Schmitt-Grohé and Uribe (2007, 2005b) and use their procedure to conduct policy evaluations by computing the welfare cost of a particular monetary/fiscal policy regime relative to the time-invariant equilibrium process associated with the Ramsey policy. I estimate the welfare conditional on a particular state in period 0 where all state variables of the economy equal their respective Ramsey-steady-state values and all policy regimes have the same steady state. Schmitt-Grohé and Uribe (2007) find that conducting policy evaluations conditional on an initial state different from the Ramsey steady state deliver similar results. Let the Ramsey-optimal policy and the alternative policy be denoted by RP and X, respectively. Let also the equilibrium processes for consumption and labor force participation associated with a particular policy be $\{C_t, LFP_t\}$. The conditional welfare related to the time-invariant equilibrium implied by the Ramsey-optimal policy evaluated at $\{C_t, LFP_t\}$ is denoted by V_0^{RP} and is defined as

$$V_0^{RP} = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^{RP}, LFP_t\right) \tag{2.35}$$

The conditional welfare related to policy regime X is denoted by V_0^X and is defined as

$$V_0^X = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^X, LFP_t\right) \tag{2.36}$$

Let Θ be the welfare cost of adopting policy X instead of the Ramsey-optimal policy. Θ measures, in fact, the fraction of the Ramsey-optimal policy consumption process that a household would be willing to give up to be as well off under price stability policy as under the Ramsey-optimal policy. More precisely,

$$V_0^X = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1-\Theta^c)\, C_t^{RP}, LFP_t\right) \tag{2.37}$$

By using the utility forms defined in Eq. (2.34) and then a second order approximation of the obtained Θ^c around the deterministic Ramsey steady state of the state vector yields

$$\Theta \approx (V_{\sigma_\varepsilon \sigma_\varepsilon}^{RP}(x,0) - V_{\sigma_\varepsilon \sigma_\varepsilon}^{X}(x,0))(1-\beta).\frac{\sigma_\varepsilon^2}{2}, \tag{2.38}$$

where $V_{\sigma_\varepsilon \sigma_\varepsilon}^{RP}$ and $V_{\sigma_\varepsilon \sigma_\varepsilon}^{X}$ represent the welfare costs of Ramsey-optimal policy and policy X conditional on initial state vector x and σ_ε is a parameter scaling the standard deviation of the exogenous shocks. In fact Eq. (2.38) has been obtained by totally differentiating Θ obtained from Eq. (2.37) twice with respect to σ_ε and evaluated at $(x_0, \sigma_\varepsilon) = (x, 0)$.

2.5.1 The Model without Search and Matching Frictions

Before turning to the welfare implications of the monetary policy rules in the baseline model, I compute welfare losses of strict inflation targeting and response to output rules for the case of Walrasian labor markets, which is in fact the Canonical New Keynesian model with distortionary income taxes and a distorted steady-state. This model is similar to the model considered by Schmitt-Grohé and Uribe (2007). Table (2.2) reports welfare costs Θ of those rules once the point of comparison for the policy evaluations is the time-invariant stochastic real allocation under the Ramsey policy. The first row of the table shows that the welfare cost of strict inflation targeting is only 0.0078% of consumption per period. The second and the next rows of table (2.2) display the welfare consequences of a Taylor rule policy for different levels of output coefficient. The rows show that how welfare losses are monotonically increasing in α_Y. Figure (2.1) illustrates this very positive relation between welfare costs and responding to output more clearly. This figure is very similar to what Schmitt-Grohé and Uribe (2007) report, where interest-rate rules that respond to output can be harmful (Panel (b) of Fig. 1 in their paper).

Table 2.2: Welfare Comparison of Alternative Monetary Policy Rules-Walrasian Labor Markets Model

Monetary policy rules	α_π	α_Y	welfare cost ($\Theta \times 100$)
Inflation targeting	1.5	0	0.0078
Inflation and output responses	1.5	0.1	0.0213
	1.5	0.2	0.0411
	1.5	0.3	0.0664
	1.5	0.4	0.095
	1.5	0.5	0.1257
	1.5	0.6	0.1576
	1.5	0.7	0.19
	1.5	0.8	0.2224
	1.5	0.9	0.2544
	1.5	1	0.286

2.5.2 Frictional Labor Markets Model

I now turn to the policy evaluations for the economy with search and matching frictions. The policy evaluations have done for the monetary rules presented above in Subsection 2.2. Table (2.3) summarizes the main properties of the policies under different values for worker's bargaining weight. In this table σ_π stands for the standard deviation of inflation, σ_{SW} and σ_{IW} stand for the standard deviations of static wedge and intertemporal wedge, respectively, which are defined below in Eqs. (2.41) and (2.42). σ_Q and σ_τ are the standard deviations of labor market tightness and labor income tax rates, respectively. The first row of table shows that in contrast to the case of Walrasian labor markets (table 2) the welfare losses associated with strict inflation targeting appear to be extremely large relative to the optimal policy once the worker's bargaining power is low and equal to the baseline calibration $\omega = 0.05$. Interestingly, the rules that respond to output or labor market tightness with interest rate smoothing or no-smoothing imply non-negligible lower welfare losses in comparison with strict inflation targeting. This is significantly the case for the

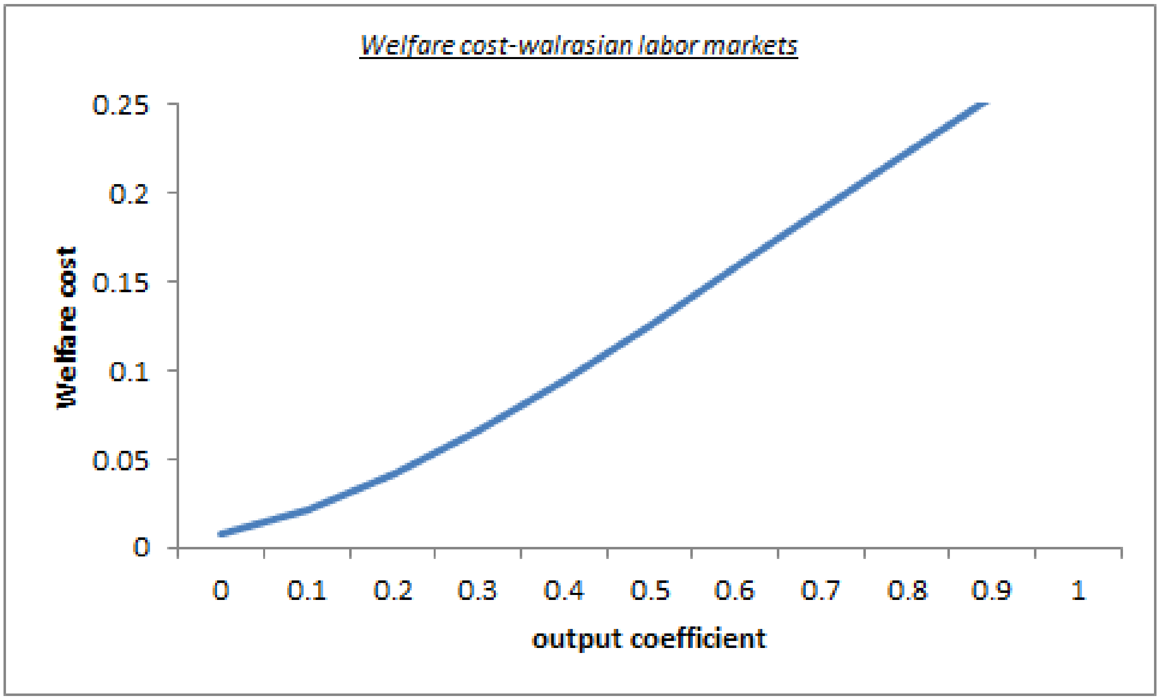

Figure 2.1: The Canonical New Keynesian Economy: the Welfare Costs of Responding to Output

labor market tightness targeting rule. Specifically, taking the difference between the welfare losses associated with the strict inflation targeting rule reveals that agents have to give up more than 23.8%, that is, more than 23.8 of one percent, of their consumption stream under the price stability rule to be as well off as under the Ramsey-optimal policy. This cost for the response to output rule with interest rate smoothing and without smoothing is about 9.65 and 3.43 percent, respectively. In the case of the rule that targets labor market tightness, the welfare costs remarkably drop to just 1% of the consumption stream.

Figure (2.2) displays another significant result of the present paper which is in a sharp contrast to the existing literature. It illustrates the impacts of increasing the output coefficient α_Y on welfare costs, in the absence of interest rate smoothing, while keeping the inflation coefficient of the monetary rule and the bargaining power at $\alpha_\pi = 1.5$ and $\omega = 0.05$, respectively. Figure (2.2) shows that, in a clear contrast to the figure (2.1), the welfare costs of the simple Taylor rule are monotonically decreasing in $\alpha_Y \in [0, 1.2]$. When, for example, $\alpha_Y = 1$, the welfare loss of the rule that responds to output is over 22% lower than the welfare loss associated with the strict inflation targeting rule.

Furthermore, the results suggest that while the welfare costs associated with the rule that responds to the labor market tightness, with and without interest-rate smoothing, are virtually identical to one another, the welfare costs associated with the rule that responds to the output and with interest-rate smoothing are significantly higher than the welfare costs of without interest-rate smoothing case.

