The Role of Firing Costs for Labor Market Dynamics and Business Cycle

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Abstract

This thesis aims to explain the effects of employment protection legislation on the long-run level of unemployment and demonstrate its influence on the cyclical properties of the labor market, as well as those of output and inflation. In order to do this, firing costs are introduced into a new Keynesian model with search and matching frictions. The firing costs are revealed to affect more strongly the firing rate than the hiring, implying that with increasing firing costs, unemployment evolves following an u-shape. Over the business cycle the lower reactiveness of job destruction induces more sluggishness in employment adjustment, hence output and unemployment are stabilized at the price of a more volatile inflation.

1 Introduction

The persistently high European unemployment rate is a great concern in the political debate. One recognized factor responsible for this so-called "eurosclerosis" is the low flexibility of the labor market due to the abundance of institutions, among other employment protection legislation[1]. This conclusion comes mainly from a comparison between the U.S. labor market, known as flexible, and the European. However the real impact of EPL on the employment level remains highly controversial.

While EPL was introduced with the aim of enhancing workers' welfare and improving employment conditions, it translates into additional labor costs for the firms, namely *firing costs*, and is thus likely to have adverse effects as well. Firing costs make the employment decision of the firm dynamic: firms are indeed less likely to dismiss workers but anticipating the future costs, they may be less likely to hire workers as well, leaving the overall effect on the long-term employment level undetermined. In this respect, neither the related empirical literature, nor the theoretical studies can not show a clear association between EPL and the level of employment.

In contrast, the fact that labor market flows are slowed down by EPL seems to receive both theoretical and empirical support. Firing costs tend to reduce the incidence of unemployment but increase the average duration of unemployment. Over the business cycle, employment protection reveals to have a stabilizing effect, reducing the volatility of both employment creation and destruction. Higher firing costs decrease hiring rates in periods of rising demand, but it will reduce firings during economic recessions as well.

Consequently, the first intent of this thesis is to provide an exhaustive analysis of the diverse economic forces in action in presence of firing costs and emphasize its implications in the three perspectives: long-run level of unemployment, job flows and cyclical pattern of the labor market.

Recently, introducing labor market search into business cycle models with nominal rigidities, some authors have shown a preeminent role for labor market outcome in determining the cyclical behavior of output and inflation[2]. This result suggests a potential influence of firing

[1] In the following denoted by EPL

[2] see e.g. Trigari (2005) and Walsh (2005)

costs on these real aggregates through its effects on the determinants in the labor market and, therefore, some relevance for monetary policy, as they may affect the adjustment of the economy. Accordingly, the second principal objective of this thesis is to explore the possible effects of firing costs on the patterns of output and inflation.

The analysis is based on a dynamic general equilibrium model with nominal price rigidities and non-walrasian labor market: there are matching frictions leading to equilibrium unemployment. Firing costs are introduced following the assumption of Mortensen and Pissarides (1999b) and Joseph, Pierrard and Sneessens (2004), firms have to pay a firing tax in case of destruction of an existing employment relationship. First the effects of firing costs on hiring decisions are isolated using a model with exogenous job destruction, then, assuming that the workers are subject to idiosyncratic shocks, job destruction is endogenously modeled.

In the case of exogenous job separation, firing costs can only affect the hiring side and the effect on employment is unambiguously negative, as in Burda (1992). The conclusion is radically different when firms are allow to vary the firing rate. In this case, indeed, firms reduce both firing and hiring rates, but the effect on firing is larger so that the effect on employment is positive. This is in line with Mortensen and Pissarides (1999b) and Joseph et al. (2004), even if they find a weaker effect on the level of unemployment due to alternative assumptions about the idiosyncratic shocks and wage rigidities, respectively. The larger effect of firing costs on the firing rate here reveals another interesting result: when firing costs are higher and firing can not further decrease, then the effect on hiring dominates and unemployment increase. Therefore, costly job destruction can have a kind of "Laffer Curve" effect on unemployment.

The business cycle properties of the model with endogenous job destruction are then studied. As in the literature firing costs are found to have a dampening effect on job creation and destruction, stabilizing the unemployment level, as well as output. Nevertheless, this is reached at the price of a more volatile inflation. More expensive firings make employment more rigid, firms have to make rather adjustments in price.

The remainder of the thesis is organized as follows: Section 2 summarizes the principal results from the existing theoretical literature about the effects of firing costs on unemployment and its dynamics. Section 3 presents the empirical findings on the subject. Section 4 introduces the model framework. Section 5 derives the necessary equations defining the equilibrium. Section 6 analyzes the effects on the steady state level of unemployment and job flows. Section 7 studies the cyclical behavior the model and section 8 concludes.

2 Literature

In this section I present some works of the existing theoretical literature analyzing the effect of firing costs. They are separated according to the focus they have on: the long-run level of employment or its dynamics over the business Cycle.

2.1 Firing Costs and the Level of Employment

Since employment protection legislation has its consequences principally on the financial situation of the firms, it is mostly synthesized and conceptualized in the literature in the form of firing costs[3]. There are two categories of costs: the first summarizes all administrative costs related to the employment termination and difficulties of dismissal including the associated time lost, the second is a severance payment.

Lazear (1990) shows that in the absence of contractual and market frictions, a severance payment has no real effect: the entry wage is reduced by the amount equal to the expected present value of the future transfer, the situation of both parts remains unchanged. This result leads most researchers to consider formally firing costs as a tax firms have to pay in the case of a separation, this is also the case in this thesis.

The earliest formal analyses of effects of firing costs are in partial equilibrium frameworks. One pioneering study is Bentolila and Bertola (1990), which used a continuous time model of a monopolist facing stochastic demand shocks. Firms can instantaneous hire workers but bear labor adjustment costs under the form of hiring and firing costs, wage and productivity are exogenous and deterministic. Firms decide to fire if the discounted expected marginal revenue product of labor does not exceed the discounted wage costs saved by doing so less the firing costs. Higher firing costs reduce both firms' firing and hiring rates, however the effect on the latter is much weaker and the final effect on the steady-state employment level can be positive.

Bertola (1990) considers a model in discrete time where revenue of the firm depends on the business conditions which are a two-state Markov chain: there are "good" or "bad" times.

[3]There are few authors considering other forms of restriction, an example is Garibaldi (1998) who introduces exogenous firing permissions and discussed further below.

Firms have the possibility to fire (hire) only when business conditions switch from good to bad (bad to good). His findings correspond to Bentolila and Bertola's (1990), in both cases of exogenous and endogenously determined wage. In both models the discounting effect seems to play an important role, in particular Bentolila and Bertola (1990) explains their results arguing that at the moment of the decision of hiring a possible separation is still very far in the future, thus the costs are heavily discounted.

Later works in general equilibrium frameworks provide more contrasted results[4]. In Hopenhayn and Rogerson (1993) individuals are assumed to choose their probability of participation to the labor market and thus to be employment by lotteries and pool their income so that they are perfectly insured. Firms are subject to idiosyncratic productivity shocks and labor is freely reallocated across firms. In opposition to Bentolila and Bertola (1990) and Bertola (1990) they find a adverse effect of lay-off costs on employment, even worse, it is shown that firing costs can imply large welfare losses due to a significant decrease in average labor productivity, even though fiscal revenues are redistributed to households under the form of lump sum transfers.

Nevertheless Alvarez and Veracierto's (1998) model of equilibrium search demonstrates that firing costs can have a positive influence on employment. They argue that the crucial difference to Hopenhayn and Rogerson (1993) lies on the nature of the equilibrium ex ante. The latter describes a frictionless world where without government intervention the equilibrium allocation is Pareto-optimal, it follows that introduction of firing costs can only deteriorate this outcome: firing costs decreases productivity so individuals substitute work in favor of leisure choosing a lower probability of working and aggregate output decreases. Alvarez and Veracierto (1998) suggest that this result can not be extended an economy with frictions. In particular their model assumes that the probability that an unemployed individual finds a new job depends on his search intensity: job reallocation is frictional. Firms react to shocks by adjusting their labor demand and job turnover may be too high. Firing costs reduce the unemployment incidence, this increases the value to be employed and individuals raise their search intensities, as a consequence job-finding rate is enhanced and employment level is higher.

[4]Ljungqvist (2002) provides a synthesis of the analyses in general equilibrium differing in the way employment is determined

Interestingly, in a later work Alvarez and Veracierto (1999) show that when allowing individuals to decide of the participation to the labor force, firing costs can reduce unemployment *and* employment. The lower wage induces individuals to renounce to search for a work preferring home activities, the drop in the number of unemployed people can be so important that employment is also negatively affected, leading to large adverse effects on aggregate production and welfare.

These two opposite results shed some light on the forces at work in this kind of models: on the one hand, firing costs can contribute to lengthen job tenure reducing the rate of frictional unemployment, on the other hand, as in the model with employment lotteries, the lower return to market work can deviate individuals from the labor market. The final outcome depends on the assumption on risk aversion and insurance market. If individuals are risk-neutral the absence of insurance market does not matter and, as reported by Ljungqvist (2002), employment increases but welfare falls. If the individuals are risk-averse and there is no insurance market (Alvarez and Veracierto, 1998), the firing costs act as a form of insurance enhancing employment and welfare, while in presence of insurance market (Alvarez and Veracierto, 1999) the effect on both can be adverse.

In matching model frameworks, where the decision of labor market participation is often abstracted from, the focus is on the employment decision of the firm. The negative effect comes from the fact that firing costs making hiring less attractive, the firms post much less vacancies. Ljungqvist (2002) points out that the net effect depends on how the costs are shared between the firm and the worker, i.e. how they enter into wage bargaining. Using a simple model framework with exogenous job destruction rate and constant wage, Burda (1992) analyzes analytically the steady-state effects of firing costs and severance payment. He concludes to a negative impact of firing costs on labor market tightness resulting in a unambiguous increase of unemployment. This result follows straightforward from the discussion above: as the unemployment incidence is constant, only the negative effect subsists and unemployment rises.

Saint-Paul (1995) illustrates the effect of bargaining setting within a matching model framework with endogenous separation rate and quits. He assumes that the presence of firing costs will lower the threat point of the firm in the wage bargaining, since it has now to pay a tax if the match is broken. This raises workers' bargaining power, firm can not share the burden of the tax with the worker as it would like to do and labor costs increase. Additionally he demonstrates the possible existence of multiple equilibria in presence of firing costs: one with high labor mobility and low unemployment and another one with low labor mobility and high unemployment. When firing costs are relatively low, the effect on unemployment can be positive, as the effect on firing dominates the one on hiring. When firing costs become larger, they generate a drop in the quit rate which has a strong positive impact on the shadow cost of labor, thus firms fire more, even if firing costs are higher and unemployment increases.

Mortensen and Pissarides (1999b) concentrate on the implications of firing costs on wage bargaining and develop a two-tier wage structure containing a initial and a subsequent wage. They assume that if the match is broken after the first negotiation the firm has not to pay the tax, as the employment relationship actually never started. Thereby the threat point of the firm in the initial bargaining does not consider firing costs while in all negotiations after the idiosyncratic shock to match productivity occurs the threat point is the negative of the firing costs. They derive a lower first tier wage reflecting the fact that the decision implies the possibility of incurring firing costs in the future and thus changes firm's position. For a set of parameter values and different hiring subsidies they find a positive effect of firing costs on employment.

The role of wages is once again underlined by Joseph et al. (2004). They develop a search and matching model with a similar two-tier wage structure as in Mortensen and Pissarides (1999b) in which they introduce, in addition to firing costs, a downward wage rigidity and unemployment benefits. They find out a small effect of firing costs, which can be of both signs. If the wages are flexible, then the decrease in wage is enough to ensure a lower unemployment but if wage are rigid, wages can not be reduced sufficiently and unemployment rises.

2.2 Firing Costs and Labor Market Dynamics

Study of the potential role of firing costs over the business cycle is of significance as they are susceptible to have an influence on the cyclical patterns of job flows, dampening or magnifying the movements of employment leading to welfare implications.

Considering the dynamic perspective in his two states model, Bertola (1990) concludes to a lower variability of employment if firing costs are higher: firms tend to hire less in a boom because they will fire less in recession.

Garibaldi (1998) uses a search model with endogenous job separation and firing permission instead of firing taxes. Simulating his model with productivity shocks he finds out that firing permissions can reduce the volatility both job flows, furthermore the effect on job destruction is stronger. When firing permissions are continuously available, job destruction is instantaneous while job creation takes time, thus job destruction reacts more strongly to shocks and job reallocation moves counter-cyclically. When firing is restricted, it becomes costly and time-consuming and the asymmetry between job flows disappears.

Joseph et al. (2004) examine the effect of firing costs on the cyclical properties of job flows as well. They simulate their stochastic general equilibrium model with productivity shocks and demonstrate an unambiguous decrease in volatilities of job creation and destruction, however the relative amplitude of both effects are uncertain and depends on the degree of wage rigidities. When the minimum wage is higher, firing costs have more effect on job destruction counteracting the effect of wage rigidities, thus the relative volatility of job destruction decreases.

3 Some Empirical Results

The potential role of employment protection in a lower labor market performance has motivated a large body of work researching for a empirical evidence as well. In this section there are some results presented from *OECD Employment Outlook (1994)*, *(1999)* and *(2004)*.

Employment protection legislation includes all legal measures aiming to restrict employer's freedom to dismiss employees. In order to determine an eventual relationship between EPL and employment it is necessary to qualify resp. quantify the importance of EPL in each country. Various papers try to construct indicators to describe the 'strictness' of employment protection in each country. Pissarides (2001) enumerates the main categories used by OECD in its scores and ranks method:

- administrative procedures. This includes requirements for written justifications to the person to be dismissed and to third parties like unions or works councils
- requirement to give several months of notice to the worker before dismissal becomes effective
- payment of severance upon dismissal
- difficulties of dismissal: provisions for appeal against dismissal
- additional measures for collective dismissals

OECD (1999) constructs a overall EPL indicator using indicators referring to strictness for regular or permanent, fixed-term contracts and collective dismissed workers.

3.1 EPL and the Level of Employment

Figures (1) in appendix shows this indicator in 2003 against measures of employment and unemployment in 2002 for some OECD countries.

The first figure suggests that EPL strictness does not influence overall unemployment, the coefficient of correlation is very small and non-significant, while from the second one can recognize a stronger negative relationship with the overall employment population ratio, the coefficient of correlation is significant at 5% significance level. Bivariate analysis of the correlation between a variety of EPL strictness indicators and employment resp. unemployment rates provides that most of the coefficients, especially the correlations with unemployment rates, are small and not significantly different from zero while the effect on employment rates are. However this effect becomes also insignificant when other factors are taken into account.

Other multivariate analyses tend to conclude to a negative effect on employment rates (e.g. Nickell, 1997; Heckman and Pages, 2000), there is no consensus about the effect on unemployment (e.g. Elmeskov and Scarpetta, 1998; Belot and van Ours, 2000; Baker, Glyn, Howell and Schmitt, 2005). Baker et al. (2006) point out the lack of robustness of these studies with widely divergent coefficients and levels of significance. It can be concluded that EPL does not seem to influence the overall unemployment rate but has small effects on employment through their impact on the labor force participation decision of the different groups of population.

3.2 EPL and Job Flows

OECD (1999) examines the associations between the EPL indicator and labor market dynamics, represented by job turnover, mean job tenure, inflows into and out of the unemployment as well as unemployment duration. The simple correlation analysis shows a weak negative effect of EPL on job turnover and a somewhat more substantial imapct on job tenure, flows into and out of unemployment, duration of unemployment is lengthened. A GLS regression using nine additional control variables confirms a significant effect on unemployment inflow and outflow and unemployment duration.

Figure (2) in appendix represents the indicator in 2003 against flows into and out of unemployment measured in 2002 for some OECD countries. There is a statistically significant strong negative effect of EPL on the proportion of people in working-age falling into unemployment, while the proportion of unemployed people getting out of unemployment seems to be only weakly affected by EPL.

Some other recent studies demonstrate more clearly the association between lower firing and hiring rates with stricter EPL. Blanchard and Portugal (2001), taking quarterly instead of annual data, observe significantly lower job creation and destruction rates in Portugal, where EPL is stricter, than in the U.S.. Gomez-Salvador, Messina and Vallanti (2004) use firm-level annual data from 13 European countries and obtain similar results. Their effect on job destruction rate is not significant, but the overall effect on the job reallocation rate is. Data seem to support the hypothesis that stricter EPL lowers some forms of labor market turnover, although they show little or no effect on overall unemployment.

3.3 EPL and the Cyclical Behavior of the Labor Market

Bertola (1990) shows some support for the stabilizing effect of employment protection on the variability of employment. He uses data for employment in manufacturing over the period 1962-1986 for 10 OECD countries and finds out that job security strongly reduces the responsiveness of unemployment to output changes. Furthermore he remarks that job security makes unemployment more persistent.

In each country job creation and destruction seem to be negatively correlated with a pro-cyclical movement of job creation and counter-cyclical movement of job destruction, however the volatility of these flows over the business cycle differs across countries. Davis and Haltiwanger (1990) and (1992) show that the U.S. labor market exhibits a much stronger increase in job destruction during recessions than the increase in job creation in booms resulting in a counter-cyclical movement of job reallocation, the same holds for the U.K.. In opposite the continental European countries have a lower volatility of job creation and particularly of job destruction, the job reallocation tends to be a- or pro-cyclical[5]. Basing on his theoretical model, Garibaldi (1998) argues that this difference is due to the level of employment protection.