Table 2.3: Welfare Comparison of Alternative Monetary Policy Rules-Frictional Labor Markets Model

Worker's bargaining power	Monetary policy rules	α_π	α_Y	α_q	α_R	welfare cost ($\Theta \times 100$)	σ_π	σ_{SW}	σ_{IW}	σ_Q	σ_τ
$\omega = 0.05$	Strict inflation targeting	1.5	0		0	23.8419	0	189.18	54.5	186.2	12.5
	Output response-with smoothing	1.5	0.5/4		0.8	9.6476	4.7	115.6	33.3	113.8	7.55
	Output response-no smoothing	1.5	0.5/4		0	3.4293	7.9	63.8	18.3	62.7	4.3
	Market tightness response-with smoothing	1.5		0.5/4	0.8	1.0742	10.7	17.9	5.2	17.6	1.6
	Market tightness response-no smoothing	1.5		0.5/4	0	0.9863	11.4	7.3	2.1	7.2	1.5
$\omega = 0.1$	Strict inflation targeting	1.5	0		0	4.5922	0	97.9	28.2	96.4	7.4
	Output response-with smoothing	1.5	0.5/4		0.8	2.4152	3.05	70.06	20.2	68.9	5.3
	Output response-no smoothing	1.5	0.5/4		0	1.1255	5.9	43.7	12.6	43.03	3.5
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.5357	8.8	15.3	4.4	15.1	1.5
	Market tightness response-no smoothing	1.5		0.5/4	0	0.5380	9.7	6.6	1.9	6.7	1.43
$\omega = 0.2$	Strict inflation targeting	1.5	0		0	0.7804	0	42.9	12.4	42.5	4.7
	Output response-with smoothing	1.5	0.5/4		0.8	0.5476	1.9	35.2	10.2	34.8	3.9
	Output response-no smoothing	1.5	0.5/4		0	0.3849	4.4	25.2	7.3	25.02	2.97
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.3446	7.2	12.6	3.6	12.4	1.6
	Market tightness response-no smoothing	1.5		0.5/4	0	0.4235	8.7	6.1	1.8	6.06	1.4
$\omega = 0.4$	Strict inflation targeting	1.5	0		0	0.1491	0	14.3	4.3	14.6	3.2
	Output response-with smoothing	1.5	0.5/4		0.8	0.1378	1.2	12.7	3.8	13.01	2.9
	Output response-no smoothing	1.5	0.5/4		0	0.1610	1.4	10.2	3.1	10.4	2.5
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.1956	4.6	7.9	2.3	8.01	1.8
	Market tightness response-no smoothing	1.5		0.5/4	0	0.3231	7.00	4.8	1.4	4.8	1.4
$\omega = 0.7$	Strict inflation targeting	1.5	0		0	0.075	0	2.6	1.1	3.7	2.4
	Output response-with smoothing	1.5	0.5/4		0.8	0.0784	0.9	2.4	0.99	3.4	2.3
	Output response-no smoothing	1.5	0.5/4		0	0.1088	2.6	2.24	0.85	2.9	2.1
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.0898	1.8	2.3	0.89	3.1	2.01
	Market tightness response-no smoothing	1.5		0.5/4	0	0.1531	3.9	2.1	0.7	2.4	1.65
$\omega = 0.9$	Strict inflation targeting	1.5	0		0	0.0689	0	5.3	0.27	0.91	2.1
	Output response-with smoothing	1.5	0.5/4		0.8	0.0724	0.82	5.18	0.24	0.84	2.01
	Output response-no smoothing	1.5	0.5/4		0	0.0989	2.3	4.98	0.22	0.74	1.9
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.0703	0.59	5.03	0.25	0.86	1.97
	Market tightness response-no smoothing	1.5		0.5/4	0	0.0867	1.85	4.6	0.23	0.77	1.8

Table (2.3) also reveals that by raising the bargaining weight of workers the welfare losses of the three monetary rules substantially drop such that at the Hosios efficiency level the welfare costs are more than 95% lesser compared to the welfare costs of the baseline calibration case $\omega = 0.05$. The higher is the workers bargaining power the lower are the welfare costs of monetary rules.

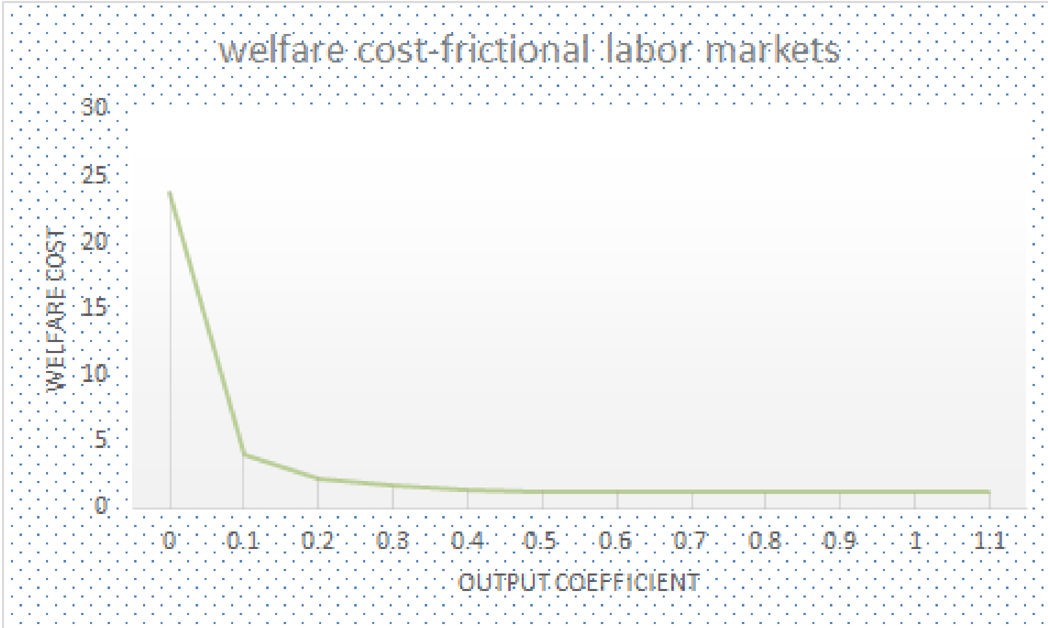

Figure 2.2: The Frictional Labor Market Economy: the Welfare Costs of Responding to Output

2.5.2.1 Interpretation

What are the main reasons behind these results? To understand the basic intuitions behind these results I use the welfare-relevant notion of efficiency for general equilibrium matching models developed by Arseneau and Chugh (2012). This welfare relevant notion helps to shed light on the role of inflation in inducing optimal fluctuations in the wedges between the marginal rate of substitution and the marginal rate of transformation that have both static and intertemporal dimensions.[4]

The following two equations (2.39) and (2.40) define static and intertemporal efficiency conditions related to the allocations of labor market with matching frictions. These two conditions are obtained by maximizing Eq. (2.1) subject to the Eqs. (2.30) and (2.34).

$$\frac{H^{'}(LFP_t)}{u^{'}(C_t)} = \gamma \frac{m_S(S_t, \vartheta_t)}{m_{\vartheta}(S_t, \vartheta_t)}, \tag{2.39}$$

$$1 = E_t\left\{\frac{\beta u^{'}(C_{t+1})}{u^{'}(C_t)}\left\{\frac{(1-\rho)\gamma[1-m_S(S_{t+1}, \vartheta_{t+1})]/m_{\vartheta}(S_{t+1}, \vartheta_{t+1})}{[\gamma/m_{\vartheta}(S_t, \vartheta_t)]-Z_t}\right\}\right\} \tag{2.40}$$

$m_S(.)$ and $m_{\vartheta}(.)$ are the marginal products of the matching function. The static efficiency

[4] It's worth mentioning that while in the Arseneau and Chugh (2012) framework achieving intertemporal efficiency in the decentralized equilibrium is possible, it is not so in my framework because of the presence of imperfect competition.

condition (2.39) states that the efficiency of labor markets requires the equality between the marginal rate of substitution between C_t and LFP_t ($\frac{H^{'}(LFP_t)}{u^{'}(C_t)}$) and the marginal rate of transformation between C_t and LFP_t ($\gamma\frac{m_S(S_t,\vartheta_t)}{m_\vartheta(S_t,\vartheta_t)}$). The intertemporal efficiency (2.40) is achieved through the equality between the intertemporal marginal rate of substitution between C_t and C_{t+1} ($\frac{u^{'}(C_t)}{\beta u^{'}(C_{t+1})}$) and the intertemporal marginal rate of transformation between C_t and C_{t+1} ($\left\{\frac{(1-\rho)\gamma[1-m_S(S_{t+1},\vartheta_{t+1})]/m_\vartheta(S_{t+1},\vartheta_{t+1})}{[\gamma/m_\vartheta(S_t,\vartheta_t)]-Z_t}\right\}$)

Now, the next two conditions show the features that create inefficiencies in a matching model. These features are labor income tax rates, a demand for money, the presence of imperfect competition and nominal rigidities, a low value for ω and $\chi \neq 0$.

$$\begin{gathered}\frac{H^{'}(LFP_t)}{\lambda_t} = \{\chi + (1-\tau_t)\gamma\frac{\omega}{1-\omega}Q_t\} \\ = \gamma\frac{\kappa}{1-\kappa}Q_t\{\frac{\chi(1-\kappa)}{\gamma\kappa Q_t}\frac{1}{\left[1+A\left(1-R_t^{-1}\right)\right]} + (1-\tau_t)\frac{\omega(1-\kappa)}{(1-\omega)\kappa}\frac{1}{\left[1+A\left(1-R_t^{-1}\right)\right]}\},\end{gathered} \tag{2.41}$$

$$\begin{gathered}\frac{\gamma Q_t^{\kappa}}{\zeta} = Z_t MC_t(1-\omega) - \frac{(1-\omega)}{(1-\tau_t)}\chi \\ + \frac{(1-\rho)\beta\left[1+A\left(1-R_t^{-1}\right)\right]}{u^{'}(C_t)}E_t\{\frac{\gamma Q_{t+1}^{\kappa}}{\zeta}\frac{u^{'}(C_{t+1})}{\left[1+A\left(1-R_{t+1}^{-1}\right)\right]}[1-\omega+\frac{\omega(1-\tau_{t+1})}{(1-\tau_t)}\left(1-\zeta Q_{t+1}^{1-\kappa}\right)]\}\end{gathered} \tag{2.42}$$

In obtaining these expressions I used the fact that $\lambda_t\left[1+A\left(1-R_t^{-1}\right)\right] = u^{'}(C_t)$ and the derivatives of Eq. (2.29) with respect to S_t and ϑ_t.