Recently Messina and Vallanti (2006) estimate the relationship between stringency of EPL and volatility of the job flows for 14 European countries during the 1990s. Using a homogenous firm-level data set they state a negative impact of EPL on the cyclicality of job creation and destruction rates. Even if only the effect on job destruction rate is significant, altogether the

[5] For a overview see Garibaldi (1998)

effect on the cyclicality of job reallocation is negative.

4 The Model

The firing costs are introduced into a general equilibrium model in infinite time horizon with nominal rigidities and matching frictions[6]. There are five types of agents in the economy: intermediate firms, retail firms, a representative household, a government and a monetary authority. To distinguish between the labor demand and the price setting problem[7] It could be assumed that there are intermediate firms producing using labor as unique input, they sell the intermediate goods in perfect competition to retail firms who differentiate them. The latter sell the retail goods in monopolistic competition to households composed of workers and unemployed members. For simplicity, it will be refered to retail firms as retailers and to intermediate firms as firms simply.

Following Mortensen and Pissarides (1999b) and Joseph et al. (2004), the total employment is divided into two kinds of jobs or workers. The "old workers", denoted by the superscript $j = 1$, are protected in the sense that firms have to pay a tax in the case of a separation, while the "new workers", who just matched with a firm in the last period and denoted by superscript $j = 0$, are not.

4.1 Labor Market

Basing on Pissarides (1990) there are frictions in the aggregate labor market leading to equilibrium unemployment. In each period[8] a fraction of unemployed workers and job vacancies match in the labor market to form new jobs, the processus of workers' reallocation across firms is costly and time-consuming.

[6]The basic model framework follows Krause and Lubik (forthcoming) and Trigari (2005)

[7]Trigari (2005) and Christoffel and Linzert (2005) make the same distinction between price setters and labor demanders, the latter assume furthermore that there are final good firms who aggregate the goods produced by the retail firms and sell this bundle in perfect competition to the households, formally this leads to the same result as by assuming that the household buy a representative bundle of the final good minimizing the costs, which is the case here.

[8]Pissarides's (1990) model is in continuous time but conceptually it is the same processus.

4.1.1 Matching Market

In order to match with a worker the intermediate firms have to search for workers in the labor market. In each period it is assumed that all unemployed people search passively for a job with the same intensity equal to 1, the number of workers seeking for a job is equal to unemployment u_t. Each firm has one job and is either filled or vacant and searching for a worker. v_t denotes the number of posted vacancies. The number of worker-firm contacts $\mathcal{M}_t$ at the end of the period is defined through the following matching function:

$$\mathcal{M}_t = m u_t^{\mu} v_t^{1-\mu} \tag{1}$$

with $\mu \in (0,1)$ and $m > 0$ a scale parameter reflecting the efficiency of the matching process. The Cobb-Douglas specification guarantees that it is increasing in its arguments, concave and homogenous of degree 1. $\theta_t = v_t/u_t$ as a measure of *labor market tightness* at time t is introduced.

$$q_t = \frac{\mathcal{M}_t}{v_t} = m\theta^{-\mu} \tag{2}$$

as the ratio between the number of matches and the number of posted vacancies is called *vacancy duration hazard*, its inverse $1/q_t$ is the mean duration of vacancies. It can be understood as the 'probability' that a open vacancy meets a job-seeker within the period. q_t is decreasing in market tightness: with more vacancies in proportion to the number of unemployed people, it is more difficult for a firm to match with a worker. By symmetry,

$$s_t = \frac{\mathcal{M}_t}{u_t} = m\theta^{1-\mu}, \tag{3}$$

called *unemployment spell duration hazard*, represents the 'probability' that a job-seeker meets a firm at time t. Its inverse $1/s_t$ corresponds to the mean unemployment spell duration. s_t is increasing in θ_t, as the relative number of vacancies increases it becomes easier for a job-seeker to match with a firm. Once matched, a worker-firm pair can become productive only in the next period. I abstract from the labor market participation decision and assume a constant labor force normalized to 1.

$$n_t + u_t = 1 \tag{4}$$

where n_t is the number of employed persons or producing jobs in t.

4.1.2 Labor Market with an Exogenous Job Destruction Rate

In this section the labor market is featured with an exogenous job destruction rate. Pissarides (1990) considers that these flows into unemployment result from job-specific shocks that affect all filled jobs at the same rate, reflecting some demand shifts not taken into account in the model. One can also think of the case of separation initiated by the worker, as they may quit[9].

All jobs are identical with the same productivity equaling to 1. At the beginning of each period, before production takes place, a constant rate $\rho \in (0,1)$ of workers and firms separate. The dynamics of total employment is thus given by:

$$n_t = (1-\rho)(\mathcal{M}_{t-1} + n_{t-1}) = n_t^0 + n_t^1 \tag{5}$$

n_t is then the sum of matches formed in the last period which was not destructed n_t^0 and existing jobs which survived n_t^1 .

In equilibrium a match generates a total return which is strictly higher than the the expected returns of searching firm and worker. This surplus is justified by the fact that if the firm-worker pair separates, they have to enter into a new costly search processus in order to meet another partner. Hence a realized match can share this economic rent corresponding to the expected search costs and this is done according to the Nash solution to a bargaining problem. Therefore in order to determine the wage, it is necessary to determine at first the surplus of the match. In the following are defined the Bellman equations of firms and workers, expressed in the form of asset value functions. The firm's expected return from a new job denoted with J_t^0 is:

$$J_t^0 = A_t d_t - w_t^0 + \mathrm{E}_t \beta_{t+1} \left[(1-\rho) J_{t+1}^1 + \rho (V_{t+1} - f) \right] \tag{6}$$

[9]On-the-job search being not explicitly modeled here, it can be included in the exogenous separation rate.

with A_t being the production of a firm with filled job and also the aggregate productivity level, d_t the competitive price at which it sells the produced goods to retail firms and w_t^0 the wage it pays the new worker. The second term is the discounted expected value of the firm in the next period, it is composed of the value of the job became old in the next period if it survives and the value of a vacancy minus the incurred firing costs if the match is dissolved after the first period. Since households are owners of the firms, the latter discounts the future values using worker's discount rate $\beta_{t+s} = \beta \frac{\lambda_{t+s}}{\lambda_t}$[10], where λ_t, shown below, stands for the marginal utility of consumption. In opposition the firm's value of a old job J_t^1 is:

$$J_t^1 = A_t d_t - w_t^1 + \mathrm{E}_t \beta_{t+1} \left[(1-\rho) J_{t+1}^1 + \rho (V_{t+1} - f) \right] \tag{7}$$

It differs from the value of the new job only in the wage. The value of an open vacancy V_t is:

$$V_t = \; - a + \mathrm{E}_t \beta_{t+1} \left[q_t (1-\rho) J_{t+1}^0 + (1 - q_t(1-\rho)) V_{t+1} \right] \tag{8}$$

is equal to $-a < 0$, the cost of posting a vacancy per period plus the discounted expected value of the firm in the next period, i.e. the value of a new job, if the firm matches with a worker and they do not separate, and the value of posting a vacancy in the next period if no match takes place or if it occurs but is destructed. As long as the value of posting a vacancy is greater than 0, firms will open new vacancies. In equilibrium, free entry into the labor market ensures that: $V_t = 0$, $\forall\ t$, it follows:

$$\frac{a}{q_t} = (1-\rho) \mathrm{E}_t \beta_{t+1} J_{t+1}^0 \tag{9}$$

Let turn us now to the worker. W_t^0, the value of a new employment for a worker is:

$$W_t^0 = w_t^0 + \mathrm{E}_t \beta_{t+1} \left[(1-\rho) W_{t+1}^1 + \rho U_{t+1} \right] \tag{10}$$

[10]In opposition to the 'classical' Mortensen-Pissarides matching model which assumes a constant discount rate the variable

It corresponds to the current wage plus the discounted expected value in the next period, where if the match is not dissolved the worker obtains the value of an old employment and if dissolved the value of unemployment. The value of an old employment W_t^1 differs only in the wage:

$$W_t^1 = w_t^1 + \mathrm{E}_t\beta_{t+1}\left[(1-\rho)W_{t+1}^1 + \rho U_{t+1}\right] \tag{11}$$

Assuming that the unemployed worker receives from the government an unemployment insurance b:

$$U_t = b + \mathrm{E}_t\beta_{t+1}\left[s_t(1-\rho)W_{t+1}^0 + (1 - s_t(1-\rho))U_{t+1}\right] \tag{12}$$

His value in this case is then the sum of this unemployment benefit and the discounted value to be newly employed in the next period, if he matches with a firm and the match is not dissolved, plus the discounted value to be unemployed, if he does not match or the match is destructed.

In the Nash bargaining the new wage w_t^0 maximizes the weighted product of the worker's and the firm's surplus from the new job:

$$\max_{w_t^0}(W_t^0 - U_t)^\eta (J_t^0)^{1-\eta}$$

with U_t, the threat point of the worker and firm's threat point is at 0. $\eta \in (0,1)$ represents the worker's relative "bargaining power".

The situation is different in the subsequent negotiations since if the match is then destroyed, firing costs f incur for the firm implying that his threat point is no longer 0 but $-f$. The bargaining becomes:

$$\max_{w_t^1}(W_t^1 - U_t)^\eta (J_t^1 + f)^{1-\eta}$$

4.1.3 Labor Market with an Endogenous Job Destruction Rate

Studying the effect of firing costs on employment, one question arises naturally: does firing costs have an influence on the firing decisions of the firm? To examine this it is necessary to allow firms to adjust their firing rates introducing endogenous job destruction.

Mortensen and Pissarides (1994) develop a model with endogenous job destruction. This is done by assuming heterogeneity in jobs' market value: each job is subject to idiosyncratic shocks. Jobs with large negative shocks are destructed. They use a continuous time model with stochastic arrival rate of the idiosyncratic shocks. This assumption implies persistence in job-specific shocks which has as consequence to produce discrete aggregate productivity shocks. To avoid the complication of such a modelling de Haan, Ramey and Watson (2000) assume within a model in discrete time that in each period the probability that an idiosyncratic shock incurs is equal to 1. I follow them and suppose that in each period all matches are subject to idiosyncratic shocks. Thereby a worker-firm pair which just matched can also be separated in opposition to Mortensen and Pissarides (1994) who assumed that a new match has always the highest value and is accordingly never destructed. As in the precedent section the new matches are not protected while the old are.

In presence of idiosyncratic productivity shocks z_t the production of a job is $A_t z_t$. z_t are i.i.d. distributed with c.d.f. $F(z)$ and p.d.f. $f(z)$ on the positive support. Similarly as in the precedent section, at the beginning of the period a match can be separated for exogenous reasons at a rate ρ. Furthermore a matched pair can decide endogenously to separate if the realized value of z_t is below a certain threshold. As a new job and an old one may generate different surpluses they may also have distinct thresholds, so $\tilde{z}_t^0$ is defined as the threshold for a new pair and $\tilde{z}_t^1$ for an old one. Hence the probabilities of endogenous separation are $\rho_t^{0,n} = F(\tilde{z}_t^0)$ and $\rho_t^{1,n} = F(\tilde{z}_t^1)$, respectively. The total separation rates are then:

$$\rho_t^0 = \rho^x + (1-\rho^x)\rho_t^{0,n} \tag{13}$$

$$\rho_t^1 = \rho^x + (1-\rho^x)\rho_t^{1,n} \tag{14}$$

Accordingly the employment evolves following:

$$n_t = n_t^0 + n_t^1 = (1-\rho_t^0)\mathcal{M}_{t-1} + (1-\rho_t^1)n_{t-1} \tag{15}$$

where n_t^0 denotes the number of employed persons in a new job and n_t^0 the number in an old one.

The job flows are defined following Krause and Lubik (forthcoming). Job destruction rate is given by $jdr_t = \rho_t^1 - \rho^x$, while job creation rate jcr_t is:

$$jcr_t = \frac{(1-\rho_t^0)m_{t-1}}{n_{t-1}} - \rho^x \tag{16}$$

The job turnover is defined as the sum of these two rates:

$$jt_t = jcr_t + jdr_t \tag{17}$$

and the net employment change is the difference between them:

$$net_t = jcr_t - jdr_t \tag{18}$$

The Bellman equations describing the problem of firms and workers are defined in the following. Firm's value of a new job with a given realization of z_t is given by:

$$J_t^0(z_t) = A_t z_t d_t - w_t^0(z_t) + \mathrm{E}_t \beta_{t+1}\left[(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty} J_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx + \rho_{t+1}^1(V_{t+1}-f)\right] \tag{19}$$

The current revenue of the new match $A_t z_t d_t$ as well as the new wage $w_t^0(z_t)$ depend now on z_t. The future expected present value of the job can be interpreted as follows. Next period with a probability $1-\rho_{t+1}^1$ the match is not destroyed and the firm obtains the future expected value of an old job, where the expected value is conditioned on having an idiosyncratic shock above the threshold $\tilde{z}_{t+1}^1$. With a Probability ρ_{t+1}^1 the match is dissolved and the firm gets the value of a vacancy minus the firing costs. The firm's value of an old job is defined similarly:

$$J_t^1(z_t) = A_t z_t d_t - w_t^1(z_t) + \mathrm{E}_t \beta_{t+1}\left[(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty} J_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx + \rho_{t+1}^1(V_{t+1}-f)\right] \tag{20}$$

again, the only element differentiating them is the wage. The value of an open vacancy is:

$$V_t = \; -a + \mathrm{E}_t\beta_{t+1}\left[q_t(1-\rho^0_{t+1})\int_{\tilde{z}^0_{t+1}}^{\infty} J^0_{t+1}(x)\frac{f(x)}{1-F(\tilde{z}^0_{t+1})}dx + (1-q_t(1-\rho^0_{t+1}))V_{t+1}\right] \tag{21}$$

Note that it does not depend on z_t as the firm with an open vacancy does not produce. The free entry condition $V_t = 0$, $\forall\ t$ implies:

$$\frac{a}{q_t} = \mathrm{E}_t\beta_{t+1}(1-\rho^0_{t+1})\int_{\tilde{z}^0_{t+1}}^{\infty} J^0_{t+1}(x)\frac{f(x)}{1-F(\tilde{z}^0_{t+1})}dx \tag{22}$$

The worker's value of a new job for a given value of z_t is:

$$W^0_t(z_t) = w^0_t(z_t) + \mathrm{E}_t\beta_{t+1}\left[(1-\rho^1_{t+1})\int_{\tilde{z}^1_{t+1}}^{\infty} W^1_{t+1}(x)\frac{f(x)}{1-F(\tilde{z}^1_{t+1})}dx + \rho^1_{t+1}U_{t+1}\right] \tag{23}$$

while his value of an old job is:

$$W^1_t(z_t) = w^1_t(z_t) + \mathrm{E}_t\beta_{t+1}\left[(1-\rho^1_{t+1})\int_{\tilde{z}^1_{t+1}}^{\infty} W^1_{t+1}(x)\frac{f(x)}{1-F(\tilde{z}^1_{t+1})}dx + \rho^1_{t+1}U_{t+1}\right] \tag{24}$$

And finally the value of unemployment does not either depend on z_t.

$$U_t = b + \mathrm{E}_t\beta_{t+1}\left[s_t(1-\rho^0_{t+1})\int_{\tilde{z}^0_{t+1}}^{\infty} W^0_{t+1}(x)\frac{f(x)}{1-F(\tilde{z}^0_{t+1})}dx + (1-s_t(1-\rho^0_{t+1}))U_{t+1}\right] \tag{25}$$

4.2 Household

The representative household is thought of as a very large family with a continuum of members indexed by i on the interval $i \in (0,1)$ who can be either employed or unemployed. Labor supply is inelastic. It maximizes its expected lifetime utility:

$$\mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\, U\left(C_t, \frac{M_t}{P_t}\right) = \mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\left[\frac{C_t^{1-\sigma}-1}{1-\sigma} + \chi\log\left(\frac{M_t}{P_t}\right)\right]$$

with $\beta \in (0,1)$ the intertemporal discount factor and σ the coefficient of relative risk aversion. Thus utility depends positively on C_t the consumption bundle in time t and M_t/P_t the real money holding. This "money in the utility function model" is an alternative formulation of the shopping time monetary economy in the spirit of Ljungqvist and Sargent (2004). The idea is that buying consumption goods takes money and time thus holding money, household can save shopping time and its utility is increased. The introduction of money directly into the utility function leads to the same result as the specification of a shopping time technology, i.e. the derivation of a money demand function. The household chooses consumption, nominal money and asset holding B_t subject to the budget constraint:

$$C_t + \frac{B_t}{P_t} = w_t^0 n_t^0 + w_t^1 n_t^1 + bu_t + R_{t-1}\frac{B_{t-1}}{P_t} + \Pi_t - T_t^b + T_t^f$$

where w_t^0 and w_t^1 are the wages for each kind of job. Following Merz (1995) and Andolfatto (1996) the members of the family pool their income so that there is perfect insurance against unemployment. By doing so the problem of heterogeneity between the individuals due to the different wages and unemployment is avoided implying that the consumption respectively saving decisions are valid for all. The household can buy a nominal one-period bond B_t issued by the government that pays a risk-free gross nominal interest rate R_t. Owner of the firms the household receives the aggregate profit Π_t. The government finances the unemployment insurance b by levying a lump sum tax T_t^b and redistributes the revenue from the firing tax under the form of a lump sum transfer T_t^f.

4.3 Retailers and Price Setting

There is a continuum of monopolistic competitive retailers indexed by $i \in (0, 1)$. Retailers buy the intermediate goods at the price d_t from firms. They produce using a linear technology transforming one unit of homogenous intermediate good into one unit of the differentiated retail goods. Since they do not use other input, the marginal costs are simply d_t. Finally they sell to the households a composite C_t of the retail goods defined by:

$$C_t = \left[\int_0^1 c_{i,t}^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}$$

where $c_{i,t}$ is the quantity of output sold by retailer i. $\epsilon > 1$ is the elasticity of substitution between the differentiated retail goods. Given $p_{i,t}$ the retail goods price and P_t the aggregate price the expenditure minimization leads to:

$$c_{i,t} = \left(\frac{p_{i,t}}{P_t}\right)^{-\epsilon} C_t$$

The aggregate price index, defined as the minimum expenditure required to purchase 1 unit of final good is then:

$$P_t = \left[\int_0^1 p_{i,t}^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$$

As in Calvo (1983) the prices are set in a staggered fashion: in every period each retailer is allowed to reset its price with probability $1-\varphi$ independently of the time elapsed since the last adjustment. As a result in each period only a fraction $1-\varphi$ of the retailers are allowed to reset their prices while the a fraction φ keep their prices unchanged. The real profit of the retailers being

$$\left[\left(\frac{p_{i,t}}{P_{t+s}}\right) - d_{t+s}\right] c_{i,t+s}$$

they reset their price maximizing:

$$\max_{p^*_{i,t}} \mathrm{E}_t \sum_{s=0}^{\infty} \varphi^s \beta_{t+s} \left[\left(\frac{p^*_{i,t}}{P_{t+s}}\right) - d_{t+s}\right] c_{i,t+s}$$

s.t.

$$c_{i,t} = \left(\frac{p^*_{i,t}}{P_t}\right)^{-\epsilon} C_t$$

The aggregate price level evolves following:

$$P_t = [\varphi P_{t-1}^{1-\epsilon} + (1-\varphi)(P_t^*)^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \tag{26}$$

4.4 Government and Monetary Authority

The government budget constraint is given by:

$$R_{t-1}\frac{B_{t-1}}{P_t} + bu_t + T_t^f = \frac{B_t}{P_t} + T_t^b + f\rho n_{t-1} \tag{27}$$

with ρ_t^1 instead of ρ when job destruction is endogenous. The monetary authority conducts monetary policy using the money supply as policy instrument and lets the nominal interest rate adjusting accordingly[11]. The logarithm of the nominal money supply growth $\phi_t = M_t/M_{t-1}$ follows a AR(1) process:

$$\log\phi_t = \psi_m \log\phi_{t-1} + \epsilon_{m,t} \tag{28}$$

where $0 < \psi_m < 1$ and $\epsilon_{m,t} \sim \text{i.i.d.}(0, \sigma_m^2)$. The steady state money growth rate is assumed to be equal to 0.

4.5 Aggregation

The aggregate income corresponds to:

$$Y_t - av_t - f\rho n_{t-1} = \Pi_t + n_t^0 w_t^0 + n_t^1 w_t^1 \tag{29}$$

The production of the firms after deduction of the firing tax and the vacancies posting costs is redistributed to the households under the form of wages or profit. It follows that in equilibrium:

$$C_t = Y_t - av_t \tag{30}$$

[11] Alternatively the money supply process can be modeled using an interest rate rule. Whenever the central bank controls the quantity of money or interest rate the money market has to be in equilibrium, thereby these two approaches are conceptually the same. The use of a money growth rule allows to avoid the typical indeterminacy problems with an interest rate rule.

the output minus the vacancies posting costs is consumed. Given that in the case of exogenous job destruction rate all jobs have the same productivity, the aggregate production is simply:

$$Y_t = A_t n_t \tag{31}$$

While when job destruction is endogenous, the aggregate production function is expressed as the weighted average of the expected production in new and old jobs, with weights being the number of persons employed in each kind of job:

$$Y_t = A_t \left[H(\tilde{z}_t^0) n_t^0 + H(\tilde{z}_t^1) n_t^1 \right] \tag{32}$$

The logarithm of the aggregate productivity is defined as an AR(1) process:

$$\log A_t = \psi_A \log A_{t-1} + \epsilon_{A,t} \tag{33}$$

where $0 < \psi_A < 1$ and $\epsilon_{A,t} \sim \text{i.i.d.}(0, \sigma_A^2)$.

5 Model Analysis

In this section the equations defining the equilibrium in the labor market, as well as the first order conditions of the household and retailers are derived.

5.1 Labor Market with an Exogenous Job Destruction Rate

5.1.1 Wages Setting

The wages are set following the Nash bargaining which yields for the new wage:

$$(1-\eta)(W_t^0 - U_t) = \eta J_t^0 \tag{34}$$

If $S_t^0 = W_t^0 - U_t + J_t^0$ is the surplus of a new job, then we obtain:

$$\begin{aligned} W_t^0 - U_t &= \eta S_t^0 \\ J_t^0 &= (1-\eta) S_t^0 \end{aligned}$$

Showing that the surplus is indeed shared between the firm and the worker according to the parameter η. Inserting (6), (10), (12) and (9) into (34) and after transformation one can obtain the new wage w_t^0:

$$w_t^0 = (1-\eta)b + \eta(A_t d_t + a\theta_t - \mathrm{E}_t \beta_{t+1} f) \tag{35}$$

From the first term it can be recognized that the worker is compensated for a fraction $(1-\eta)$ for the forgone benefit from unemployment, the second term shows that the worker is rewarded for a fraction η of the firm's benefits, i.e. the sum of the revenue plus the saved search costs for another worker minus the discounted firing costs. The firing costs, which diminish the firm's value from a match, reduces the new wage as well. In this case the presence of firing costs does not modify the threat point of the firm, its bargaining power is intact and it can share the future firing costs with the worker as much as it can, i.e. according to the bargaining power. Note that the firing costs are discounted for only one period, even in average they will incur later in the future. Similarly it results for the old wage:

$$(1-\eta)(W_t^1 - U_t) = \eta(J_t^1 + f) \tag{36}$$

In this case Mortensen and Pissarides (1999a) define the surplus of an old job as $S_t^1 = W_t^1 - U_t + J_t^1 + f$, this is higher than the surplus of a new job, since now if the match is not destructed the firm "saves" the firing costs. As before the surplus is shared between the worker and the firm:

$$\begin{aligned} W_t^1 - U_t &= \eta S_t^1 \\ J_t^1 + f &= (1-\eta) S_t^1 \end{aligned}$$

However, due to the different definition of the surplus, the part going to the firm is actually diminished, since it receives $J_t^1 = (1-\eta)(W_t^1 - U_t + J_t^1) - \eta f$. In opposite, the part owning to the worker is larger. Similarly the old wage is obtained by inserting (7), (11), (12) and (9) into (36):

$$w_t^1 = (1-\eta)b + \eta(A_t d_t + a\theta_t + f - \mathrm{E}_t \beta_{t+1} f) \tag{37}$$

is accordingly higher, more exactly it is augmented by ηf, the amount firm saves as the match is continued weighted by the worker's bargaining power. The bargaining solution induces a two-tiers wage structure: the lower first tier wage reflects the fact that hiring implies to accept that firing costs will incur in the future so the worker shares these costs according to his bargaining power, the second tier wage is higher because firing costs are directly relevant to continuation decision and a separation would be costly to both parts. Therefore firing costs acts as a posted 'bond' reducing the new wage and in the following periods, as the match survives, the net interest on this 'bond' are paid under the form of a higher old wage. The difference between both wages $w_t^1 - w_t^0 = \eta f$ implies $J_t^0 - J_t^1 = \eta f$.

The firm's old job value can then be substituted in (9) and inserting the expression for the new wage (35) yields:

$$\frac{a}{q_t} = (1-\rho)\mathrm{E}_t\beta_{t+1}\left[(1-\eta)(A_{t+1}d_{t+1} - b - \beta_{t+2}\rho f) - \eta a\theta_{t+1} + \frac{a}{q_{t+1}}\right] \tag{38}$$

The expected costs of posting a vacancy must be equal to the discounted expected return. When the job survives in the following period then the production generates a revenue, this is diminished by the opportunity costs of employment for the worker and the net burden represented by the future firing costs, $-\eta a\theta_{t+1}$ expresses the pressure exercised on wages by greater market tightness and the last term represents the saving of search costs for another worker.

5.2 Labor Market with an Endogenous Job Destruction Rate

5.2.1 Wages Setting

The wages are again determined through the Nash bargaining resulting in:

$$(1-\eta)\left[W_t^0(z_t) - U_t\right] = \eta J_t^0(z_t) \tag{39}$$

for the new wage and

$$(1-\eta)\left[W_t^1(z_t) - U_t\right] = \eta\left[J_t^1(z_t) + f\right] \tag{40}$$

for the old wage. Inserting (19), (23), (25) and (22) into (39) yields after rearranging:

$$w_t^0(z_t) = (1-\eta)b + \eta(A_t z_t d_t + a\theta_t - \mathrm{E}_t\beta_{t+1}f) \tag{41}$$

The old wage is obtained similarly plugging (20), (24), (25) and (22) into (40):

$$w_t^1(z_t) = (1-\eta)b + \eta(A_t z_t d_t + a\theta_t + f - \mathrm{E}_t\beta_{t+1}f) \tag{42}$$

Note that, as in the case of exogenous separation, for a given realization of z_t the subsequent wage is higher than the initial one, implying that the firm's value of a new job is higher.

$$\begin{aligned} w_t^1(z_t) - w_t^0(z_t) &= \eta f \\ J_t^0(z_t) - J_t^1(z_t) &= \eta f \end{aligned}$$

The aggregate wages are the average wages among the workers in a new respectively old job, thus they represent the expected wages conditional on the idiosyncratic productivity shock being above the respective thresholds:

$$\begin{aligned} w_t^0 &= \int_{\tilde{z}_t^0}^{\infty} (1-\eta)b + \eta(A_t x d_t + a\theta_t - \mathrm{E}_t \beta_{t+1} f) \frac{f(x)}{1-F(\tilde{z}_t^0)} dx \\ &= (1-\eta)b + \eta(A_t H(\tilde{z}_t^0) d_t + a\theta_t - \mathrm{E}_t \beta_{t+1} f) \qquad (43) \\ w_t^1 &= \int_{\tilde{z}_t^1}^{\infty} (1-\eta)b + \eta(A_t x d_t + a\theta_t + f - \mathrm{E}_t \beta_{t+1} f) \frac{f(x)}{1-F(\tilde{z}_t^1)} dx \\ &= (1-\eta)b + \eta(A_t H(\tilde{z}_t^1) d_t + a\theta_t + f - \mathrm{E}_t \beta_{t+1} f) \qquad (44) \end{aligned}$$

with $H(z) = \int_z^{\infty} x \frac{f(x)}{1-F(z)} dx$, remark that:

$$w_t^0 - \eta[A_t H(\tilde{z}_t^0) d_t] = w_t^1 - \eta[A_t H(\tilde{z}_t^1) d_t + f]$$

5.2.2 Endogenous Separation

As a new match destruction is no-costly, a new match is only destroyed, if the realized idiosyncratic shock makes the firm's value of the new job equal to zero or negative. Therefore the condition defining the new job destruction threshold (also called reservation productivity) $\tilde{z}_t^0$ is:

$$J_t^0(\tilde{z}_t^0) = A_t \tilde{z}_t^0 d_t - w_t^0(\tilde{z}_t^0) + \mathrm{E}_t \beta_{t+1} \left[(1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} J_{t+1}^1(x) \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx - \rho_{t+1}^1 f \right] \stackrel{!}{=} 0 \qquad (45)$$

The surplus of a new job defined in section (5.1.1) depends on productivity shocks z_t as well, it becomes $S_t^0(z_t) = W_t^0(z_t) - U_t + J_t^0(z_t)$. Remember that firm and worker share the surplus according to the bargaining power η, $W_t^0(z_t) - U_t = \eta S_t^0(z_t)$ and $J_t^0(z_t) = (1-\eta) S_t^0(z_t)$, therefore $J_t^0(\tilde{z}_t^0) = 0$ if and only if $S_t^0(\tilde{z}_t^0) = 0$ and $W_t^0(\tilde{z}_t^0) - U_t = 0$. A new match is dissolved when the surplus associated is zero implying that firm's and worker's values are both equal to zero, thereby a decision of separation is always optimal for both worker and firm.

When an old job is destructed, the firm has to pay a firing tax f. This implies that, as in the precedent section, the threat point of the firm is $-f$ instead of 0. The old job destruction threshold is then:

$$J_t^1(\tilde{z}_t^1) + f = A_t \tilde{z}_t^1 d_t - w_t^1(\tilde{z}_t^1) + \mathrm{E}_t \beta_{t+1} \left[(1 - \rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} J_{t+1}^1(x) \frac{f(x)}{1 - F(\tilde{z}_{t+1}^1)} dx - \rho_{t+1}^1 f \right] + f \overset{!}{=} 0 \tag{46}$$

Again, combining the definition of the surplus $S_t^1(z_t) = W_t^1(z_t) - U_t + J_t^1(z_t) + f$ with (40) yields $W_t^1(z_t) - U_t = \eta S_t^1(z_t)$ and $J_t^1(z_t) + f = (1-\eta) S_t^1(z_t)$, this highlights that $J_t^1(\tilde{z}_t^1) + f = 0$ if and only if $S_t^1(\tilde{z}_t^1) = 0$ and $W_t^1(\tilde{z}_t^1) - U_t = 0$, implying that the decision of separation in an old job is always optimal for both parts as well.

After inserting (20) and (46) and rearranging the condition for the new job destruction threshold (45) can be rewritten as[12]:

$$A_t \tilde{z}_t^0 d_t = b + \frac{\eta}{1-\eta} a \theta_t - \mathrm{E}_t \beta_{t+1} (1 - \rho_{t+1}^1) A_{t+1} d_{t+1} \left[H(\tilde{z}_{t+1}^1) - \tilde{z}_{t+1}^1 \right] + \mathrm{E}_t \beta_{t+1} f \tag{47}$$

The left hand side is the lowest return acceptable to firms to keep the match. The right hand side represents the costs which incur, when the match is retained. They contain the opportunity costs of employment for the worker, i.e. the unemployment benefit and the expected gain from search, the third term is the expected return from the job in the next period and finally the firing costs, as additional costs which will incur in the future, raises the current costs of creating a job. From (45) and (46) the relation between $\tilde{z}_t^0$ and $\tilde{z}_t^1$ can be established:

$$A_t \tilde{z}_t^1 d_t = A_t \tilde{z}_t^0 d_t - f \tag{48}$$

[12]For derivation see appendix

Firing costs reduces the costs of keeping one additional worker employed as in this case, the firm saves exactly this amount. Note that this equation defines a linear relationship between new and old job destruction thresholds, it shows that with positive f, $\tilde{z}_t^0$ is always higher than $\tilde{z}_t^1$. Vacancy creation condition (22) can be transformed inserting (19) and (45) into:

$$\frac{a}{q_t} = (1-\eta)\mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^0)A_{t+1}d_{t+1}\left[H(\tilde{z}_{t+1}^0) - \tilde{z}_{t+1}^0\right] \tag{49}$$

Again, the costs of posting vacancy is equal to the discounted expected return.

5.3 Household

The first order conditions of the representative household from the intertemporal optimization are:

$$\lambda_t = C_t^{-\sigma} \tag{50}$$

$$\lambda_t = \beta R_t \mathrm{E}_t\left(\lambda_{t+1}\frac{P_t}{P_{t+1}}\right) \tag{51}$$

$$\frac{M_t}{P_t} = \chi\frac{R_t}{R_t-1}C_t^{\sigma} \tag{52}$$

(51) is the Euler equation relating the marginal utility of consumption in t to the one in $t+1$, the last equation is the money demand equation.

5.4 Retailers

The retailers aim to maximize:

$$\Rightarrow \quad \max_{p_{i,t}^*}\mathrm{E}_t\sum_{s=0}^{\infty}\varphi^s\beta_{t+s}\left[\left(\frac{p_{i,t}^*}{P_{t+s}}\right)^{1-\epsilon} - d_{t+s}\left(\frac{p_{i,t}^*}{P_{t+s}}\right)^{-\epsilon}\right]C_{t+s}$$

This leads them to choose the following price:

$$p_{i,t}^* = P_t^* = \frac{\epsilon}{\epsilon-1}\mathrm{E}_t\sum_{s=0}^{\infty}\frac{\varphi^s\beta_{t+s}d_{t+s}P_{t+s}\left(\frac{P_t}{P_{t+s}}\right)^{1-\epsilon}C_{t+s}}{\mathrm{E}_t\sum_{k=0}^{\infty}\varphi^k\beta_{t+k}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}C_{t+k}} \tag{53}$$

due to symmetry, it is the same for all retailers resetting price.

6 Steady State Analysis

This section examines the effects of firing costs on the steady state values of the key labor market variables. In particular the change in unemployment, job creation and destruction are shown. First the equations defining the steady state in the labor market are analyzed. Then, the effects of firing costs are shown analytically, when it is possible, and otherwise numerically for both exogenous and endogenous job destruction.