Comparing Eq. (2.41) with the efficient condition (2.39) shows that once $A \neq 0$, $\omega \neq \kappa$ and $\chi \neq 0$ achieving static efficiency is possible through an appropriate setting of income tax rate τ_t. This is not the case, however, for the intertemporal efficiency conditions. Specifically, since $MC_t \neq 1$, due to the presence of imperfect competition and the fact that the government has no access to lump-sum taxes to finance output subsidies aimed at eliminating monopolistic distortions in product and factor markets, achieving full intertemporal efficiency which is the paramount concern of the social planner in the DSGE models based on the matching framework is not possible. Therefore once the bargaining power on the part of workers is low, the Ramsey government finds it optimal to impose an extremely high annual inflation rate which is also highly volatile, along with high fluctuations in nominal interest and income tax rates, to achieve near intertemporal efficiency by minimizing intertemporal distortions over time as much as possible in spite of the existence of sticky prices. Remember that fluctuations in inflation affect the intertemporal efficiency condition (2.42) through the marginal utility of wealth λ_t which enters directly into the Phillips curve condition (2.22).

[5]This brief analysis is based on Arseneau and Chugh (2012). They develop, nicely, a welfare relevant notion of efficiency for search and matching models. To see these derivations in more details I refer you to their paper.

To make this analysis more clear table (2.4) documents a number of sample moments of key macroeconomic variables under the Ramsey-optimal policy for different values of the bargaining parameter ω. The first row of table that displays the quantitative results for the baseline calibration $\omega = 0.05$ makes it very clear that the Ramsey-optimal monetary policy features a very volatile rate of inflation with a mean that is significantly high and equal to 25 percent per year. At the same time the optimal fiscal policy calls for a highly volatile income tax rate. In fact, because the labor market tightness is extremely volatile, the Ramsey government uses an appropriate combination of time-varying inflation, nominal interest and labor tax rates to minimize intertemporal distortions. However, it is inflation, both its mean and its standard deviation, that plays the crucial role in inducing efficient fluctuations in labor market. Although not reported here, there is, indeed, a trade-off between the mean and the standard deviation of inflation in achieving wedge smoothing. In the absence of a demand for money by households, $A = 0$, the optimal rate of inflation falls to very near zero and the standard deviation of inflation rises from 4% to more than 15.5% per year. The reason behind the optimality of an extreme inflation rate lies in two facts. First, money demand friction on the part of households on the one hand directly enters the Phillips curve and so has a direct effect on inflation. On the other hand, such a friction also enters static and intertemporal wedges, as the Eqs.(2.41) and (2.42) clearly show, due to the matching frictions and the optimal vacancy creation condition. Taken together these two facts, the existence of money demand friction by households induces the Ramsey planner to use inflation to minimize intertemporal and static distortions to ensure efficient labor market fluctuations.

This result, that it is optimal for the Ramsey planner to impose an extremely high inflation rate and to use unexpected variations in it, is very striking given that the presence of price adjustment costs which make the use of inflation costly would make one to expect that the monetary policy is the most appropriate instrument to deal with the sticky price distortion and it should be the labor tax rate as the most appropriate instrument to deal with distortions in the labor market. However, the results show that this is not the case and in fact the optimal volatility of inflation is even higher than the optimal volatility of labor tax rate once the worker's bargaining power is low enough.

Taking all these together, therefore, in these circumstances it is reasonable to expect that strict inflation targeting causes extremely large welfare losses because it reduces the inflation variability and its mean to zero and induces substantially high and inefficient fluctuations in static and intertemporal wedges, shown by σ_{SW} and σ_{IW}, respectively, and in the labor market tightness, Q, in the face of two shocks, in comparison with the optimal policy, as the last five columns of table (2.3) and the impulse responses to the shocks, presented in the next subsection, clearly show. These columns make it clear that the reason the rules that respond to the labor market tightness and output imply lower welfare costs than a strict inflation targeting rule, once ω is low, is that they induce large variability in inflation and smaller fluctuations in intertemporal wedge and labor market tightness. This is remarkably the case for the rule that responds to Q. Interestingly, in the case of the output targeting rule the main reason that makes it significantly welfare inferior to the simple interest-rate rule that responds solely to inflation in the New Keynesian models with Walrasian labor markets is that this rule induces variability in inflation. While in the context of this model with frictional labor markets this is exactly the reason that makes it welfare superior to the strict inflation targeting rule. Indeed in the standard New Keynesian models the optimal policy features an inflation volatility that is near zero while the response to output rule makes inflation relatively volatile that is not optimal and costly. However this Taylor rule still in the present context implies large welfare losses, because, compared to the optimal policy, it still generates high variabilities in static and intertemporal wedges and labor market tightness, which lead to inefficient fluctuations in labor markets.

To understand why increasing the bargaining weight reduces the welfare costs of monetary rules, we should regard the Ramsey-optimal policy implications of higher bargaining weights. A comparison of the panel B and next panels of table (2.4) with panel A of that table shows that by raising ω the optimal policy features substantially lower variability in tax rate, nominal interest and inflation rates, such that at the Hosios efficiency level $\omega = 0.4$ and higher the optimal inflation volatility is close to zero. The optimal variability of income tax rate also drops to about 1 percent per year at the Hosios level and even lower for higher values of ω. Although not reported here, these optimal moments implied by the high values of bargaining power are very close to the optimal moments implied by the Walrasian labor market model.[6]

Although in a quite different environment with imperfect competition, sticky prices and non-state contingent bonds, my quantitative results on optimal tax volatility is 2 percent lower than Arseneau and Chugh (2012) reports. In terms of volatility relative to that of GDP, volatility of the income tax rate is 5.6 percent in their economy, while 3.6 percent in my model. The reason is that their economy is a real economy and there is no nominal aspect in it. While the present model is a monetary model and it is the inflation rate that plays the main role of shock absorbing. Regarding the negative relationship between the optimal inflation volatility and the worker's bargaining power, it contrasts with the conclusions from a related analysis in Faia (2009). Faia derives optimal monetary policy in a model with matching frictions, monopolistic and sticky prices. More precisely, she finds that in response to government expenditure and technology shocks the optimal inflation volatility increases with the workers' bargaining power. There are, however, several contrasts between her framework and analysis and mine. First, Faia assumes lump sum taxes and so no fiscal policy. Second, she doesn't include the unemployment benefits in her model. Third, she doesn't incorporate a labor force participation decision in her model and households utility func-

[6] It is worth mentioning that I do not address and report the results for the case that the unemployment benefits are absent because in this case the zero lower bound on nominal interest rate was violated most of the time.

tion is a function of only consumption. Fourth, the standard deviation of inflation in her model for different values of bargaining power is also extremely low and in the range of (0.02-0.12) which in the present framework are accounted as near zero.

For different calibrations and different utility functional forms and even the availability of lump-sum taxes, this negative relation still clearly holds. However, once I exclude the distortionary income taxes from the model and assume lump-sum taxes and the unemployment transfers are also assumed to be zero ($\chi = 0$) , I get qualitatively the same results as Faia, but of course quantitatively the results change very much. More specifically, in this case there is a positive relationship between the optimal inflation volatility and the bargaining power. However, with lump-sum taxes and for the baseline $\omega = 0.05$ the optimal inflation volatility is much lower than the case with distortionary taxes and smaller than 0.5 percent per year.

Table 2.4: Ramsey-optimal policy with different values for ω

variable	mean	Std.dev	Autocorrelation
	A. $w = 0.05$		
τ	25.5	3.6	0.2002
π	24.9	4.002	0.3672
R	29.9	3.7	0.4296
$output$	0.55	0.89	0.7693
$static\,wedge$	0.65	3.5	0.6533
$intertemporal\,wedge$	0.49	1.8	0.5574
Q	0.48	1.1	0.5882
	B. $w = 0.1$		
τ	28.3	2.6	0.2417
π	8.3	3.2	0.3990
R	12.2	2.6	0.7856
$output$	0.55	0.98	0.8083
$static\,wedge$	0.69	3.1	0.4752
$intertemporal\,wedge$	0.43	1.04	0.4831
Q	0.69	3.6	0.4821
	C. $\omega = 0.4$		
τ	26.6	1.15	0.8847
π	-0.28	0.57	0.2555
R	3.8	0.54	0.8378
$output$	0.55	0.93	0.9065
$static\,wedge$	0.86	3.4	0.9510
$intertemporal\,wedge$	0.32	0.99	0.9520
Q	0.66	3.4	0.9520
	D. $\omega = 0.9$		
τ	20.3	0.84	0.9204
π	-0.23	0.14	0.0273
R	3.8	0.38	0.6347
$output$	0.55	0.82	0.9051
$static\,wedge$	2.9	2.37	0.9162
$intertemporal\,wedge$	0.12	0.1	0.9280
Q	0.68	0.36	0.9280

Note: R_t and π_t are expressed in percent per year, and τ_t is expressed in percent. The steady-state values of $output$, Q and $wedges$ are expressed in levels. The standard deviations and serial correlations of these 4 variables correspond to percent deviations from their steady-state values.

2.5.3 Monetary Policy Rules Responses to Shocks

How does strict inflation targeting and responses to output or labor market tightness affect, qualitatively and quantitatively, the responses of key macro variables to aggregate shocks? To address this question I compare, for the baseline calibration, the responses to government expenditure shock (figure (2.3)) and technology shock (figure (2.4)) of all variables of the model under the

Ramsey-optimal policy (cyan lines), under the strict inflation targeting rule (magenta lines), the response to output (black lines) and the response to market tightness (green lines), both without interest-rate smoothing. The figures suggest remarkable deviations of the impulse responses associated with the strict inflation targeting rule and also the response to output rule, although significantly smaller deviations in comparison with the strict inflation targeting rule, from the Ramsey optimal responses. On the other hand, the equilibrium dynamics of most of endogenous variables induced by the response to labor market tightness policy rule mimic those associated with the Ramsey economy quite well. The only variable that its dynamics is very different from the optimal policy is public debt.

Both figures make clear that how the strict inflation targeting rule induces extremely inefficient fluctuations in static and intertemporal wedges which lead to far departures from intertemporal efficiency, that is the paramount concern of the social planner in the frictional labor markets. Also, as is well known in matching frictions literature, with constant returns matching, labor market tightness, Q_t, is a good summary statistics of period t labor market outcomes. While in response to the both shocks the optimal policy keeps fluctuations in labor market tightness as small as possible, the strict inflation targeting role features highly inefficient fluctuations in that variable. This is also, to some extent, the case for the role that responds to output. While the role that responds to labor market tightness in almost all cases induces responses to the shocks that are virtually the same as the optimal policy responses. Both figures, however, make clear that it is the price stability rule that in all cases induces very larger deviations from the optimal responses.

2.6 Lump-Sum Taxation

Keeping fixed the structural parameters from the fiscal-policy model, I now rule out distortionary labor income taxes and assume that the government has access to lump-sum tax/transfers vis-a-vis households, which allows me to ignore government financing issues. This is the common practice in all of the existing papers on optimal monetary policy in New Keynesian frameworks with search and matching frictions. In such models, the presence of lump-sum taxes makes the government budget constraint a residual object. The top panel of table (2.5) displays results for the baseline calibration of the general equilibrium model. It shows that the welfare costs of the strict inflation targeting rule relative to the Ramsey-optimal policy conditional on the initial state being the deterministic Ramsey steady state drops from 23.8419 percent of consumption per period in the presence of distortionary taxes to only 0.3378 percent of consumption per period in the absence of distortionary taxes. This implies a decline by more than 98 percent in the welfare losses associate with strict inflation targeting. At the same time, response to labor market tightness, with or without interest-rate smoothing, leads to significantly higher welfare costs than the strict inflation

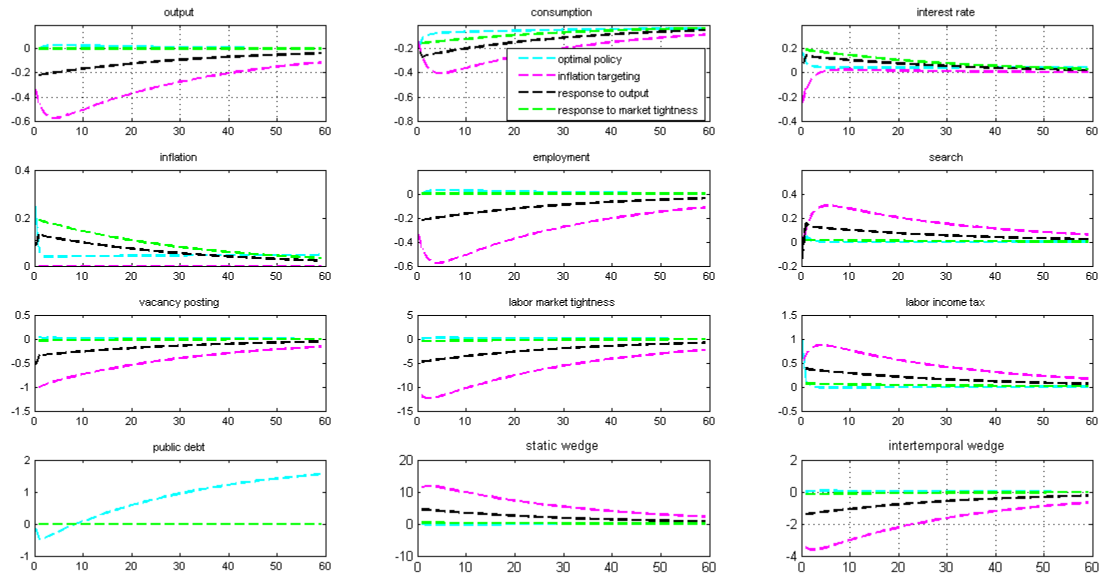

Figure 2.3: Dynamic Path for the Frictional Labor Market Economy with Different Monetary Policy Rules in Response to 1 Percent Positive Shock to G_t.

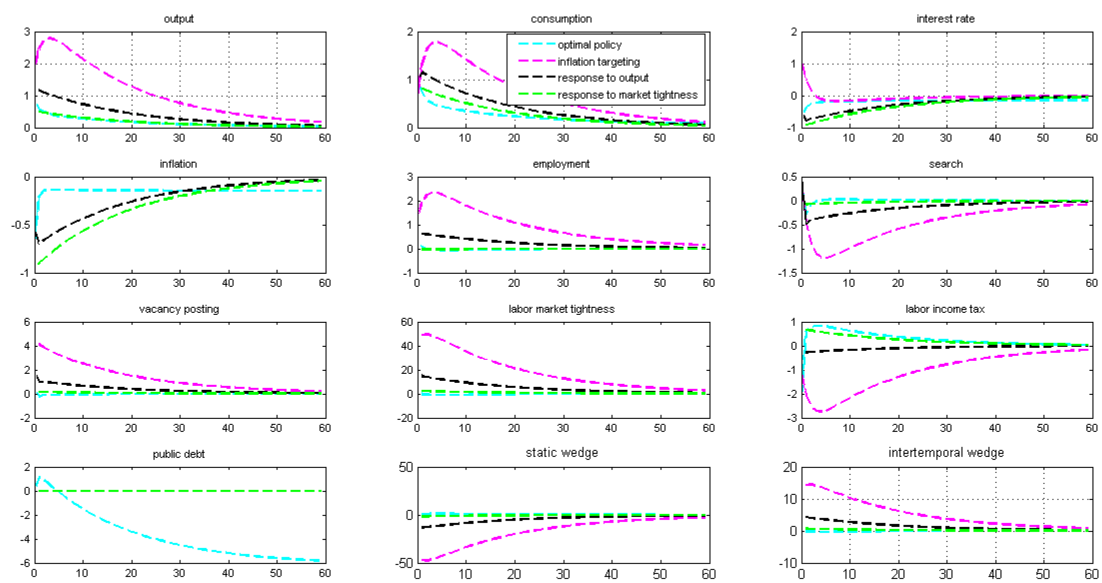

Figure 2.4: Dynamic Path for the Frictional Labor Market Economy with Different Monetary Policy Rules in Response to 1 Percent Positive Shock to Z_t.

targeting rule. In the case of response to output, while with interest-rate smoothing the rule implies virtually the same welfare losses, and even a bit lower, as the strict inflation targeting rule but it leads to larger welfare costs in the absence of interest-rate smoothing. However, although not reported here, in a sharp contrast to the fiscal-policy model, with or without interest-rate smoothing, the welfare costs monotonically increase in output coefficient.

Two other results which worth to emphasize are that: first, like the case with labor income taxes, the model features a negative relationship between the welfare costs associated with the simple monetary rules and worker's bargaining power. Second, for high workers bargaining power the welfare costs associated with the monetary rules are virtually feature identical in the two models.