6.1 With an Exogenous Job Destruction Rate

6.1.1 Equilibrium Conditions in the Labor Market

Vacancy creation condition in steady state yields:

$$\frac{a}{\bar{q}} = (1-\rho)\beta\left[(1-\eta)(\bar{A}\bar{d} - b - \beta\rho f) - \eta a\bar{\theta} + \frac{a}{\bar{q}}\right] \tag{54}$$

where variables with a "bar" denote the steady-state values. From (53) and (33) I obtain $\bar{d} = \frac{\epsilon-1}{\epsilon}$ and $\bar{A} = 1$. This equation determines the steady state market tightness. The equation for employment dynamics (5) in steady state provides the long-term relationship between $\bar{u}$ and $\bar{v}$. Following Mortensen and Pissarides (1994) it can be rewritten replacing $\bar{m}$ by $\bar{s}\bar{u}$ yielding the long-term *Beveridge curve*:

$$\bar{u} = \frac{\rho}{\rho + (1-\rho)\bar{s}} \tag{55}$$

It depends only on the exogenous job destruction rate and market tightness but not on f. In order to verify the negative relationship between $\bar{u}$ and $\bar{v}$, one can take the first derivative with respect to $\bar{v}$:

$$\frac{\partial \bar{u}}{\partial \bar{v}} = -\frac{\rho(1-\rho)(1-\mu)m\bar{\theta}^{-\mu}\frac{1}{\bar{u}}}{[\rho + (1-\rho)\bar{s}]^2} < 0$$

The equilibrium values for $\bar{u}$ and $\bar{v}$ can be obtained using (54), (55) and the definition for $\bar{\theta}$.

6.1.2 Effect of Firing Costs

The effect of small variations in f on $\bar{\theta}$ can be determined by taking the total differential of (54), it yields:

$$\frac{d\bar{\theta}}{df} = -\frac{\beta^2(1-\rho)\rho(1-\eta)f}{[1-\beta(1-\eta)]\frac{a}{m}\mu\bar{\theta}^{\mu-1} + \beta(1-\rho)\eta a} < 0$$

Firing costs unambiguously reduces labor market tightness. Using (55) and the definition of $\bar{\theta}$ it can be shown analytically that firing costs affect negatively $\bar{v}$ and positively $\bar{u}$, however the graphical method used in Burda (1992), reproduced in figure (3), is more appealing. The Beveridge curve and vacancy creation condition are drawn in the $\bar{u}$-$\bar{v}$ space. Beverigde curve is decreasing and vacancy creation, defining the ratio $\bar{v}/\bar{u}$, is a simply a line through the origin. The equilibrium employment and unemployment are determined at the intersection of the two curves. When f increases the Beveridge curve remains unchanged but the slope of the vacancy creation condition falls as $\bar{\theta}$ decreases. Therefore $\bar{u}$ is raised and $\bar{v}$ reduced.

6.1.3 Discussion

I obtain the same result as in Burda (1992) with endogenously determined wages. Even though the first period wage (35) is strongly reduced in presence of firing costs, this is only transitory and from the next period firing costs will even increase the wage. Therefore the net present value of a job at the moment of hiring is negatively affected, accordingly (54) shows that the value of a filled job in the first period is reduced in presence of firing costs. Consequently the expected costs of a vacancy must decreases, this is reached with a higher probability of finding a worker, thereby market tightness has to decrease as well as vacancy. Firing costs reduces the return of a match, hence less jobs are created and unemployment increases. In this case where the firm can not adjust the firing rate, the only way for it to avoid firing costs is to lower the hiring rate having an univocal adverse effect on employment. One can expected a different outcome when firms are allowed to change the firing rate, this will be examined in the next section.

6.2 With an Endogenous Job Destruction Rate

6.2.1 Equilibrium Conditions in the Labor Market

$$0 = (1-\eta)\left\{\bar{A}\bar{\bar{z}}^0\bar{d} - b + \beta(1-\bar{\rho}^1)\bar{A}\left[H(\bar{\bar{z}}^1) - \bar{\bar{z}}^1\right]\bar{d} - \beta f\right\} - \eta a\bar{\theta} \tag{56}$$

$$\bar{A}\bar{\bar{z}}^0\bar{d} = \bar{A}\bar{\bar{z}}^1\bar{d} + f \tag{57}$$

$$\frac{a}{\bar{q}} = \beta(1-\bar{\rho}^0)(1-\eta)\bar{A}\left[H(\bar{\bar{z}}^0) - \bar{\bar{z}}^0\right]\bar{d} \tag{58}$$

$$1-\bar{u} = (1-\bar{\rho}^0)\bar{m} + (1-\bar{\rho}^1)(1-\bar{u}) \tag{59}$$

$$\bar{w}^0 = (1-\eta)b + \eta\left[\bar{A}H(\bar{\bar{z}}^0)\bar{d} + a\bar{\theta} - \beta f\right] \tag{60}$$

$$\bar{w}^1 = (1-\eta)b + \eta\left[\bar{A}H(\bar{\bar{z}}^1)\bar{d} + a\bar{\theta} + f - \beta f\right] \tag{61}$$

The steady-state conditions for matches respectively jobs destruction thresholds (56) and (57) define a negative relationship between the reservation productivities and market tightness. A higher $\bar{\theta}$ raises the wages, both new and old jobs are less profitable, more of them are destroyed so the destruction rates raise. This can be verified by taking the total derivation, after inserting (57) into (56), and setting all variations except $d\bar{\bar{z}}^1$ and $d\bar{\theta}$ to 0. After rearranging it follows:

$$\frac{d\bar{\bar{z}}^1}{d\bar{\theta}} = \frac{\eta a}{(1-\eta)\bar{A}\bar{d}[1-\beta(1-\bar{\rho}^1)]} > 0$$

Since the relationship between $\bar{\bar{z}}^0$ and $\bar{\bar{z}}^1$ depends only on parameters it can be deduced that $d\bar{\bar{z}}^0/d\bar{\theta} > 0$ as well. $d\bar{\rho}^0/d\bar{\theta} > 0$ and $d\bar{\rho}^1/d\bar{\theta} > 0$ follow straightforward, since $\rho^x + (1-\rho^x)F(\bar{\bar{z}}^i) = \bar{\rho}^i$ is monotone increasing in $\bar{\bar{z}}^i$, for $i = 0, 1$. The opposite happens with the vacancies creation condition (58): As $\bar{\bar{z}}^0$ increases more matches are destructed, this reduced the expected future value of a match, hence less jobs are created and market tightness decreases:

$$\frac{d\bar{\bar{z}}^0}{d\bar{\theta}} = -\frac{a\mu\bar{\theta}^{\mu-1}}{(1-\eta)m\beta\bar{A}\bar{d}(1-\bar{\rho}^0)} < 0$$

The equation (59) for the equilibrium unemployment provides the *long-term Beveridge curve* in the case of endogenous job destruction, explicitly it is:

$$\bar{u} = \frac{\bar{\rho}^1}{\bar{\rho}^1 + (1-\bar{\rho}^0)\bar{s}} \tag{62}$$

where $\bar{s} = \bar{s}(\bar{\theta}) = \frac{\bar{m}}{\bar{u}}$. Taking the first derivative with respect to $\bar{v}$ we can remark that it is not necessarily downward sloped:

$$\frac{\partial \bar{u}}{\partial \bar{v}} = \frac{\frac{\partial \bar{\rho}^1}{\partial \bar{v}}(1-\bar{\rho}^0)\bar{s} + \bar{\rho}^1 \frac{\partial \bar{\rho}^0}{\partial \bar{v}}\bar{s} - \bar{\rho}^1(1-\bar{\rho}^0)\frac{\partial \bar{s}}{\partial \bar{v}}}{[\bar{\rho}^1 + (1-\bar{\rho}^0)\bar{s}]^2}$$

where $\partial\bar{s}/\partial\bar{v} = m(1-\mu)\left(\frac{\bar{v}}{\bar{u}}\right)^{-\mu}\frac{1}{\bar{u}} > 0$. As the match respectively job destruction conditions imply that, ceteris paribus, the match respectively job destruction rates response positively to an increase in market tightness, hence $\partial\bar{\rho}^0/\partial\bar{v}$ and $\partial\bar{\rho}^1/\partial\bar{v}$ are positive, it results that the numerator can be positive. As noted by Mortensen and Pissarides (1994), there are here 2 opposing forces in action: On the one hand, higher vacancies imply more job matchings, so unemployment has to decrease to maintain the steady-state matching rate. On the other hand, more matches resp. jobs are destroyed due to the increase in match resp. job destruction rates and $\bar{u}$ needs to be higher to compensate it. In the case case of exogenous job destruction rate only the last term remains so that the relationship is unambiguously negative.

6.2.2 Effects of Firing Costs: Analytically

Comparative statics is used in order to examine the effect of firing costs f on steady-state values of determinants on the labor market. To do that I take the total differential of (56) to (61) setting all parameters variations to 0 except f, then apply the Cramer's Rule to solve. For simplicity the system is transformed to obtain subsystems containing at most 3 equations.

(56), (57) and (58), a system in $\bar{\bar{z}}^0$, $\bar{\bar{z}}^1$ and $\bar{\theta}$ yield:

$$\underbrace{\begin{pmatrix} (1-\eta)\bar{A}\bar{d} & -\beta(1-\eta)\bar{A}\bar{d}(1-\bar{\rho}^1) & -\eta a \\ \bar{A}\bar{d} & -\bar{A}\bar{d} & 0 \\ \beta(1-\eta)\bar{A}\bar{d}(1-\bar{\rho}^0) & 0 & \frac{a\mu}{m}\bar{\theta}^{\mu-1} \end{pmatrix}}_{A} \begin{pmatrix} d\bar{\bar{z}}^0 \\ d\bar{\bar{z}}^1 \\ \bar{\theta} \end{pmatrix} = \begin{pmatrix} \beta(1-\eta) \\ 1 \\ 0 \end{pmatrix} df$$

Solving yields:

$$|A| = a(1-\eta)\bar{A}^2\bar{d}^2\left\{[\beta(1-\bar{\rho}^1)-1]\frac{\mu}{m}\bar{\theta}^{\mu-1} - \beta(1-\bar{\rho}^0)\right\} < 0$$

$$\frac{d\bar{\bar{z}}^0}{df} = -\frac{\beta(1-\eta)\bar{A}\bar{d}\bar{\rho}^1\frac{a\mu}{m}\bar{\theta}^{\mu-1}}{|A|} > 0 \tag{63}$$

$$\frac{d\bar{\bar{z}}^1}{df} = \frac{(1-\eta)\bar{A}\bar{d}a\left[(1-\beta)\frac{\mu}{m}\bar{\theta}^{\mu-1} + \beta\eta(1-\bar{\rho}^0)\right]}{|A|} < 0 \tag{64}$$

$$\frac{d\bar{\theta}}{df} = \frac{\beta^2(1-\eta)^2\bar{A}^2\bar{d}^2\bar{\rho}^1(1-\bar{\rho}^0)}{|A|} < 0 \tag{65}$$

$d\bar{\rho}^0/df > 0$ and $d\bar{\rho}^1/df < 0$ follow straightforward. As in Mortensen and Pissarides (1999a) both job destruction rate and market tightness fall when firing costs increase. It is more to expensive to fire workers so they lay off less people, and the probability for a worker to become unemployed decreases. Vacancies fall relatively to unemployment because the firms anticipate the additional costs implied by job creation, as over the lifetime it will have to pay the separation costs with probability 1. The increase in matches destruction rate reflects also the lower incentive to create new jobs. It follows from (65) that $d\bar{q}/df > 0$ and $d\bar{s}/df < 0$, as the number of vacancies drops it becomes easier for firms posting a vacancy to match a job-seeker but for the latter it is more difficult to meet a firm. Thereby the effect on $\bar{u}$ can be derived more easily by taking the derivative of (62):

$$\frac{d\bar{u}}{df} = \frac{\frac{\partial\bar{\rho}^1}{\partial f}(1-\bar{\rho}^0)\bar{s} + \bar{\rho}^1\frac{\partial\bar{\rho}^0}{\partial f}\bar{s} - \bar{\rho}^1(1-\bar{\rho}^0)\frac{\partial\bar{s}}{\partial f}}{[\bar{\rho}^1 + (1-\bar{\rho}^0)\bar{s}]^2}$$

The first term in the numerator is negative, the second positive and third positive, making the sign of the whole à priori undetermined. As expected if $|\partial\bar{\rho}^1/\partial f|$ is very high, then the numerator can be negative meaning a reduction in $\bar{u}$ in reaction to an increase in f. If in response to a rise in firing costs firms reduce very strongly the firing rate, then the effect on unemployment can be positive. In contrast, if $\partial\bar{\rho}^0/\partial f$ is very high and/or $d\bar{s}/df$ very small, the whole can be positive representing an increase in $\bar{u}$. Firms react to higher firing costs by reducing strongly the hiring rate, this is reached by posting less vacancies and raising the matches destruction rate, hence unemployment rate increases.

Inserting (57) into (56) forms with (58) and (60) a system in $\bar{w}^0$, $\bar{\tilde{z}}^0$ and $\bar{\theta}$ and can be solved for $\bar{w}^0$. This results in $d\bar{w}^0/df < 0$: An increase in f raises the match destruction threshold and thus the expected productivity of a new worker but this effect is completely offset by the downward pressure exercised by the decrease in market tightness and the direct impact of f on the initial wage, as firing costs enters into the new wage with the coefficient $-\eta\beta$.

For the variables $\bar{u}$, $\bar{v}$, $\bar{m}$ and $\bar{w}^1$ this analysis providing any unambiguous result so I have to use numerical methods.

6.2.3 Calibration

Before the model can be solved numerically it has to be calibrated. I choose values close to those found in the U.S. data, representative of an economy with low firing costs. Accordingly $f = 0$ in the baseline calibration. Whenever the contrary is not mentioned, the chosen values follow Krause and Lubik (forthcoming). The discount factor β for one quarter is set to 0.99, the coefficient of relative risk aversion σ is 2 and ϵ, the elasticity of substitution between the retail goods, is 11 implying a steady-state markup of 10%. The elasticity of matches with respect to unemployment is $\mu = 0.5$, the household's bargaining power η is set equal to 0.4. The idiosyncratic productivity shocks are i.i.d. log-normally distributed with $\mu_z = 0$ and $\sigma_z = 0.2$. The latter is between the values used by Krause and Lubik (forthcoming) and estimated by Trigari (2005), 0.12 and 0.41 respectively.

The unemployment rate is set to $\bar{u} = 0.15$. It is a common assumption in search business cycle models to choose a higher unemployment rate in order to integrate searching persons out of the labor force. This value is between Trigari's (2005) estimate and the one chosen by Krause and Lubik (forthcoming), 0.25 and 0.12 respectively. The steady state job separation rate is $\bar{\rho}^1 = 0.1$ and the exogenous job separation rate $\rho^x = 0.068$. The firm's matching probability $\bar{q} = 0.7$. Therefore the values for unemployment benefit b, vacancy posting costs a and the level parameter m in the matching function have to be computed, it provides $m = 0.67$, $b = 0.82$, $a = 0.1$.

6.2.4 Effects of Firing Costs: Numerically

Once the values of the parameters m, b, a are calculated, the reverse exercise is done, i.e. keeping the parameters constant the variables values for different f are computed. As the system is highly non-linear, notably due to the presence of the expectation of a log-normally distributed variable, the steady-state is solved numerically using the Optimization Toolbox `fsolve`[13] in MatLab. The codes used for the solution and to produce the plots are in the appendix (C.1) and (C.2). The calculated values for $\bar{\tilde{z}}^0, \bar{\tilde{z}}^1, \bar{\rho}^0, \bar{\rho}^1, \bar{u}, \bar{v}, \bar{jd}, \bar{w}^0, \bar{w}^1$ with an increasing f are plotted in figure (4).

It can be seen from the two upper panels in figure (4) that as shown above, $\bar{\tilde{z}}^0$ and $\bar{\rho}^0$ increase, while $\bar{\tilde{z}}^1$ and $\bar{\rho}^1$ decrease. In line with job destruction rate $\bar{jd}$ respectively job creation rate $\bar{jc}$, $\bar{\rho}^1$ decreases strongly when f increases but remains small. In this area $\bar{u}$ decreases and then increases when $f > 0.15$ approximatively. As discussed above, unemployment decreases when the fall in $\bar{\rho}^1$ is relatively strong in comparison with the increase in $\bar{\rho}^0$ and the decrease in $\bar{s}$. However, as $\bar{\tilde{z}}^1$ decreases, it reaches the tail of the distribution of z_t, so that $\bar{\rho}^1$ barely varies when $\bar{\tilde{z}}^1$ further decreases. Accordingly the distribution function evaluated at these points $F(\bar{\tilde{z}}^1) = \bar{\rho}^{n,1}$ is very close to 0, as illustrated by the plot for $\bar{jd} = \bar{jc}$, as $\bar{jd} = (1 - \rho^x)\bar{\rho}^{1,n}$. With higher f the endogenous job separation is almost zero, therefore all firings are exogenous and they can not be reduced anymore. In this second area the situation is similar as in the exogenous job destruction case, only the hiring effect acts, as $\bar{\tilde{z}}^0$ respectively $\bar{\rho}^0$ further increase

[13] I thank Michael Krause for his help.

and unemployment increases.

As one could have expected, the effect on $\bar{v}$ is negative. $\bar{v}$ decreases more strongly at the beginning in line with $\bar{u}$. Additionally to the direct effect of firing costs, lower $\bar{u}$ reduces $\bar{v}$ as the probability to match a worker is lower and the expected costs of posting a vacancy higher. $\bar{w}^0$ decrease as f increases, $\bar{w}^1$ decrease as well but to a lesser extent. The latter is augmented as firing costs enter with $\eta(1-\beta)$ in (61), however the value of the coefficient is small thus the effect is offset by the falls in market tightness and productivity as $\bar{\tilde{z}}^1$ decreases strongly. The line in magenta represents the exogenous unemployment benefits. One can see that with higher f, $\bar{w}^0$ is lower than the unemployment benefit. The worker is ready to accept a lower wage in the first period because he expects a higher wage in the following periods and that the employment relationship will hold longer.

However, with large value of f increases some "abnormalities" appear. Even if $\bar{\rho}^1$ can not further decrease $\bar{\tilde{z}}^1$ becomes still smaller and can be negative implying a negative idiosyncratic productivity, which is a non-sense. If $\bar{\tilde{z}}^1$ is restrained to be bigger or equal to 0 the other variables evolve very unusually and their movements are highly amplified. So the model can not support high values of f.

6.2.5 Welfare Implications

Given that utility depends only on consumption, welfare is measured in unit of aggregate consumption. This corresponds to the individual consumption as well, since there is perfect insurance between the members of a household. I assume that the tax revenues are redistributed to the households so that there is no resource consumed by the levying of firing taxes, the changes in consumption are solely due incentive effects resulting in variations in aggregate production and costs implied by the search activities of the firm. Figure (5) in appendix displays the result for the baseline calibration.

The path of consumption is very similar to the one of unemployment but inverse. As unemployment decreases consumption increases and vice versa, furthermore the changes are almost in the same amplitudes. This suggests the preponderant role played by employment level in determining the production and thus consumption.

Alvarez and Veracierto (1999) find out that in an equilibrium search model with risk averse individuals and perfect insurance the firing costs have a adverse effect on welfare. In my model, in opposite to theirs, the production depends on the incentive of the firms to create jobs and not on the individual decision of the participation to the labor force. Therefore if unemployment decreases employment increases necessarily and the aggregate production rises enhancing welfare.

6.2.6 Discussion

The model provides that the firing costs reduce strongly job destruction rate, the firm lowers the threshold productivity at which the worker is fired. It is less expensive to keep an unproductive worker than to fire him, the drop in productivity is also reflected by the fall in aggregate old wage. Therefore unemployment falls and increases only once the endogenous job destruction rate can not be further diminished. Accordingly job creation and job destruction decrease to reach the value zero. The number of workers becoming unemployed is reduced thus the existing jobs are safer but once unemployed it is also more difficult to get out.

In order to understand the large decrease in $\bar{\tilde{z}}^1$, it can be helpful to write out the expressions for the old surplus[14]:

$$\begin{aligned} S_t^1(z_t) \quad = \quad & A_t z_t d_t - b + f - \mathrm{E}_t\beta_{t+1} f - \eta s_t \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty} S_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx \\ & + \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty} S_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx + \eta s_t \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^0)f \qquad (66) \end{aligned}$$

Therefore, firing costs increase the surplus of a old job directly and through the increase in its future value. Recalling the definition of the old job threshold productivity $S_t^1(\tilde{z}_t^1) = 0$ it follows that when f increases, $\tilde{z}_t^1$ has to decrease strongly.

Given the lower $\bar{\tilde{z}}^1$, the larger decrease in the endogenous job destruction rate is due to the shape of the distribution function of z_t, when $\tilde{z}_t^1$ approaches the tail of the function $\mathrm{F}(\tilde{z}_t^1)$ is

[14] Computational details can be found in the appendix.

strongly reduced. However the use of the uniform distribution function, as in Mortensen and Pissarides (1999b) and Joseph et al. (2004), does not provide better results. With a z_t uniformly distributed over $[0, 1]$, $\bar{\rho}^{n,1}$ is simply equal to $\bar{\bar{z}}^1$. When f increases, both $\bar{\rho}^{n,1}$ and $\bar{\bar{z}}^1$ decrease quickly to reach negative values.

Using alternative calibration, unemployment still shows a similar pattern. The result with $f = 0.5$ and $\bar{\rho}^1 = 0.1$, as in Joseph et al. (2004) is plotted in figure (6). However this does not longer hold when $\sigma_z = 0.12$, as in Krause and Lubik (forthcoming). In that case, $\bar{u}$ does not decrease at all, its minimum value being at $f = 0.5$. The lower variance of the idiosyncratic shocks implies lowers values for the conditional expectation, this reduces the future value of a job and unemployment is negatively affected.

The prevailing effect on firing implying a positive effect on unemployment is in concordance with Mortensen and Pissarides (1999b) and Joseph et al. (2004), when the wages are relatively flexible. The latter assert an important role for wage in stimulating employment, as the lower incentive of the firms to hire implies, furthermore, a lower market tightness, thus the bargaining power of the worker is weakened inducing a lower average wage. Additionally, the lower first period wage, although not sufficient to offset the effect of the firing costs on hiring as shown when studying the case with exogenous job destruction, can at least attenuate the fall in hiring and the positive effect on employment is enhanced.

Quantitatively, I obtain a decrease in unemployment rate of 13% proportionately to the calibrated steady state unemployment rate when firing costs increases from zero to 0.05, while Joseph et al. (2004) get only a decrease of 7% with the benchmark minimum wage. Their assumption of wage rigidities dampens the effect of firing costs. When wages are partly rigid, the downward wage adjustment has a lower amplitude and the positive effect is smaller. They do not show results if firing costs continues to increase so that it is not possible to know the evolution of employment in their model if f continues to increase. My results are comparable even if calibrated for $f = 0.5$.

Mortensen and Pissarides (1999b) increase the firing costs from zero to 1 and always find a positive effect on employment. However the effect is small as unemployment falls maximum

11% in response to an increase in firing costs of 0.25 point. This result lies probably on their assumption on the arrival rate of the idiosyncratic shock. They calibrate the probability of arrival of an idiosyncratic productivity shock to 0.1, that means every 10 periods in average the wages are renegotiated and low productive workers are fired. This leads to a very small probability in each period that firing costs incur. Consequently the first period wage is only barely diminished and can only have a small positive effect on hiring. Therefore the net positive effect on unemployment is weak.

7 The Dynamic Perspective

This section presents the dynamic behavior of the model with endogenous job destruction rate from the precedent section. The solution method is shortly presented and then the results of the model simulation are shown. In order to study the effects of firing costs I first discuss the results in the benchmark calibration with $f = 0$, then, considering several values for f, the implications of increasing firing costs are demonstrated.

7.1 Solving Using the `Toolkit`

For the model to be solved it has to be first linearized. In order to do this the model variables are expressed in term of percentage deviations and linearized around the steady state using a first order Taylor approximation: $\hat{x}_t \equiv \ln\left(\frac{X_t}{\bar{X}}\right) \approx \frac{X_t - \bar{X}}{\bar{X}}$. The resulting system of equations listed in appendix (B), after substituting out $\hat{\mathcal{M}}_t$ and $\hat{q}_t$, is solved using the `Toolkit`[15] of programs written by Harald Uhlig and described in Uhlig (1999).

The vector x_t containing the endogenous state variables is defined as:

$$x_t \equiv (n_t^0, n_t^1, v_t, m_t, w_t^0, w_t^1, d_t, net_t)$$

while the 'true' model state variables are n_t^0, n_t^1, v_t and m_t, the other have to be declared as such in order to guarantee that the matrix CC is of full rank. The vector y_t containing the other endogenous variables is:

$$y_t \equiv (C_t, Y_t, R_t, \pi_t, u_t, \theta_t, \rho_t^0, \rho_t^1, n_t, jcr_t, jdr_t, \tilde{z}_t^0, \tilde{z}_t^1, \rho_t^{0,n}, \rho_t^{1,n}, jt_t)$$

and the exogenous state vector z_t:

$$z_t \equiv (A_t, \phi_t).$$

The codes are in appendix (C.3). Impulse responses to shocks in aggregate productivity and in

[15] The `Toolkit` Program can be downloaded at the homepage of the Institute for Economic Policy I at the Humboldt-University Berlin and the codes can be found in the appendix

money growth rate are produced as well as business cycles statistics in presence of both shocks. The latter are calculated without resorting to simulations using the method of the moments.

Note that the Phillips curve (90) is obtained assuming a steady state with zero inflation. Following Krause and Lubik (forthcoming) φ the probability that the firms does not adjust prices within a period is equal to 0.5. The shocks processes are calibrated with $\psi_m = 0.49$, $\sigma_M = 0.01$, $\psi_A = 0.95$ and $\sigma_A = 0.00712$. These values are from Uhlig (2003) and Krause and Lubik (forthcoming).

7.2 The Benchmark Model

The impulse responses of the benchmark model with no firing costs is qualitatively similar to those in Krause and Lubik (forthcoming).

Consider first the effects of one percent increase in aggregate productivity depicted in the figure (7). At the point of impact output increases, note that its rise is slightly lower than the productivity. Inflation falls. The larger fall in marginal costs is due to the increase in aggregate productivity and in the threshold productivity. With sticky price, the retailers can not adjust the price sufficiently in order to have demand meeting the increase in supply, therefore output is diminished augmenting the threshold productivity and so job destruction. Employment is reduced, the number of both new and old workers is cut. Wages decrease slightly because of the fall in marginal costs. The job creation condition tells us that the firms, anticipating the higher profit in the next periods, post vacancies stimulating job creation. After the shock firms reduce job destruction, this results in a fall in unemployment making matching more difficult and, in turn, job creation rate is reduced as well as the number of new workers. Nevertheless unemployment continues to decrease as long as job creation is above job destruction, i.e. until 2 years after the shock. The sluggish reaction of employment induces inflation and marginal costs to adjust more slowly as well.

The response of the economy to an one percent increase in money growth rate is shown in the figure (9). On the impact output and inflation increase. The increase in nominal money stimulates the demand and output increases to satisfy it. The higher market tightness exercises a upward pressure on marginal costs directly and through the rise in wages, as explained in Krause and Lubik (forthcoming). In order to raise production firms reduce strongly the reservation productivities, job destruction rate decreased and job creation increases, the number of new and old workers grows. The fall in job destruction rate leads to such an important reduction in unemployment that vacancies as well as job creation decrease, therefore job creation rate decreases from the second period after the shock. Again, the slow movement of employment to recover the steady state level is responsible for the gradual adjustment in output and in inflation.

The labor market response to a productivity shock and a monetary shock are qualitatively similar. The opposite movements of the marginal costs and output in the case of a productivity shock has as a consequence that the labor market reacts more slowly. Unemployment decreases slowly, this implies the hump-shaped adjustment of the output, vacancies increase, in opposition to the case of a monetary shock.

The model dynamics is summarized by the business cycles statistics in table (2). Job creation and destruction rates have a negative correlation, however this value is much smaller than shown by the data in different countries[16]. Firms react to shocks adjusting first the job destruction rate, since it is instantaneous and no-costly. Due to the search and matching process job creation's response comes one period later, so that job destruction deeply influences the dynamics of job creation. When the job destruction rate falls, the resulting lower unemployment rate has an adverse effect on job creation: firms have less incentive to post vacancies when the probability to match a worker is lower. This explains also the positive correlation between vacancies and unemployment contradicting the negative relationship found in the data. The effect is particularly strong in the case of a monetary shock as it can be seen from the second panel in figure (9). The job creation is pro-cyclical (with respect to the net employment change) and job destruction is counter-cyclical as observed in the data. Even though the ratio standard deviation of job destruction to job creation is smaller than the value for U.S. data, it is still greater than one implying a slightly counter-cyclical job turnover. The relative standard deviation of job

[16]see section 3.3

destruction and creation to output are both too high, while the these of unemployment and vacancies are too low in comparison to the data. Due to the co-movement of unemployment and vacancies the volatility of market tightness is still lower.

The volatility of output is close to the value found in the data, its persistence measured by the first-order autocorrelation coefficient is slightly smaller than the calibrated value for the productivity process. The variability of inflation is similar to output, its persistence is smaller.

7.3 With a Positive f

When studying the responses of an economy with positive firing costs, one question arises: how to calibrate in order to obtain results which are interpretable as well as comparable? A first possibility would be to calibrate using the same steady state values, it implies to assume that $\bar{u}$, $\bar{q}$ and $\bar{\rho}^1$ are equal in two economies with or with no firing costs. The second is to keep the parameters values constant and let the steady state values adjust endogenously as in the steady state analysis. Even though there is no empirical evidence for an effect of firing costs on the steady state level of unemployment, section (2) suggests that it may generate different paths of job flows, it is then difficult to assume that the worker's finding rate and job destruction rates are the same when firing costs differs. Therefore the second approach is chosen.

The impulse responses of the system with $f = 0.1$ to productivity and money growth shocks are represented in the figures (8) and (10), respectively. Qualitatively, they are similar to those obtained with no firing costs. For a better comparison of the quantitative changes, I put the corresponding steady state values below the graphs.

Again, let's consider first the response to an one percent productivity shock. The reaction of output on the impact is slightly larger and the adjustment is dampened, while inflation reacts stronger and then adjusts in a similar way. The reactions of both job creation and destruction are strongly amplified. However, the number of old workers diminishes hardly, reflecting some difficulties in reducing employment by varying the job separation rate, while the number of new workers decreases more. Altogether, however, the employment's reduction is minor, despite the higher increase in both job and match threshold productivities. The marginal costs decreases more strongly due the higher reservation productivities, so inflation diminishes more and the higher demand corresponds to the higher output. Since the employment adjustment through job destruction is more difficult, the augmentation in employment after the shock can incur only if job creation increases strongly, therefore vacancies augment largely and remains longer above the steady state level. The fall in unemployment is weaker and the increase in output smaller.

In the case of a money growth shock, market tightness, vacancies and unemployment's responses are smaller but remain in the same proportion. On the impact the reaction of inflation is stronger, while the rise in output is more modest. After the shock inflation falls strongly again. Similarly as in the productivity shock case, on the impact employment can not be sufficiently raised through the job destruction, albeit the larger decrease in reservation productivities, the number of old workers increases hardly. Job creation reacts more strongly but employment's rise is minor, which explains the smaller increase in output. Marginal costs increase is larger due to the lower reservation productivities, inflation follows it.

Table (2) shows the business cycle statistics of the model economy for $f = 0$, 0.05, 0.1 and 0.2 . It confirms the smaller standard deviation of output, while the standard deviation of inflation, relatively to output, increases. However the persistence of inflation is reduced, while for output it remains unchanged and unemployment it increases. In line with output the volatility of employment decreases, as well as unemployment in absolute value. The volatilities of job destruction and creation increase largely, however, when the standard deviations of the percentage deviations are multiplied with the steady state values, one can see that the absolute values are in fact less volatile. Furthermore, the 12th row shows the dramatic reduction in relative volatility of job destruction to job creation when f increases. This leads to a more pro-cyclical (with respect to the net employment change) movement of job turnover, these two flows are even perfectly correlated, when with higher f the volatility of job destruction is tiny in comparison to job creation. The negative correlation between job creation and destruction becomes more pronounced. As explained above, job destruction has significant effect on job creation because it occurs earlier. The effect of job destruction on unemployment is now much weaker, therefore its effect on job creation as well. For the same reason unemployment and employment become slightly negative correlated, this raises the volatility of market tightness.

7.4 Discussion

The presence of firing costs considerably affects the dynamics of labor market. In line with Garibaldi (1998), the relative volatility of job destruction to job creation is reduced, this is due to the large fall in steady state endogenous job separation rate, when firing costs increase. Having a look at the equation (78) in appendix, one can see that if $\bar{\rho}^{1,n}$ is very small, then the response of job separation rate will be considerably reduced as well. In opposite, the steady state endogenous match separation rate is slightly raised by f, hence the response of match separation rate is only weakly affected. Figure (11) shows that with $f = 0.3$, the response of job separation rate is already annihilated. Therefore, the volatility of job destruction relatively to job creation is reduced, leading job reallocation to be pro-cyclical. This is conjunction with the data which show a rather a- or pro-cyclical pattern of job reallocation in countries with higher employment protection. Furthermore, the fall in steady state endogenous job separation rate implies a large drop in the steady state job creation rate, respectively, job destruction rates, thereby their percentage deviations are amplified. Their smaller volatilities, when one only considers their absolute values, reflects the responsiveness of job creation to job destruction implying that when job destruction's variability diminishes, the volatility of job creation falls as well.

Firing costs has noticeable effects on the cyclical pattern of inflation and output. The reactions of inflation are amplified, while the variability of output is reduced. Furthermore, the persistence of inflation is diminished and unemployment is raised. This results from the tiny responsiveness of job separation rate as well, which increases the sluggishness of employment. On the impact employment can be adjusted only when there is more variations in match destruction rate, this necessitates more variability in the reservation productivity which, in turn, induces more volatilities in marginal costs and therefore, in inflation. Despite the increase in the relative volatility of job creation, because now the adjustment occurs only on one side the capacity of adaptation of the firms by changing employment is diminished, the output is not as variable as before. The increase in the volatility of inflation can also be explained using its role in adjustment. With no firing costs the adjustment in job destruction plays an important role in counteracting the shocks, weakening the response of inflation. The rigidity in employment, implied by the firing costs, induces the firms resetting their prices to make larger adjustments in prices and the volatility of inflation to increase. The stronger response of inflation allows a faster adjustment, particularly in the case of a monetary shock and inflation's persistence is reduced.