Table 2.5: Welfare Comparison of Alternative Monetary Policy Rules-Lump Sum Taxation

Worker's bargaining power	Monetary policy rules	α_π	α_Y	α_q	α_R	welfare cost ($\Theta \times 100$)	σ_π	σ_Q
	Strict inflation targeting	1.5	0		0	0.3378	0	26.6
	Output response-with smoothing	1.5	0.5/4		0.8	0.3256	0.4	25.3
$\omega = 0.05$	Output response-no smoothing	1.5	0.5/4		0	0.3872	1.1	23.6
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.8287	2.7	18.5
	Market tightness response-no smoothing	1.5		0.5/4	0	1.9519	4.6	13.5
	Strict inflation targeting	1.5	0		0	0.2824	0	20.7
	Output response-with smoothing	1.5	0.5/4		0.8	0.2772	0.27	20.1
$\omega = 0.1$	Output response-no smoothing	1.5	0.5/4		0	0.3060	0.73	19.2
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.6902	2.3	15.6
	Market tightness response-no smoothing	1.5		0.5/4	0	1.8049	4.1	11.9
	Strict inflation targeting	1.5	0		0	0.1009	0	6.9
	Output response-with smoothing	1.5	0.5/4		0.8	0.1040	0.2	6.7
$\omega = 0.4$	Output response-no smoothing	1.5	0.5/4		0	0.1297	0.57	6.5
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.1759	0.9	6.1
	Market tightness response-no smoothing	1.5		0.5/4	0	0.4785	1.99	5.4
	Strict inflation targeting	1.5	0		0	0.0829	0	0.65
	Output response-with smoothing	1.5	0.5/4		0.8	0.0862	0.2	0.62
$\omega = 0.9$	Output response-no smoothing	1.5	0.5/4		0	0.1066	0.49	0.6
	Market tightness response-with smoothing	1.5		0.5/4	0.8	0.0844	0.12	0.63
	Market tightness response-no smoothing	1.5		0.5/4	0	0.0968	0.37	0.62

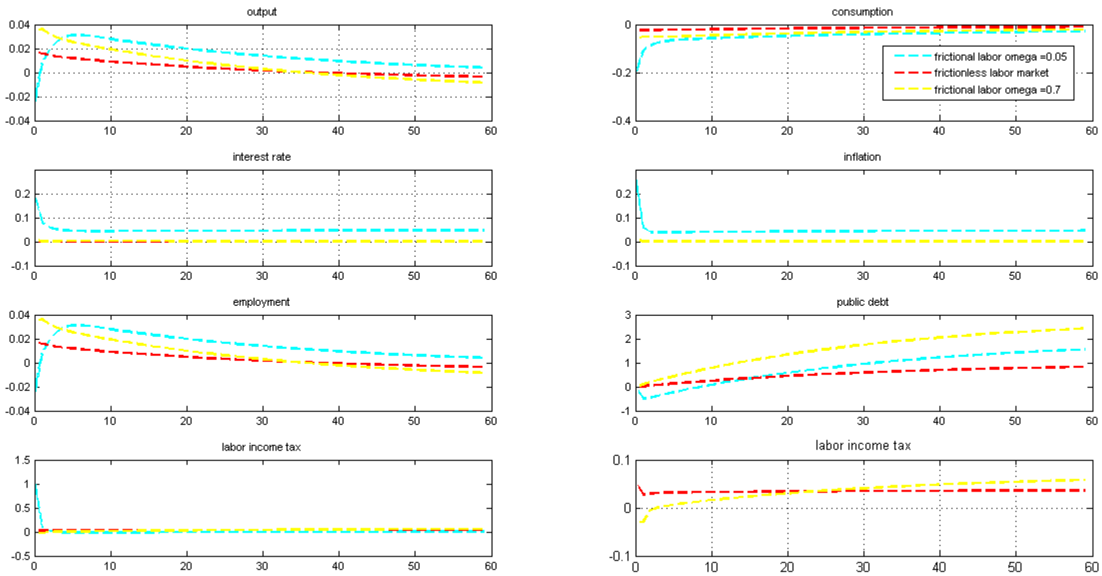

Figure 2.5: Dynamic Path for the Canonical New Keynesian Economies with and without Matching Frictions in Response to 1 Percent Positive Shock to G_t.

2.7 Near Random Walk Property of Inflation under Low Bargaining Power

To ascertain the role played by a low value for the bargaining power of workers in a frictional labor market in shaping the economy's response to the fiscal shock, I compare the model's implied responses to that shock in the presence or not of such frictions. A perfectly competitive labor market is assumed in the case of no frictions.

The most important policy implications of models featuring a New Keynesian Phillips curve is the optimality of price stability. In those models once both monetary and fiscal policies are jointly considered, the Ramsey government in response to a positive fiscal shock doesn't change inflation because it is costly and, instead, finances its expenditures partly through public debt and partly through tax rates. In fact, these two variables in response to the fiscal shock are permanently affected and exhibit random walk behavior.

Figure (2.5) depicts the response of a number of endogenous variables to a one percent increase in the government expenditures. The figure displays impulse response functions associated with the Walrasian labor markets model (the red line) and with two alternative values for the bargaining power, $\omega = 0.05$ and $\omega = 0.7$, in frictional labor markets model (the cyan and yellow lines, respectively). In a stark contrast to the standard New Keynesian frameworks prediction, in response to the positive fiscal shock and once $\omega = 0.05$, not only the Ramsey government finds it optimal to increase the price level on impact, but also the inflation rare is permanently affected by the shock and exhibits a random walk behavior. On the other hand, and again in contrast to the New Keynesian model, once $\omega = 0.05$, public debt due to the sharp rise in inflation drops on impact and then rises permanently and the income tax rate while rises on impact but doesn't show any random walk behavior and after two quarters converges to zero. Raising worker's bargaining power to $\omega = 0.7$, changes the impulse responses dramatically. Not only increase in inflation is not optimal at all but also both public debt and income tax rate rise and are permanently affected, which are very in line with the standard New Keynesian model predictions. To see it more clearly that how the income tax rate for $\omega = 0.7$ becomes a near-random-walk the bottom right panel of figure (2.5) displays the income tax response for only this case and the standard New Keynesian model. In both cases the income tax rate exhibits a near-random-walk behavior. Therefore, for high values of ω, in line with the standard results, the planner in response to an unexpected increase in government spending does not generate a surprise increase in the price level. Instead, in order to finance the increase in government purchases, it chooses to do that partly through an increase in income tax rates and partly through an increase in public debt.

The figure makes quite clear that when the workers bargaining power is high, the Ramsey impulse responses to an innovation in government purchases are qualitatively and even quantitatively in both Walrasian and frictional labor markets models with sticky prices close to each other.

2.8 Conclusion

In this paper I explored the implications of different levels of worker's bargaining power for optimal monetary policy and for three monetary policy rules in a general equilibrium search framework that incorporates a labor force participation decision under sticky prices. I also shed light on the different implications of Ramsey-optimal policy for inflation and other key macro variables in the presence and absence of matching frictions. I find that the workers bargaining weight is a crucial parameter for the welfare costs of monetary policy rules. The lower is workers bargaining power the higher is the optimal inflation volatility and the welfare losses of monetary rules responding to inflation. My quantitative findings indicate that the welfare losses associated with the rules that respond to output and, specifically, labor market tightness targeting are remarkably lower than the welfare losses associated with strict inflation targeting rule. In contrast to the existing literature that finds that responding to output is always welfare detrimental compared to the strict inflation targeting rule, my results suggest that this is not the case once the bargaining power of workers is low. I also show that with a low value for the bargaining parameter, the Ramsey government not only finds it optimal to use inflation surprises in response to a positive fiscal shock, but also inflation exhibits a near random walk behavior. At the same time, another main policy implication of the New Keynesian models with distortionary taxes that the tax rate has unit roots doesn't hold in this case. Important to emphasize is that both low worker's bargaining power and the presence of distortionary labor income taxes are necessary to generate the main optimal inflation volatility and extremely high inflation rate results.

Chapter 3

The Friedman rule in monetary economies with cash-in-advance for firms

3.1 Introduction

"Our final rule for the optimum quantity of money is that it will be attained by a rate of price deflation that makes the nominal rate of interest equal to zero. Friedman (1969) wrote in "The Optimum Quantity of Money". By setting money growth at a rate that causes a deflation equal in magnitude to the real rate of return to physical assets, the central bank can make the return to holding money equal to the return to holding bonds. With that rate of deflation, the nominal interest rate is zero. The intuition for the Friedman rule is that because the marginal cost of creating additional money is zero, the opportunity cost of holding money, the nominal interest rate, faced by private agents should be zero. The main criticism to the Friedman rule is attributed to Phelps (1973). Phelps noted that analyzing inflation tax without consumption and labor supply functions is like that "professor Friedman has given us Hamlet without prince". In a public finance context and a general equilibrium model where inflation tax is optimally treated like other distortionary taxes, Phelps counterargued the optimality of the Friedman rule in favor of a positive rate of inflation. Following Phelps a large literature that tried to analyze the optimal inflation rate in different models from different point of views, emerged.

In all this body of work that studied the optimality of the Friedman rule, except Faig (1991), [1]

[1] Faig (1991) studied the optimality of the Friedman rule when the transactions activity is performed by firms. There are several difference between his model and this approach. First, his model is a simple one-period static model but here I consider a stochastic and dynamic general equilibrium model. Second, he introduces money as an intermediate good in the transactions activity, here the role of money is as a medium of exchange by requiring explicitly that money be used to purchase goods. Third, in Faig paper policy evaluations do not take the Ramsey approach to solve the problem.

one motivates the existence of a liquidity premium by supposing that households obtain a service flow from cash balances. Realistically it is not only households that have motivation to hold cash balances, but firms as well. Important to emphasize is that in these frameworks that the attention is restricted to the case in which money is hold only by households, variations in the nominal interest rate affect real variables solely through their effect on aggregate demand. This paper studies the optimality of the Friedman rule by considering a demand for money by firms that is motivated by the facts that a substantial part of M1 is held by firms. For example, the Federal Reserve's demand deposit ownership survey (1988) surveyed changes over the 1980's in the shares of demand deposits. According to DDOS, consumers held one-third of demand deposits at all insured commercial banks in 1980. This share had declined to about one-quarter by 1987 while holdings of demand deposits by financial and non-financial businesses rose from three-fifths to about two-thirds of total demand deposits.[2] Also Mulligan (1997) estimates a model of the demand for money by firms using longitudinal data on sales, money holdings, and other variables at the firm level. He shows, using COMPUSTAT data on 12,000 firms for the years 1961–92, in industrialized economies about two-thirds of M1 are held by firms. Also a large literature in finance documented a very significant increase in cash holdings by firms during the recent years.[3] It is therefore natural to motivate a demand for money by firms and study the optimality of the Friedman rule under this motivation. My purpose in this paper is to pursue this line of reasoning. The focus is to investigate whether the policy conclusion arrived at by the existing literature regarding the optimality of the Friedman rule is robust with respect to a more realistic specification of the economic environment, that is, where firms have motivations to hold money.