In steady state, the job separation rate falls to the exogenous separation rate, in line with the endogenous job separation rate becoming zero. This implies, over the business cycle, that the volatility of job separation rate is radically reduced. Therefore, the model features an exogenous job separation rate, unsensitive to shocks.

8 Concluding Remarks

This thesis analyzes the impact of employment protection legislation, conceptualized as firing costs, on the level of unemployment, job flows, the dynamics of the labor market as well as those of inflation and output. In order to do this, a simple matching model with constant search intensity is introduced into an otherwise standard new Keynesian business cycle model. Firms have to pay a firing tax in case of separation from a worker who was productive in the last period. The study of steady state is done assuming exogenous, and then endogenous job destruction.

The differentiation between “new” and “old” employment relationships leads to a two-tiers wage structure with a lower first period wage. With exogenous job destruction, this is however not sufficient to offset the negative effect of firing costs on hiring and unemployment rises. In the case of endogenous job destruction, the weaker fall in hiring combined with the strong decrease in firing rate, notably because of the assumption about the distribution function of the idiosyncratic shocks, leads to a positive effect for relatively low firing costs. However, with higher firing costs, this does not longer hold. When the job destruction rate can not be reduced, the situation is similar to the case with exogenous job destruction: unemployment rises.

This non-linearity in the pattern of the long-run unemployment suggests that there is no an unique policy prescription in order to fight unemployment. The impact of more restrictive employment protection legislation can be either positive or negative, it depends on the existing degree of strictness. However, the results suggest that in countries with high firing costs and low labor market mobility, rendering firings more difficult will probably raise unemployment.

While the findings here do not provide an absolute support for the role of firing costs in explaining the unemployment differential between Europe and the U.S., modeling a variable labor force could be a remedy. As shown by Hopenhayn and Rogerson (1993) and Alvarez and Veracierto (1999), allowing individuals to choose between market or home production has considerable effects on employment. The lower wage due to higher firing costs can deviate individuals from the labor market and precisely, the European labor market exhibits a higher unemployment rate associated with a lower labor market participation.

The behavior of the model variables over the business cycle is studied using simulations in presence of aggregate productivity and money growth shocks. It reveals that firing costs reduce strongly the relative volatility of job destruction to job creation, due to the very large fall in the responsiveness of job separation rate. In steady state the job separation rate falls to reach the exogenous rate, over cycle its volatility is reduced to zero. This suggests that with more expensive firings the behavior of the model with endogenous job destruction converges to the model with exogenous destruction. The consequences of a rigid job destruction on employment follows straightforward, its movements are dampened. Accordingly adjustments in output are more sluggish implying more volatility in price and therefore, in inflation.

An natural extension of the present model would be to replace the money growth rate rule with a nominal interest rate rule. Instead to let the interest rate adjust endogenously, it is given by an exogenous rule and this setting is susceptible to influence the dynamics of inflation.

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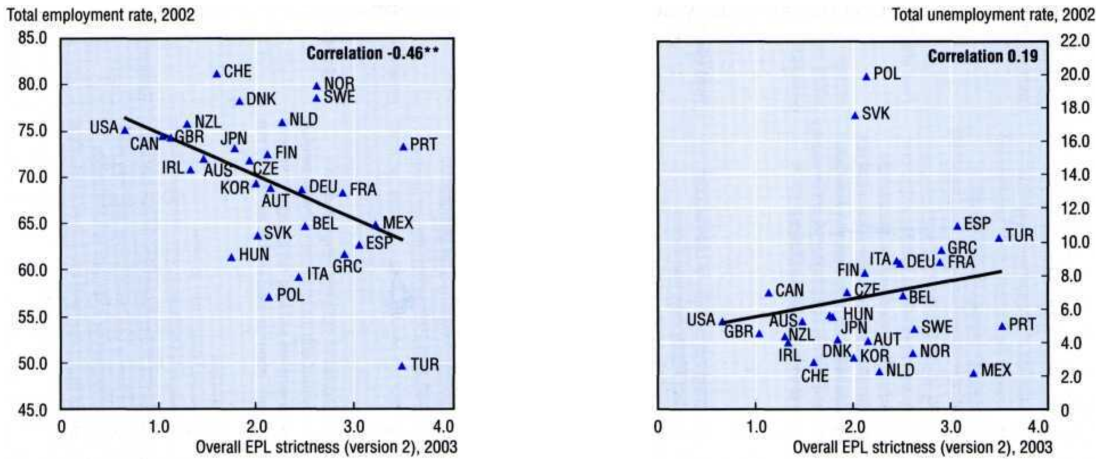

Figure 1: Total unemployment rate respectively total employment rate vs. employment protection

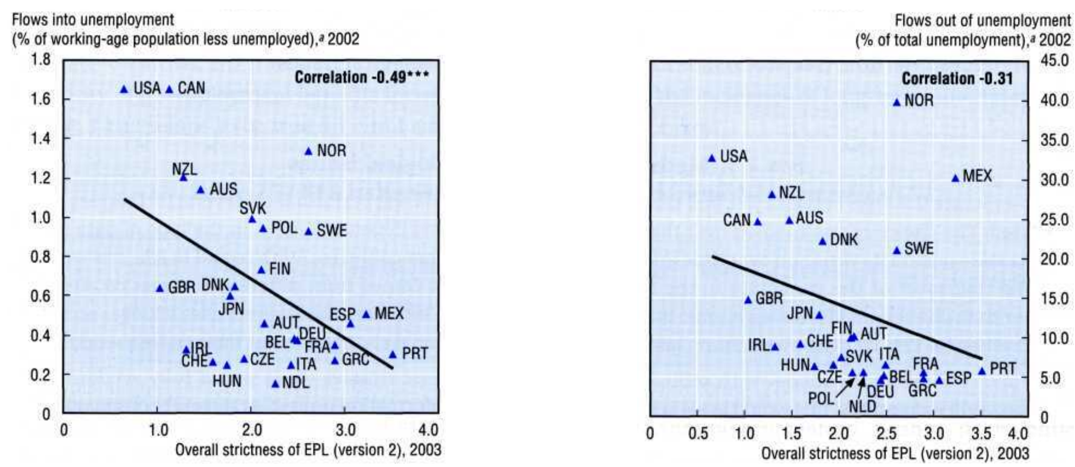

Figure 2: Flow into unemployment respectively flow out of unemployment vs. employment protection

, * means statistically significant at 5% and at 1% levels, respectively.

Source: OECD (2004)

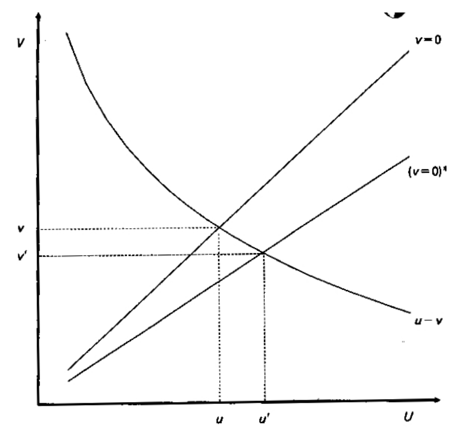

Fig. 3.

Figure 3: Effects of firing costs with exogenous job destruction

Table 1: Calibration

Parameters	Values	Description
β	0.99	Discount factor
ϵ	11	Elasticity of substitution between retail goods
φ	3/4	Fraction of firms leaving their price unchanged
σ	2	Coefficient of relative risk aversion
μ	0.5	Elasticity of the matching function w.r.t. unemployment
η	0.4	Workers' bargaining power
μ_z	0	Distribution Parameter of the idiosyncratic shocks
σ_z	0.2	Distribution Parameter of the idiosyncratic shocks
ρ^x	0.068	Exogenous Job Separation Rate
f	0	firing costs
$\bar{u}$	0.15	Unemployment rate
$\bar{q}$	0.7	Firms' probability to match a worker
$\bar{\rho}^1$	0.1	Old job destruction rate

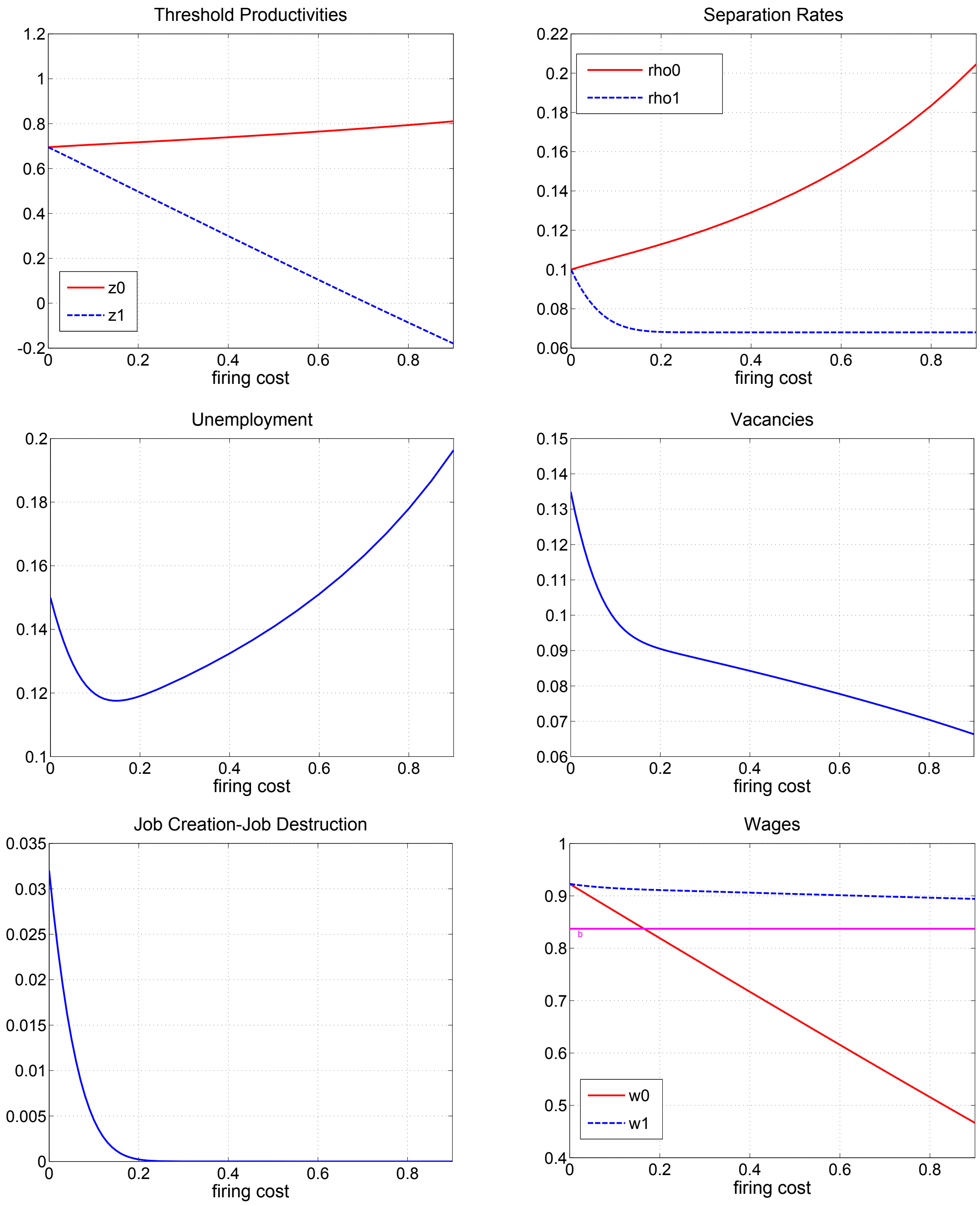

Figure 4: The Steady state Effect of f. Baseline Calibration: $f = 0$

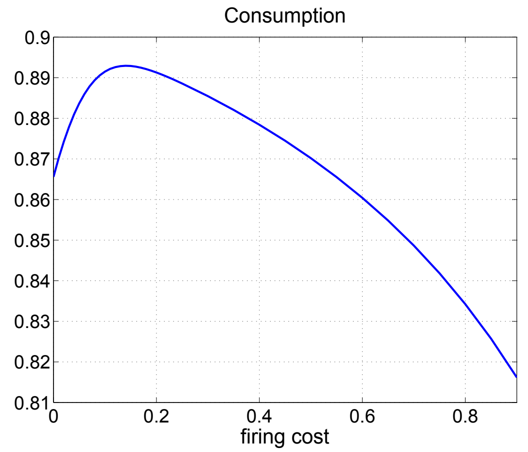

Figure 5: Effect on steady state consumption

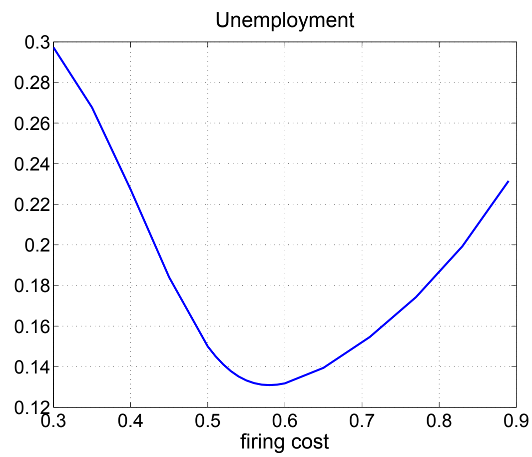

Figure 6: Effects on $\bar{u}$ with calibration: $f = 0.5$

	$f = 0$	$f = 0.05$	$f = 0.1$	$f = 0.2$
Standard Deviations σ_i/σ_y				
Output	1.48	1.35	$1,27$	1.26
Inflation	1.04	1.27	1.52	1.68
Unemployment	4.34	4.41	3.9	3.03
Employment	0.77	0.65	0.53	0.45
Vacancies	2.34	3.07	3.53	3.93
Tightness	3.6	4.37	5.07	5.68
JCR	10.89	21.98	53.88	996
JDR	13.63	23.59	36.07	54.8
JT	17.03	28.21	50.45	963
$\sigma_{JDR}/\sigma_{JCR}$	1.25	1.07	0.67	0.05
Autocorrelation				
Output	0.87	0.86	0.86	0.85
Inflation	0.29	0.16	0.08	0.04
Unemployment	0.72	0.73	0.78	0.87
Labor Market Statistics				
$Corr(u_t, v_t)$	0.56	0.36	0.07	-0.23
$Corr(JCR_t, Net_t)$	0.65	0.77	0.9	0.99
$Corr(JDR_t, Net_t)$	-0.79	-0.8	-0.77	-0.65
$Corr(JT_t, Net_t)$	-0.22	-0.07	0.41	0.99
$Corr(JCR_t, JDR_t)$	-0.05	-0.24	-0.43	-0.61

Table 2: Business Cycle and Labor Market Properties

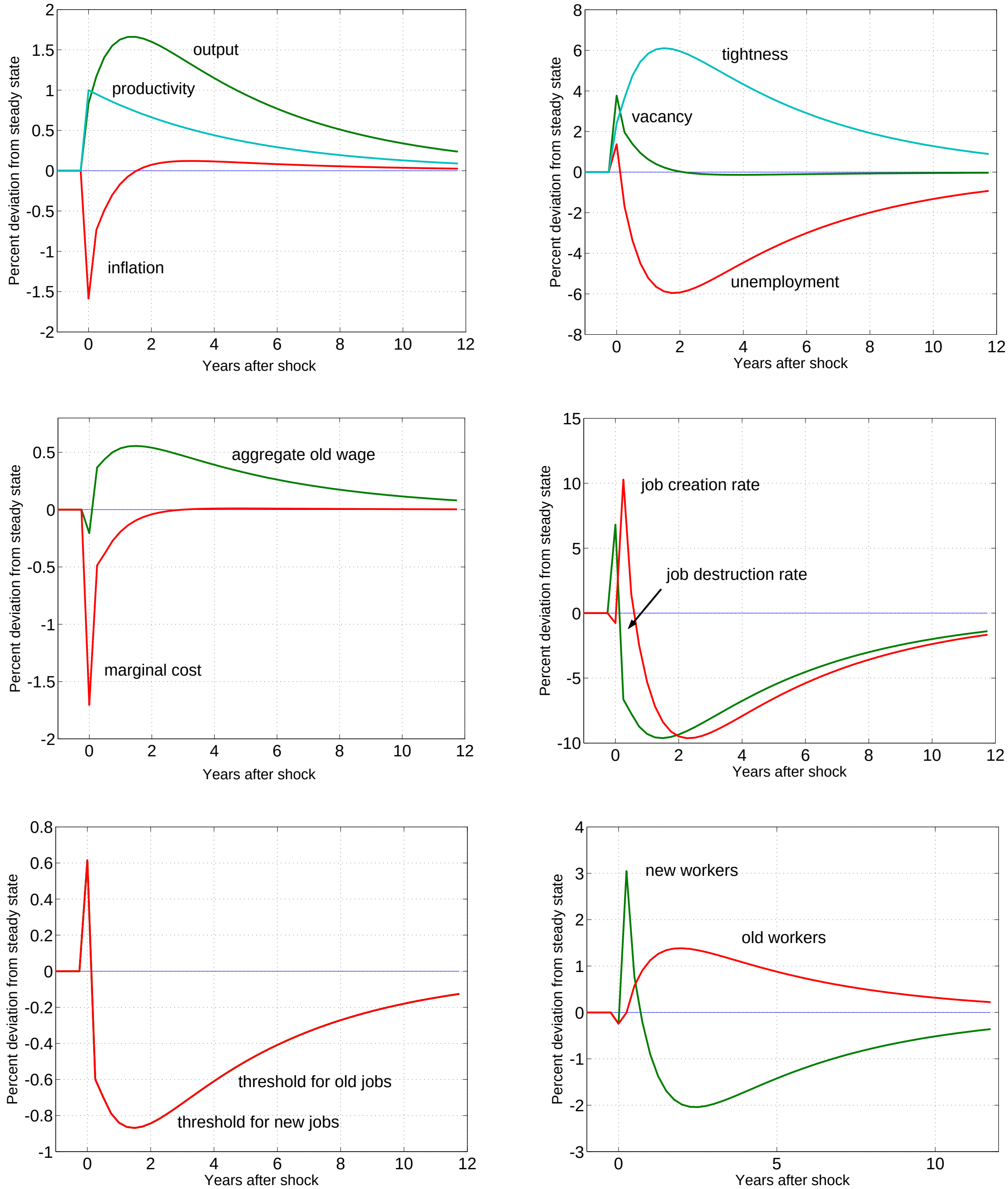

Figure 7: Impulse responses to an one percentage point positive productivity shock. Baseline calibration with $f = 0$. Steady state values: $\bar{y} = 0.88$, $\bar{u} = 0.15$ $\bar{v} = 0.13$, $\bar{\theta} = 0.9$, $\bar{w}^1 = 0.92$, $j\bar{d}r = j\bar{c}r = 0.032$, $\bar{\bar{z}}^0 = 0.69$, $\bar{\bar{z}}^1 = 0.69$, $\bar{n}^0 = 0.09$, $\bar{n}^1 = 0.77$

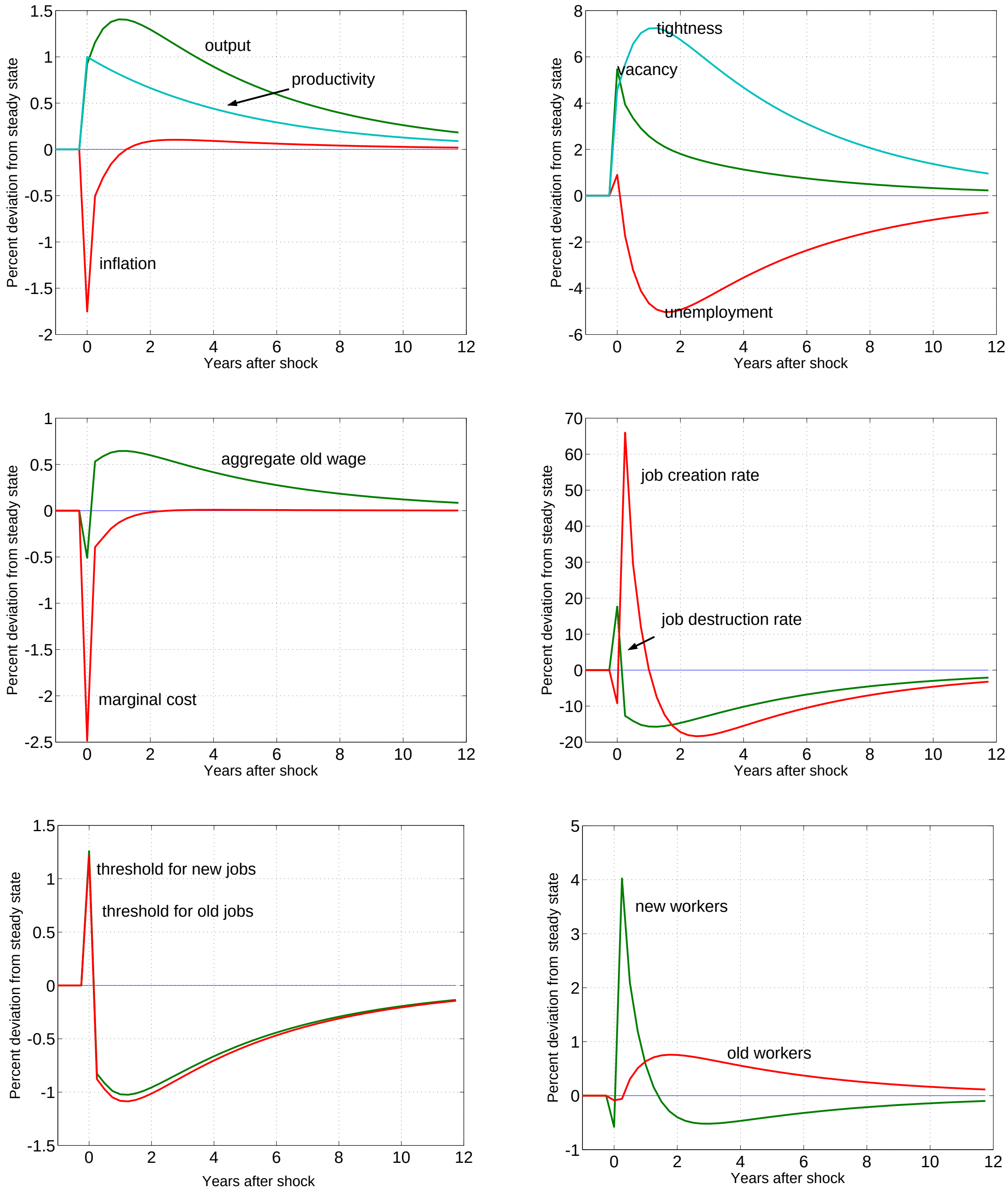

Figure 8: Impulse responses to an one percentage point positive productivity shock. $f = 0.1$. Steady state values: $\bar{y} = 0.89$, $\bar{u} = 0.13$ $\bar{v} = 0.11$, $\bar{\theta} = 0.86$, $\bar{w}^1 = 0.92$, $j\bar{d}r = j\bar{c}r = 0.005$, $\bar{\bar{z}}^0 = 0.71$, $\bar{\bar{z}}^1 = 0.6$, $\bar{n}^0 = 0.06$, $\bar{n}^1 = 0.82$

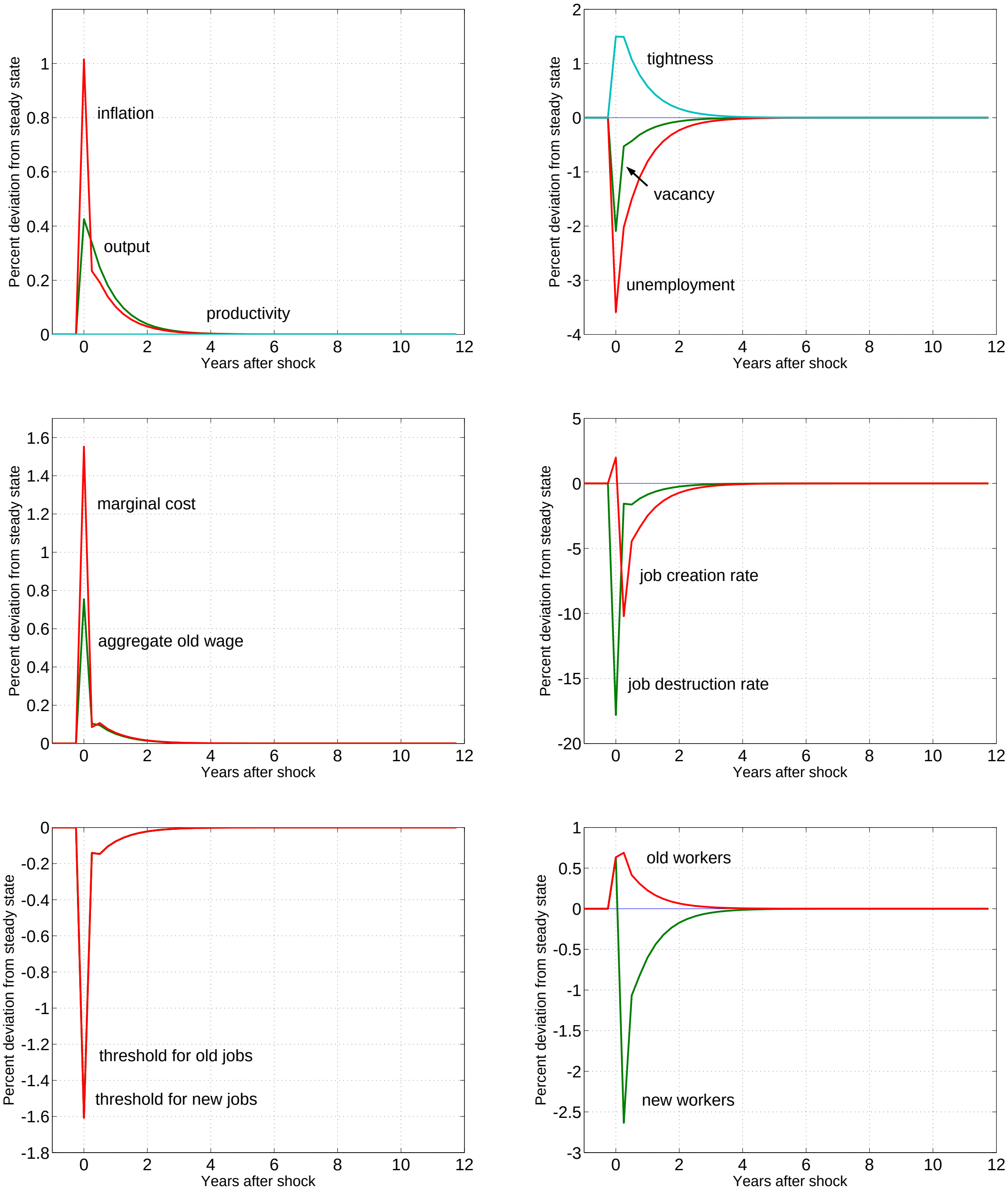

Figure 9: Impulse responses to an one percentage point positive money growth shock. Baseline calibration with $f = 0$. Steady state values: $\bar{y} = 0.88$, $\bar{u} = 0.15$ $\bar{v} = 0.13$, $\bar{\theta} = 0.9$, $\bar{w}^1 = 0.92$, $j\bar{d}r = j\bar{c}r = 0.032$, $\bar{\bar{z}}^0 = 0.69$, $\bar{\bar{z}}^1 = 0.69$, $\bar{n}^0 = 0.09$, $\bar{n}^1 = 0.77$

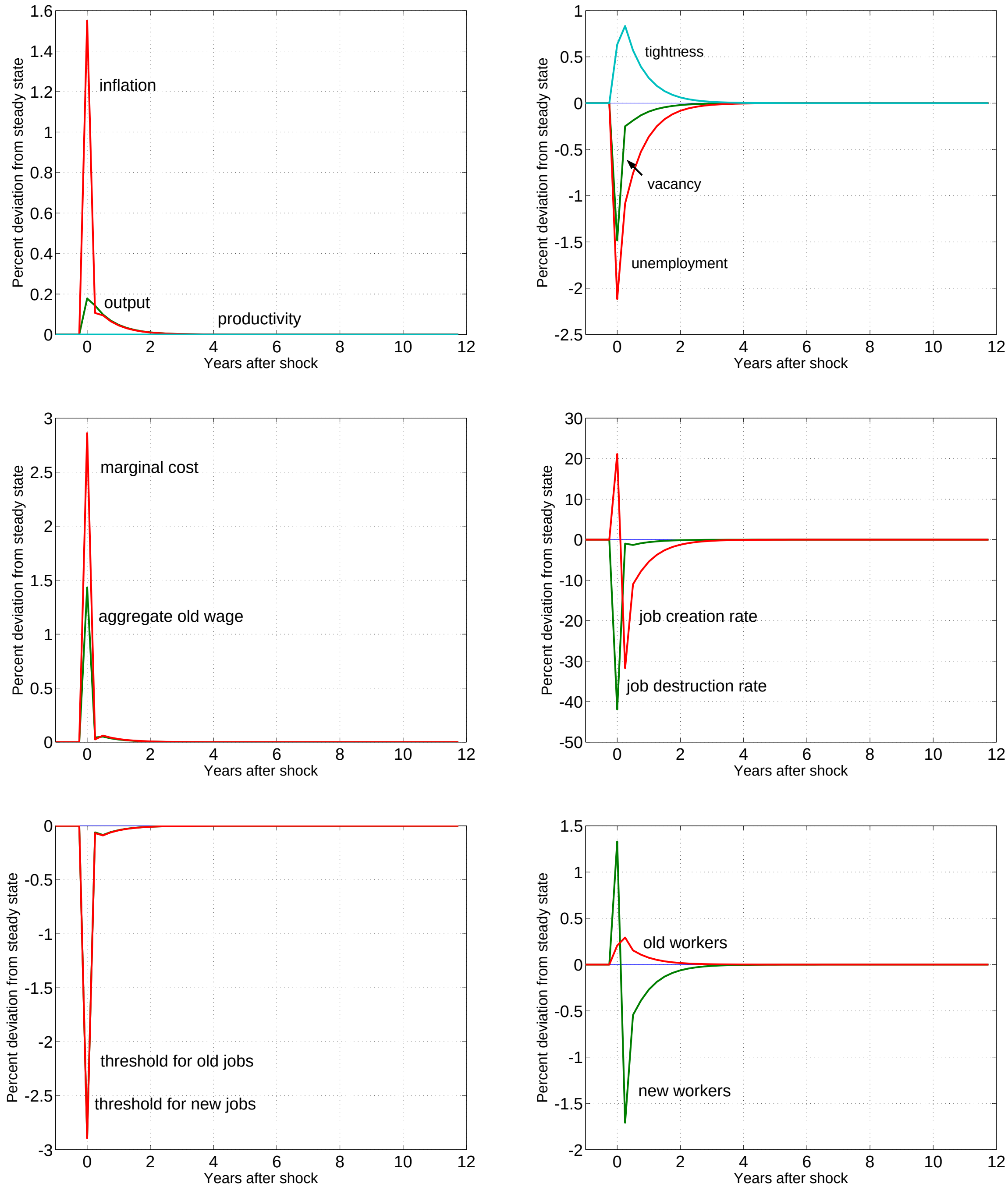

Figure 10: Impulse responses to an one percentage point positive money growth shock. $f = 0.1$. Steady state values: $\bar{y} = 0.89$, $\bar{u} = 0.13$ $\bar{v} = 0.11$, $\bar{\theta} = 0.86$, $\bar{w}^1 = 0.92$, $j\bar{d}r = j\bar{c}r = 0.005$, $\bar{\tilde{z}}^0 = 0.71$, $\bar{\tilde{z}}^1 = 0.6$, $\bar{n}^0 = 0.06$, $\bar{n}^1 = 0.82$

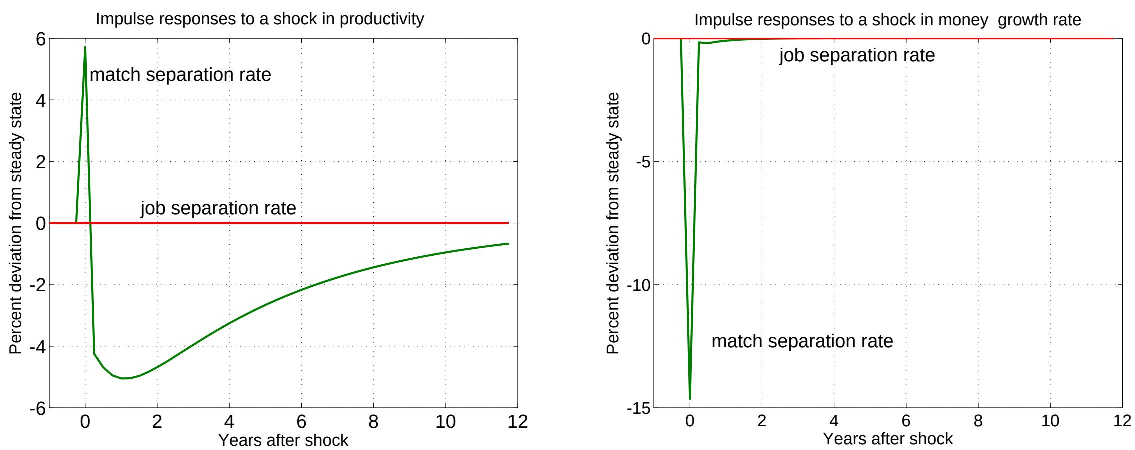

Figure 11: Impulse responses of job and match separation rates to a productivity and a money growth shock, respectively. $f = 0.3$.