To do so, I consider monetary economies models, somehow similar to the models described in Chari et al. (1996) and Schmitt-Grohé and Uribe (2004). Specifically, I build models to study the optimality of the Friedman rule in a stochastic, flexible-price, production economy without capital, where two sources of inefficiency in the models stem from the nominal friction of the demand for cash balances by firms and a distortionary tax. I rationalize a money demand by firms by assuming that wage payments are subject to a cash-in-advance constraint. This is a very common assumption in the literature (for a review see Christiano et al. (2010)). I show that the Friedman rule, irrespective of the form of the utility function and in the presence of distortionary taxes on consumption, is not optimal. It can be shown that it is also the case with distortionary taxes on labor instead of consumption. This non-optimality of the Friedman rule recalls the Phelps's criticism that Friedman's first best argument ignores the second best fact that inflation produces seigniorage incomes for the fiscal authority and all forms of taxation produce distortions of some

[2]The Federal Reserve surveys for years prior to this period also show that a substantial part of M1 was held by firms. The Federal Reserve discontinued the DDOS in 1990.

[3]See for example Ferreira and Vilela (2004), Almeida et al. (2004), Han and Qiu (2007), Bates et al. (2009) and Gao et al. (2013) among so many others.

kind. More precisely, it is not anymore optimal to put nominal interest rate equal to zero when the government has no access to lump-sum taxes and only to one distorting tax. Put another way, the optimal way to deal with a distortion depends on other existing distortion.

I then follow Jones et al. (1997), and consider a model where households sell two types of labor, raw and effective labors, to the market. In contrast to the cash-credit goods model that both goods have the same price, different types of labor face different wages. I assume that only the raw labor wages are subject to a cash-in-advance constraint. My motivation for this assumption comes from the facts that there are a range of jobs where the employee is paid his wages on hourly basis. In this case, the optimality of the Friedman rule with distorting consumption taxes reemerged if the production function exhibits constant-returns-to-scale and the utility function is a homothetic function of those two types of labor and separable in consumption. This optimality is valid in the presence of different wages for the two labor types. This is an advantage of the model over the cash-credit goods model where in order to have the optimality of the Friedman rule both goods have to have the same price. If the production technology has decreasing or increasing-returns-to-scale, then the optimality of the Friedman rule needs the equality of wage rates. The optimality of the Friedman rule with two types of labor, homotheticity and separability of preferences is similar to the result of Atkinson and Stiglitz (1972). They find that if the preferences are homothetic over consumption goods and separable in labor then it is optimal to tax all consumption goods at the same rate. Thus, once the Friedman rule is not optimal, that is $R_t > 1$, then in fact the raw labor wages are taxed at a higher rate than the efficient labor wages which is not optimal.

The government in these environments issues nominal, one period, non-state-contingent bonds, prints money and impose distortionary taxes on consumption to finance its expenditure.

3.2 The model

This section develops an infinite-horizon production economy with perfectly competitive product markets and flexible prices. A demand for money by firms is motivated by assuming that wage payments are subject to a cash-in-advance constraint. The government finances an exogenous stream of purchases by printing money, imposes distorting taxes only on labor income and issuing one-period nominally risk-free bonds.

3.2.1 Households

The economy is populated by a continuum of identical households who consume different varieties of goods, save and work. Households save in one-period, non state-contingent, nominal bonds and their preferences are defined over consumption, c_t, and labor effort, h_t. The household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, h_t\right), \tag{3.1}$$

Where E_0 denotes the mathematical expectations operator conditional on information available at time zero and β is the subjective discount factor. The utility function U is strictly concave and satisfies the Inada conditions.

The flow budget constraint of the household in period t reads as follows:

$$p_t c_t \left(1+\tau_t\right) + B_{t+1} \leq p_t w_t h_t + R_{t-1} B_t + \Pi_t. \tag{3.2}$$

where households are assumed to invest in non-state contingent nominal bonds, B_{t+1}, which pay a nominal interest rate R_t one period later. τ_t is the distorting tax on consumption, w_t is the real wage rate and Π_t are profits received from firms. Households are also assumed to be subject to a borrowing limit that prevents them from engaging in Ponzi schemes.

Households choose the set of processes $\{c_t, h_t, B_{t+1}\}$, taking as given the set of processes $\{p_t, w_t, R_t, \tau_t\}$ so as to maximize utility 3.1 subject to the budget constraint 3.2. The first-order conditions are:

$$U_c\left(c_t, h_t\right) = \lambda_t \left(1+\tau_t\right) \tag{3.3}$$

$$U_h\left(c_t, h_t\right) = \lambda_t w_t, \tag{3.4}$$

$$\frac{\lambda_t}{P_t} = \beta R_t E_t \frac{\lambda_{t+1}}{P_{t+1}}, \tag{3.5}$$

where λ_t refer to the Lagrange multiplier on equation 3.2.

The interpretation of these equilibrium conditions is as follows: Eq. 3.3 states that the distortionary taxes distort the equality between the marginal utilities of consumption and wealth. Eq. 3.4 shows that the equality between marginal utility of leisure and the marginal utility of labor income. Eq. 3.5 is the Euler condition with respect to bonds.

3.2.2 Firms

Firms use labor to produce consumption goods. One unit of labor is assumed to produce one unit of good which is perishable. Firms money holdings are motivated by assuming that wage payments are subject to a cash-in-advance constraint of the form:

$$w_t h_t \leq m_t, \tag{3.6}$$

where $m_t = \frac{M_t}{p_t}$ is the demand for real money balances by firms in period t and M_t denotes nominal money holdings.

The period by period budget constraint that the firm faces is

$$M_t = M_{t-1} + p_t h_t - p_t w_t h_t - p_t \Pi_t, \tag{3.7}$$

The firm chooses $\{h_t, M_t\}$ to solve the following maximization problem :

$$Max \Pi_t = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \frac{1}{p_t} \{p_t h_t - p_t w_t h_t + M_{t-1} - M_t\} \tag{3.8}$$

subject to eq. (3.6).

$\frac{\lambda_t}{\lambda_0}$ is the period 0 value to the representative household of period t goods, which the firm uses to discount profit flows because households are the ultimate owners of firms.

This maximization implies the following first-order condition:

$$\frac{1}{w_t} = 2 - R_t^{-1}, \tag{3.9}$$

From this optimality condition it is clear that the presence of a cash constraint for firms introduces a financial cost of labor which is an increasing function of nominal interest rate.

3.2.3 The government

The budget constraint that the government is facing is given by

$$M_t + B_t + p_t \tau_t c_t = R_{t-1} B_{t-1} + M_{t-1} + p_t g_t. \tag{3.10}$$

The consolidated government issues one period nominally risk-free bonds, B_t, prints money, M_t, imposes distortionary taxes, and faces a stream of public consumption, denoted by g_t.

3.3 Competitive equilibrium

Absent arbitrage opportunities in equilibrium implies that, $R_t \geq 1$. This implies that based on eq. 3.9, $1 \geq w_t$ in equilibrium must hold.

A competitive equilibrium is a set of plans $\{c_t, h_t, M_t, B_t, w_t, \lambda_t, R_t, p_t\}$, satisfying eqs. (3.3), (3.4), (3.5), (3.6), (3.9), (3.10) and :

$$R_t \geq 1, \tag{3.11}$$

$$1 \geq w_t, \tag{3.12}$$

$$U_c(c_t, h_t) \geq (1+\tau_t) U_h(c_t, h_t), \tag{3.13}$$

$$c_t + g_t = h_t, \tag{3.14}$$

given policies $\{R_t, \tau_t\}$.

Eq. 3.9 denotes that the nominal interest rate distorts the equality between the marginal product and real wages and eq. 3.11 ensures that in equilibrium, the nominal interest rate is non-negative. Eqs 3.12 and 3.13 result from the non-negativity of nominal interest rate and Eq. 3.14 shows the real resource constraint.

3.3.1 The Ramsey problem

The optimal fiscal and monetary policy is the process $\{\tau_t, R_t\}$ associated with the competitive equilibrium that yields the highest level of utility to the representative households. We know that if the initial financial wealth held by consumers is positive, the welfare is maximized by increasing the initial price level to infinity. To avoid this feature, I restrict the initial price level to be given.

3.3.1.1 the primal form

The problem of determining the optimal structure of prices and taxes to finance a given level of expenditures is called the Ramsey problem, after the classic treatment of Ramsey (1928). In the representative agent models, like one studied here, the Ramsey problem is to maximize the utility of the representative agent subject to the government's revenue requirement.

There are two approaches to solve this problem. The first approach, often called the dual approach employs the indirect utility function to express utility as a function of the government's control variables. The second approach, called the primal approach, that is considered here, involves the elimination of all prices and tax rates from the equilibrium conditions, so that the resulting reduced form involves only real variables. The primal form of the equilibrium conditions, consists of two equations. One equation is a feasibility constraint, given by the resource constraint 3.14, which must hold at every date and under all contingencies. The other equation is a single, present-value constraint known as the implementability constraint.

The real variables that appear in the primal form are consumption and labor effort. I obtain the Ramsey problem as follows. Iterating the government budget constraint forward and using the first-order conditions to eliminate prices yields the following implementability condition

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U_c\left(c_t, h_t\right) C_t + U_h\left(c_t, h_t\right) h_t\right] = A_0 \frac{\lambda_0}{P_0}, \tag{3.15}$$

$$U_c\left(c_t, h_t\right) \geq \left(1+\tau_t\right) U_h\left(c_t, h_t\right), \tag{3.16}$$

$$c_t + g_t = h_t, \tag{3.17}$$

given $A_0 = \left(M_{-1} + R_{-1} B_{-1}\right)$, $\lambda_0 = U_c\left(c_0, h_0\right)$ and P_0, are the same as those satisfying the competitive equilibrium

3.3.1.2 Non-optimality of the Friedman rule

The Ramsey problem is to maximize the lifetime utility function subject to eqs. (3.15) - (3.17). Let focus on the less restricted form and ignore the inequality constraint (3.16).

Let φ and ψ_t denote the Lagrange multipliers on the implementability constraint (3.15) and on the feasibility constraint (3.17), respectively.

The F.O.Cs of the Ramsey planner's problem are

$$\frac{\partial L}{\partial c_t} = U_c\left(c_t, h_t\right) + \varphi U_{hc}\left(c_t, h_t\right) h_t + \varphi U_c\left(c_t, h_t\right) + \varphi U_{cc}\left(c_t, h_t\right) c_t - \psi_t = 0,$$

$$\frac{\partial L}{\partial h_t} = U_h\left(c_t, h_t\right) - \varphi U_{hh}\left(c_t, h_t\right) h_t + \varphi U_h\left(c_t, h_t\right) + \varphi U_{ch}\left(c_t, h_t\right) c_t + \psi_t = 0.$$

After rewriting the above equations we get the following expressions

$$(1+\varphi) + \varphi\left(\frac{U_{cc}\left(c_t, h_t\right) c_t + U_{hc}\left(c_t, h_t\right) h_t}{U_c\left(c_t, h_t\right)}\right) = \frac{\psi_t}{U_c\left(c_t, h_t\right)},$$

$$(1+\varphi) + \varphi\left(\frac{U_{ch}\left(c_t, h_t\right) c_t + U_{hh}\left(c_t, h_t\right) h_t}{U_h\left(c_t, h_t\right)}\right) = \frac{-\psi_t}{U_h\left(c_t, h_t\right)}.$$

As it is quite clear the optimality conditions of the Ramsey problem imply the non-optimality of the Friedman rule. Because from eq. (3.9) it is clear that once the Friedman rule is optimal $R_t = 1$ then $w_t = 1$ and $U_c\left(c_t, h_t\right) = \left(1+\tau_t\right) U_h\left(c_t, h_t\right)$ but we cannot conclude this from the above conditions.

Thus we conclude that in a model with cash constraint for firms and in the presence of distortionary taxes only on consumption, the Friedman rule is not optimal. The basic intuition for this conclusion recalls the result due to Phelps (1973). Phelps in a model with the money-in-the-utility function and distorting labor income taxes shows that the Friedman rule is not optimal because inflation produces seigniorage revenues for the government. More precisely, instead of just making one of the distortions equal to zero and only using the other one, it is optimal to equalize the marginal distortion caused by one unit of revenue collected with distortionary income tax with the marginal distortion caused by one unit of revenue collected with inflation tax. This can be shown that is the case if instead of distorting consumption taxes, the government has access to only distortionary taxes on labor. When the government has access to both taxes on consumption and labor income, it also can be shown that the optimal tax policy is not unique and in fact there are a variety of tax policies that can implement the optimal allocation. Some of these have the optimality of the Friedman rule, but others do not.

3.4 Optimality of the Friedman rule in an economy with CIA for firms and raw-effective labors

How the Friedman rule can be optimal when firms are subject to a cash-in-advance constraint? In this section, following Jones et al. (1997), I assume a model that is added with two features relative to the model with CIA only for firms in section 3: a raw labor-effective labor model where the wages of two types of labor are different and only wage payments of raw labor are subject to a cash-in-advance constraint. I also consider distortionary consumption taxes. I show that in this set up once the production function is a constant returns to scale function, the Friedman rule is optimal under homotheticity of preferences between raw and effective labors and separability in consumption.

3.4.1 Households

Now I assume households draw utility from consumption goods, c_t, and disutility from raw labor, h_{1t}, and effective labor, h_{2t}, according to the following utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, h_{1t}, h_{2t}\right),$$

The budget constraint can be written as:

$$\left(1+\tau_t\right) c_t + B_{t+1} = R_{t-1} B_t + w_{1t} h_{1t} + w_{2t} h_{2t},$$

where w_{1t} and w_{2t} are the wage rates of raw and effective labors, respectively.

The first-order conditions of the household problem are eq. (3.5) as before and

$$U_c(c_t, h_{1t}, h_{2t}) = \lambda_t(1+\tau_t), \tag{3.18}$$

$$\frac{U_{h_1}(c_t, h_{1t}, h_{2t})}{U_{h_2}(c_t, h_{1t}, h_{2t})} = \frac{w_{1t}}{w_{2t}}, \tag{3.19}$$

Eq. (3.19) states that the marginal utilities between the two types of labors should be equal to the their relative wage rates.

3.4.2 Firms

To produce output, I now assume that firms use raw labor h_{1t} and effective labor h_{2t} as inputs. The production technology is given by $z_t F(h_{1t}, h_{2t})$, which is homogenous of degree one and z_t is an exogenous, aggregate productivity shock to production. It is also assumed that wage payments of raw labor are subject to a CIA such that

$$w_{1t} h_{1t} \leq m_t \tag{3.20}$$

As I mentioned in the introduction, the intuition behind assuming cash constraint for one types of workers comes from the fact that there are a wide range of jobs where the employee is paid on hourly basis. For example, based on Lemieux et al. (2009) study of non-performance-pay and in performance-pay jobs, there is a large fraction of workers paid by the hour in non-performance-pay.

The firm's maximization problem is the same as section 2.2 and again the firm uses $\frac{\lambda_t}{\lambda_0}$ to discount profit flows. The first-order conditions of the firm's maximization problem with respect to raw labor and effective labor are, respectively,

$$z_t F_1(h_{1t}, h_{2t}) = w_{1t}\left(2 - R_t^{-1}\right), \tag{3.21}$$

$$z_t F_2(h_{1t}, h_{2t}) = w_{2t}. \tag{3.22}$$

As is clear from eqs. (3.21) and(3.22), the presence of working capital distorts only the equality between the marginal product and the real wage of raw labor. When $R_t > 1$ then the raw labor wage is less than its marginal product. In fact, the financial cost of labor is increasing in the opportunity cost of holding money, $2 - R_t^{-1}$, which is an increasing function of nominal interest rate.

3.4.3 Competitive equilibrium

A competitive equilibrium is a set of plans $\{c_t, h_{1t}, h_{2t}, M_t, B_t, w_{1t}, w_{2t}, p_t, \lambda_t, R_t\}$ satisfying Eqs. (3.5), (3.10), (3.18)-(3.22) and the following conditions:

$$R_t = \frac{1}{E_t r_{t+1}} \geq 1, \tag{3.23}$$

$$z_t F_1 (h_{1t}, h_{2t}) \geq w_{1t}, \tag{3.24}$$

$$c_t + g_t = z_t F (h_{1t}, h_{2t}). \tag{3.25}$$

given policies $\{R_t, \tau_t\}$.

3.4.4 The Ramsey problem and the primal form

The Ramsey policy is the process $\{\tau_t, R_t\}$ associated with the competitive equilibrium that yields the highest level of utility to the representative households.

Again, to obtain the Ramsey problem I iterate the government budget constraint forward and use the first-order conditions to eliminate prices to get implementability condition

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U_c (c_t, h_{1t}, h_{2t}) c_t + U_{h_1} (c_t, h_{1t}, h_{2t}) h_{1t} + U_{h_2} (c_t, h_{1t}, h_{2t}) h_{2t}\right] = A_0 \frac{\lambda_0}{p_0}, \tag{3.26}$$

where $A_0 = R_{-1} B_{-1} + M_{-1}$ and I used the fact that

$$F (h_{1t}, h_{2t}) = w_{1t} \left(2 - R_t^{-1}\right) h_{1t} + w_{2t} h_{2t}. \tag{3.27}$$

The second implementability condition because of no-arbitrage condition is:

$$F_1 (h_{1t}, h_{2t}) w_{2t} - F_2 (h_{1t}, h_{2t}) w_{1t} \geq 0, \tag{3.28}$$

The Ramsey allocation problem must also satisfies the resource constraint 3.25.

3.4.5 Optimality of the Friedman rule

The Ramsey maximization problem consists of maximizing the representative household utility, subject to eqs. 3.25-3.28.

Proposition 3.1 *The Friedman rule in a raw-efficient labors model with distortionary taxes on consumption is optimal if the production function is constant-returns-to scale and the utility function is homothetic in the raw-efficient labor types ans separable in consumption.*

Proof. I solve the Ramsey problem for the less restricted problem where the constraint 3.28 is dropped. Let Θ be the Lagrange multiplier on 3.26 and Λ_t denotes the Lagrange multiplier on eq. 3.25. Then the first-order conditions are

$$\begin{gathered} U_c(c_t,h_{1t},h_{2t})+\Theta\left[U_c(c_t,h_{1t},h_{2t})+U_{cc}(c_t,h_{1t},h_{2t})\,c_t\right] \\ +\Theta\left[U_{h_1c}(c_t,h_{1t},h_{2t})\,h_{1t}+U_{h_2c}(c_t,h_{1t},h_{2t})\,h_{2t}\right]-\Lambda_t=0, \end{gathered} \tag{3.29}$$

$$\begin{gathered} U_{h_1}(c_t,h_{1t},h_{2t})+\Theta\left[U_{h_1}(c_t,h_{1t},h_{2t})+U_{h_1h_1}(c_t,h_{1t},h_{2t})\,h_1\right] \\ +\Theta\left[U_{h_1c}(c_t,h_{1t},h_{2t})\,c_t+U_{h_2h_1}(c_t,h_{1t},h_{2t})\,h_{2t}\right]+\Lambda_t z_t F_1(h_{1t},h_{2t})=0, \end{gathered} \tag{3.30}$$

$$\begin{gathered} U_{h_2}(c_t,h_{1t},h_{2t})+\Theta\left[U_{h_2}(c_t,h_{1t},h_{2t})+U_{h_2h_2}(c_t,h_{1t},h_{2t})\,h_2\right] \\ +\Theta\left[U_{ch_2}(c_t,h_{1t},h_{2t})\,c_t+U_{h_1h_2}(c_t,h_{1t},h_{2t})\,h_{1t}\right]+\Lambda_t z_t F_2(h_{1t},h_{2t})=0. \end{gathered} \tag{3.31}$$

It is hardly possible to reach a conclusion about the optimality of the Friedman rule based on these first-order conditions. Thus I consider utility functions of the form:

$$U(c_t,h_{1t},h_{2t})=V(c_t,Q(h_{1t},h_{2t})) \tag{3.32}$$

,

where $Q(h_{1t},h_{2t})$ is homothetic. Then the first-order conditions 3.30 and 3.31 reduce to

$$(1+\Theta)+\Theta\left(\frac{U_{h_1h_1}(c_t,h_{1t},h_{2t})\,h_1+U_{h_2h_1}(c_t,h_{1t},h_{2t})\,h_{2t}}{U_{h_1}(c_t,h_{1t},h_{2t})}\right)=-\frac{\Lambda_t z_t F_1(h_{1t},h_{2t})}{U_{h_1}(c_t,h_{1t},h_{2t})}, \tag{3.33}$$

$$(1+\Theta)+\Theta\left(\frac{U_{h_2h_2}(c_t,h_{1t},h_{2t})\,h_2+U_{h_2h_1}(c_t,h_{1t},h_{2t})\,h_{1t}}{U_{h_2}(c_t,h_{1t},h_{2t})}\right)=-\frac{\Lambda_t z_t F_2(h_{1t},h_{2t})}{U_{h_2}(c_t,h_{1t},h_{2t})}. \tag{3.34}$$

From homotheticity we have

$$\left(\frac{U_{h_1h_1}(c_t,h_{1t},h_{2t})h_1+U_{h_2h_1}(c_t,h_{1t},h_{2t})h_{2t}}{U_{h_1}(c_t,h_{1t},h_{2t})}\right)=\left(\frac{U_{h_2h_2}(c_t,h_{1t},h_{2t})h_2+U_{h_2h_1}(c_t,h_{1t},h_{2t})h_{1t}}{U_{h_2}(c_t,h_{1t},h_{2t})}\right).$$

Use this and taking together eqs. 3.33 and 3.34 we have

$$\frac{U_{h_1}(c_t, h_{1t}, h_{2t})}{U_{h_2}(c_t, h_{1t}, h_{2t})} = \frac{F_1(h_{1t}, h_{2t})}{F_2(h_{1t}, h_{2t})}, \tag{3.35}$$

Using this, from 3.19 we have

$$\frac{w_{1t}}{w_{2t}} = \frac{F_1(h_{1t}, h_{2t})}{F_2(h_{1t}, h_{2t})}, \tag{3.36}$$

This solution satisfies eq. 3.28. Thus the solution to the less constrained problem is also a solution to the Ramsey allocation problem.

Also eqs. 3.21 and 3.22 imply

$$\frac{F_1(h_{1t}, h_{2t})}{F_2(h_{1t}, h_{2t})} = \frac{w_{1t}}{w_{2t}}\left(2 - R_t^{-1}\right). \tag{3.37}$$

Now from 3.36 and 3.37 we have $R_t = 1$. ■

If the production function exhibits decreasing or increasing-returns-to-scale and wage rates are different, then we cannot anymore have condition 3.27 that resulted because of the presence of constant-returns-to-scale. Thus the competitive equilibrium conditions don't anymore reduce to an implementability constraint and resource constraint. But if wage rates are identical, then the primal form will be the same and thus the Friedman rule is optimal even when the production technology doesn't exhibit constant-returns-to-scale. Thus the standard result of Atkinson and Stiglitz (1972) in public finance reemerges. That is, once the preferences are homothetic in labor types and separable in consumption, the distortionary consumption taxes implicitly tax both types of labors so it is optimal to tax both raw labor and efficient labor at the same rate. In other words, $R_t = 1$ is the optimal policy. If $R_t > 1$, then the raw labor is effectively taxed at a higher rate than the efficient labor , since wages of raw labor must be paid for immediately but efficient labor wages are paid for with a one-period lag. Thus, with preferences of the form eq. (3.32) , efficiency requires that $R_t = 1$ and, therefore, the Friedman rule is optimal.

It is interesting to compare the optimality of the Friedman rule in this model with a constant-returns-to-scale production function with the optimality of the Friedman rule in a cash-credit goods model. In the cash-credit goods model, the Friedman rule is optimal because of the assumption of two types of consumption goods along with the homotheticity of preferences between cash and credit goods and separability in leisure. In this model the Friedman rule is optimal because of the two different types of labor and the assumption that the utility function is separable in consumption goods and homothetic in raw-efficient labor. The advantage of the model with two different types of labor over the model with two different types of goods is that different types of labor can face different wages. It is worth to note that in both cases only one type of goods or labors should be subject to a cash constraint, otherwise the optimality of the Friedman rule doesn't emerge. With distortionary taxes on labor income, it can be shown easily that the Friedman rule is optimal if income tax rates on both types of labors are the same.

3.5 Conclusion

In this paper I study the optimality of the Friedman rule in monetary economies, where money enters into the model through cash-in-advance constraint for firms. First I show that the Friedman rule is not optimal when firms have a motive for cash holdings and the government in order to finance its expenditures imposes distortionary taxes on consumption. Then I prove that the optimality of the Friedman rule holds in a model with cash-in-advance for firms and in the presence of distortionary consumption taxes, if we consider two types of labor where one of them is subject to a cash-in-advance constraint and the utility function is homothetic in these two types of labor and separable in consumption. Unlike the cash-credit goods economy where two types of goods have the same price, in this model wage rates are different if the production function exhibits a constant-returns-to-scale. This optimality is also satisfied with increasing or decreasing-returns-to-scale production functions if wage rates are identical.

General Conclusion

This dissertation consists of three essays on optimal fiscal and monetary policies. In the first two essays, I consider general equilibrium search and matching models with money and distortionary labor income taxes and study the joint determination of optimal fiscal and monetary policy and the welfare costs of simple monetary policy rules under sticky product prices. The models also incorporate a labor force participation decision that has recently attracted attention, since it has been shown in a number of papers that it can be an important margin of adjustment in labor markets. The models' fluctuations are conditional on exogenous government spending and productivity processes.

In the first essay, I show that, in a sharp contrast to the standard results on the optimality of price stability in the presence of price adjustment costs, the Ramsey-optimal policy calls for remarkably high inflation rate and inflation volatility once the worker's bargaining power is low. The results in a quite clear way show that the social planner finds it optimal to rely more on inflation, not fluctuations in distortionary income tax rate, to induce efficient fluctuations in labor markets by keeping distortions constant over the business cycle. I also find that by increasing the bargaining weight to the Hosios efficiency level and higher, the optimal inflation rate and its variability significantly decline to near zero. This is also the case for the Ramsey-optimal volatility of income taxes.

In the second essay, I study the welfare consequences of simple monetary policy rules in a DSGE search and matching model with sticky prices, a cash constraint on households expenditures, flexible real wages and distortionary labor income taxes. The monetary rules that I consider are: a rule that strictly targets inflation rate, and two rules that respond to output and labor market tightness, with and without interest-rate smoothing. In this context, the point of comparison is the Ramsey-optimal policy. I find the role of worker's bargaining weight crucial for the results. When the workers bargaining power is low, because the optimal inflation rate is significantly high, the welfare costs associated with the strict inflation targeting rule is remarkably high. The results also indicate that the rules that respond to output and labor market tightness feature considerably lower welfare costs than the strict inflation targeting rule. By raising the worker's bargaining power, the optimal inflation rate and its volatility and thus the welfare costs associated with the strict inflation targeting rule remarkably drop and the rules that respond to output or labor market tightness do not anymore imply lower welfare losses relative to the strict inflation targeting rule.

In the third and last essay, I study the optimality of the Friedman rule in monetary economies models with two sources of inefficiency, steming from the nominal friction of the demand for cash balances by firms and distortionary taxes on consumption. The money demands by firms have been rationalized by assuming that wage payments are subject to a cash-in-advance constraint. I first show that the Friedman rule, irrespective of the form of the utility function and due to the presence of distortionary taxes, ceases to be optimal. This result is in line with the Phelps's criticism that Friedman's first best argument ignores the second best fact that inflation produces income for the government. I then prove that the optimality of the Friedman rule emerges if we allow for two types of labor where one of them is subject to a cash-in-advance constraint and the utility function is homothetic in these two types of labor and separable in consumption.

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