A Appendix: Computational Details

A.1 Threshold Productivity for a New Job

Plugging equations (20), (46), (41) and (42) into (45):

$$
\begin{aligned}
& A_t \tilde{z}_t^0 d_t - w_t^0(\tilde{z}_t^0) + \mathrm{E}_t \beta_{t+1} \left[(1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} J_{t+1}^1(x) \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx - \rho_{t+1}^1 f \right] \\
= \;& A_t \tilde{z}_t^0 d_t - w_t^0(\tilde{z}_t^0) + \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} \left[A_{t+1} x d_{t+1} - w_{t+1}^1(x) \right] \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx - \mathrm{E}_t \beta_{t+1} \rho_{t+1}^1 f \\
& + \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} \mathrm{E}_{t+1} \beta_{t+2} \left[(1-\rho_{t+2}^1) \int_{\tilde{z}_{t+2}^1}^{\infty} J_{t+2}^1(z) \frac{f(z)}{1-F(\tilde{z}_{t+2}^1)} dz - \rho_{t+2}^1 f \right] \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx \\
= \;& A_t \tilde{z}_t^0 d_t - w_t^0(\tilde{z}_t^0) \\
& + \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} \left[A_{t+1} x d_{t+1} - w_{t+1}^1(x) \right] \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx - \mathrm{E}_t \beta_{t+1} \rho_{t+1}^1 f \\
& + \mathrm{E}_t \beta_{t+1} \beta_{t+2} (1-\rho_{t+1}^1) \left[(1-\rho_{t+2}^1) \int_{\tilde{z}_{t+2}^1}^{\infty} J_{t+2}^1(z) \frac{f(z)}{1-F(\tilde{z}_{t+2}^1)} dz - \rho_{t+2}^1 f \right] = 0 \\
= \;& A_t \tilde{z}_t^0 d_t - w_t^0(\tilde{z}_t^0) \\
& + \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) \int_{\tilde{z}_{t+1}^1}^{\infty} \left[A_{t+1} x d_{t+1} - w_{t+1}^1(x) \right] \frac{f(x)}{1-F(\tilde{z}_{t+1}^1)} dx - \mathrm{E}_t \beta_{t+1} \rho_{t+1}^1 f \\
& - \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) \left[A_{t+1} \tilde{z}_{t+1}^1 d_{t+1} - w_{t+1}^1(\tilde{z}_{t+1}^1) + f \right] \\
= \;& (1-\eta) \left\{ A_t \tilde{z}_t^0 d_t - b + \mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^1) A_{t+1} d_{t+1} \left[H(\tilde{z}_{t+1}^1) - \tilde{z}_{t+1}^1 \right] - \mathrm{E}_t \beta_{t+1} f \right\} - \eta a \theta_t = 0
\end{aligned}
$$

A.2 Surplus of an Old Job

The surplus is derived making use of $W_t^0(z_t) = W_t^1(z_t) - w_t^1(z_t) + w_t^0(z_t) = W_t^1(z_t) - \eta f$ and of $(1-\eta)\left[W_t^1(z_t) - U_t\right] = \eta\left[J_t^1(z_t) + f\right]$.

$$
\begin{aligned}
S_t^1(z_t) &= W_t^1(z_t) - U_t + J_t^1(z_t) + f \\
&= w_t^1(z_t) + \mathrm{E}_t\beta_{t+1}\left\{(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty}[W_{t+1}^1(x) - U_{t+1}]\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx + U_{t+1}\right\} \\
&\quad - b - \mathrm{E}_t\beta_{t+1}\left\{s_t(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty}[W_{t+1}^1(x) - U_{t+1}]\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx + U_{t+1}\right\} \\
&\quad + A_t z_t d_t - w_t^1(z_t) + \mathrm{E}_t\beta_{t+1}\left\{(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty}[J_{t+1}^1(x) + f]\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx\right\} \\
&\quad + f - \mathrm{E}_t\beta_{t+1}f + \mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\eta f \\
&= A_t z_t d_t - b + f - \mathrm{E}_t\beta_{t+1}f + \mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\eta f \\
&\quad + \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty} S_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx \\
&\quad - \mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty}[W_{t+1}^1(x) - U_{t+1}]\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx \\
&\quad - \eta\mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty}[J_{t+1}^1(x) + f]\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx \\
&\quad + (1-\eta)\mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty}[W_{t+1}^1(x) - U_{t+1}]\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx \\
&= A_t z_t d_t - b + f - \mathrm{E}_t\beta_{t+1}f + \mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\eta f \\
&\quad + \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^1)\int_{\tilde{z}_{t+1}^1}^{\infty} S_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^1)}dx \\
&\quad - \mathrm{E}_t\beta_{t+1}s_t(1-\rho_{t+1}^0)\int_{\tilde{z}_{t+1}^0}^{\infty} S_{t+1}^1(x)\frac{f(x)}{1-F(\tilde{z}_{t+1}^0)}dx
\end{aligned}
$$

B Appendix: Model Equations

1. Euler

$$C_t^{-\sigma} = \beta R_t \mathrm{E}_t \left(C_{t+1}^{-\sigma} \frac{P_t}{P_{t+1}} \right)$$
$$\sigma \mathrm{E}_t \hat{c}_{t+1} = \sigma \hat{c}_t + \hat{R}_t - \mathrm{E}_t \hat{\pi}_{t+1} \tag{67}$$

2. Real Money Demand

$$\frac{M_t}{P_t} = \chi \frac{R_t}{R_t - 1} C_t^{\sigma}$$
$$\hat{m}_t = -\frac{1}{\bar{R} - 1} \hat{R}_t + \sigma \hat{c}_t \tag{68}$$

3. Real Money Supply

$$\frac{M_t}{P_t} = \left(\frac{M_{t-1}}{P_{t-1}} \right) \left(\frac{P_{t-1}}{P_t} \right) \phi_t$$
$$\hat{m}_t = \hat{m}_{t-1} + \hat{\phi}_t - \hat{\pi}_t \tag{69}$$

with $\hat{m}_t$ denoting the log-deviation of the real money from steady state

4. Matching Function

$$\mathcal{M}_t = m u_t^{\mu} v_t^{1-\mu}$$
$$\hat{\mathcal{M}}_t = \mu \hat{u}_t + (1-\mu) \hat{v}_t \tag{70}$$

5. Tightness

$$\theta_t = \frac{v_t}{u_t}$$
$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t \tag{71}$$

6. Matching probability

$$q_t = \frac{\mathcal{M}_t}{v_t}$$
$$\hat{q}_t = \hat{\mathcal{M}}_t - \hat{v}_t \tag{72}$$

7. Labor force

$$n_t + u_t = 1$$
$$\bar{n}\hat{n}_t + \bar{u}\hat{u}_t = 0 \tag{73}$$

8. Total Employment

$$n_t = n_t^0 + n_t^1$$
$$\bar{n}\hat{n}_t = \bar{n}^0\hat{n}_t^0 + \bar{n}^1\hat{n}_t^1 \tag{74}$$

9. New Workers

$$n_t^0 = (1 - \rho_t^0)\mathcal{M}_{t-1}$$
$$\hat{n}_t^0 = -\frac{\bar{\rho}^0}{1 - \bar{\rho}^0}\hat{\rho}_t^0 + \hat{\mathcal{M}}_{t-1} \tag{75}$$

10. Old Workers

$$n_t^1 = (1 - \rho_t^1)n_{t-1}$$
$$\hat{n}_t^1 = -\frac{\bar{\rho}^1}{1 - \bar{\rho}^1}\hat{\rho}_t^1 + \hat{n}_{t-1} \tag{76}$$

11. Match Separation Rate

$$\rho_t^0 = \rho^x + (1-\rho^x)\rho_t^{0,n}$$
$$\hat{\rho}_t^0 = \frac{(1-\rho^x)\bar{\rho}^{0,n}}{\bar{\rho}^0}\hat{\rho}_t^{0,n} \tag{77}$$

12. Job Separation Rate

$$\rho_t^1 = \rho^x + (1-\rho^x)\rho_t^{1,n}$$
$$\hat{\rho}_t^1 = \frac{(1-\rho^x)\bar{\rho}^{1,n}}{\bar{\rho}^1}\hat{\rho}_t^{1,n} \tag{78}$$

13. Endogenous Match Separation Rate

$$\rho_t^{0,n} = F(\tilde{z}_t^0)$$
$$\hat{\rho}_t^{0,n} = \frac{\partial F(\bar{\tilde{z}}^0)}{\partial \bar{\tilde{z}}^0}\frac{\bar{\tilde{z}}^0}{F(\bar{\tilde{z}}^0)}\hat{\tilde{z}}_t^0 = e_{\bar{\tilde{z}}^0 F}\hat{\tilde{z}}_t^0 \tag{79}$$

14. Endogenous Job Separation Rate

$$\rho_t^{1,n} = F(\tilde{z}_t^1)$$
$$\hat{\rho}_t^{1,n} = \frac{\partial F(\bar{\tilde{z}}^1)}{\partial \bar{\tilde{z}}^1}\frac{\bar{\tilde{z}}^1}{F(\bar{\tilde{z}}^1)}\hat{\tilde{z}}_t^1 = e_{\bar{\tilde{z}}^1 F}\hat{\tilde{z}}_t^1 \tag{80}$$

15. Match Separation Threshold

$$(1-\eta)\left\{A_t\tilde{z}_t^0 d_t - b + \mathrm{E}_t\beta_{t+1}(1-\rho_{t+1}^1)A_{t+1}d_{t+1}\left[H(\tilde{z}_{t+1}^1) - \tilde{z}_{t+1}^1\right] - \mathrm{E}_t\beta_{t+1}f\right\} - \eta a\theta_t = 0$$
$$\frac{\bar{A}\bar{\tilde{z}}^0\bar{d}}{\zeta}(\hat{A}_t + \hat{\tilde{z}}_t^0 + \hat{d}_t) - \frac{\eta a\bar{\theta}}{(1-\eta)\zeta}\hat{\theta}_t - \beta\sigma\left(\frac{f}{\zeta}-1\right)\hat{c}_t$$
$$+ \beta(\mathrm{E}_t\hat{A}_{t+1} + \mathrm{E}_t\hat{d}_{t+1}) + \beta\sigma\left(\frac{f}{\zeta}-1\right)\mathrm{E}_t\hat{c}_{t+1} - \beta\frac{\bar{\rho}^1}{1-\bar{\rho}^1}\mathrm{E}_t\hat{\rho}_{t+1}^1 + \beta\frac{\frac{\partial H(\bar{\tilde{z}}^1)}{\partial\bar{\tilde{z}}^1}\bar{\tilde{z}}^1 - \bar{\tilde{z}}^1}{H(\bar{\tilde{z}}^1) - \bar{\tilde{z}}^1}\mathrm{E}_t\hat{\tilde{z}}_{t+1}^1 = 0 \tag{81}$$

with $\zeta = (1-\bar{\rho}^1)\bar{A}\bar{d}[H(\bar{\tilde{z}}^1) - \bar{\tilde{z}}^1]$

16. Job Separation Threshold

$$
\begin{aligned}
&A_t \tilde{z}_t^1 d_t + f = A_t \tilde{z}_t^0 d_t \\
&\bar{\tilde{z}}^0 (\hat{A}_t + \hat{\tilde{z}}_t^0 + \hat{d}_t) = \bar{\tilde{z}}^1 (\hat{A}_t + \hat{\tilde{z}}_t^1 + \hat{d}_t)
\end{aligned} \tag{82}
$$

17. Vacancy Creation

$$
\begin{aligned}
&\frac{a}{q_t} = (1-\eta)\mathrm{E}_t \beta_{t+1} (1-\rho_{t+1}^0) A_{t+1} d_{t+1} \left[H(\tilde{z}_{t+1}^0) - \tilde{z}_{t+1}^0 \right] \\
&-\hat{q}_t - \sigma \hat{c}_t = -\sigma \mathrm{E}_t \hat{c}_{t+1} + \mathrm{E}_t \hat{A}_{t+1} + \mathrm{E}_t \hat{d}_{t+1} - \frac{\bar{\rho}^0}{1-\bar{\rho}^0} \mathrm{E}_t \hat{\rho}_{t+1}^0 + \frac{\frac{\partial H(\bar{\tilde{z}}^0)}{\partial \bar{\tilde{z}}^0} \bar{\tilde{z}}^0 - \bar{\tilde{z}}^0}{H(\bar{\tilde{z}}^0) - \bar{\tilde{z}}^0} \mathrm{E}_t \hat{\tilde{z}}_{t+1}^0
\end{aligned} \tag{83}
$$

18. Job Destruction Rate

$$
\begin{aligned}
&jdr_t = \rho_t^1 - \rho^x \\
&j\hat{d}r_t = \frac{\bar{\rho}^1}{\bar{\rho}^1 - \rho^x} \hat{\rho}_t^1
\end{aligned} \tag{84}
$$

19. Job Creation Rate

$$
\begin{aligned}
&jcr_t = \frac{(1-\rho_t^0)\mathcal{M}_{t-1}}{n_{t-1}} - \rho^x \\
&\frac{\bar{\rho}^1 - \rho^x}{\bar{\rho}^1} j\hat{c}r_t = -\frac{\bar{\rho}^0}{1-\bar{\rho}^0} \hat{\rho}_t^0 + \hat{\mathcal{M}}_{t-1} - \hat{n}_{t-1}
\end{aligned} \tag{85}
$$

20. Job Turnover

$$
\begin{aligned}
&jt_t = jcr_t + jdr_t \\
&\hat{jt}_t = j\hat{c}r_t + j\hat{d}r_t
\end{aligned} \tag{86}
$$

with $\hat{jt}_t = \frac{jt_t - \bar{jt}}{\rho^x}$

21. Net Employment Change

$$
\begin{aligned}
net_t &= jcr_t - jdr_t \\
\hat{net}_t &= \hat{jcr}_t - \hat{jdr}_t
\end{aligned}
\tag{87}
$$

with $\hat{net}_t = \frac{net_t - \bar{net}}{\rho^x} = \frac{net_t}{\rho^x}$

22. Aggregate New Wage

$$
\begin{aligned}
w_t^0 &= (1-\eta)b + \eta(A_t H(\tilde{z}_t^0)d_t + a\theta_t - \mathrm{E}_t\beta_{t+1}f) \\
\bar{w}^0\hat{w}_t^0 &= \eta\bar{A}\bar{d}H(\bar{\tilde{z}}^0)(\hat{A}_t + \hat{d}_t) + \eta\bar{A}\bar{d}\frac{\partial H(\bar{\tilde{z}}^0)}{\partial\bar{\tilde{z}}^0}\bar{\tilde{z}}^0\hat{\tilde{z}}_t^0 + \eta a\bar{\theta}\hat{\theta}_t + \eta\beta f\sigma(\mathrm{E}_t\hat{c}_{t+1} - \hat{c}_t)
\end{aligned}
\tag{88}
$$

23. Aggregate Old Wage

$$
\begin{aligned}
w_t^0 - \eta(A_t H(\tilde{z}_t^0)d_t) &= w_t^1 - \eta(A_t H(\tilde{z}_t^1)d_t + f) \\
\bar{w}^0\hat{w}_t^0 - \eta\bar{A}\bar{d}H(\bar{\tilde{z}}^0)(\hat{A}_t + \hat{d}_t) - \eta\bar{A}\bar{d}\frac{\partial H(\bar{\tilde{z}}^0)}{\partial\bar{\tilde{z}}^0}\bar{\tilde{z}}^0\hat{\tilde{z}}_t^0 & \\
&= \bar{w}^1\hat{w}_t^1 - \eta\bar{A}\bar{d}H(\bar{\tilde{z}}^1)(\hat{A}_t + \hat{d}_t) - \eta\bar{A}\bar{d}\frac{\partial H(\bar{\tilde{z}}^1)}{\partial\bar{\tilde{z}}^1}\bar{\tilde{z}}^1\hat{\tilde{z}}_t^1
\end{aligned}
\tag{89}
$$

24. Phillips Curve

$$
\begin{aligned}
p_{i,t}^* = P_t^* &= \frac{\epsilon}{\epsilon-1}\mathrm{E}_t\sum_{s=0}^{\infty}\frac{\varphi^s\beta_{t+s}d_{t+s}P_{t+s}\left(\frac{P_t}{P_{t+s}}\right)^{1-\epsilon}y_{t+s}}{\mathrm{E}_t\sum_{k=0}^{\infty}\varphi^k\beta_{t+k}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}y_{t+k}} \\
P_t &= [\varphi P_{t-1}^{1-\epsilon} + (1-\varphi)(P_t^*)^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \\
\pi_t &= \varphi_d\hat{d}_t + \beta\mathrm{E}_t\pi_{t+1}
\end{aligned}
\tag{90}
$$

with $\varphi_d = \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}$

25. Aggregate Production

$$Y_t = A_t\left[H(\tilde{z}_t^0)n_t^0 + H(\tilde{z}_t^1)n_t^1\right]$$
$$\hat{y}_t = \hat{A}_t + \frac{\frac{\partial H(\bar{\tilde{z}}^0)}{\partial \bar{\tilde{z}}^0}\bar{\tilde{z}}^0\bar{n}^0}{\nu}\hat{\tilde{z}}_t^0 + \frac{\frac{\partial H(\bar{\tilde{z}}^1)}{\partial \bar{\tilde{z}}^1}\bar{\tilde{z}}^1\bar{n}^1}{\nu}\hat{\tilde{z}}_t^1 + \frac{H(\bar{\tilde{z}}^0)\bar{n}^0}{\nu}\hat{n}_t^0 + \frac{H(\bar{\tilde{z}}^1)\bar{n}^1}{\nu}\hat{n}_t^1 \tag{91}$$

with $\nu = H(\bar{\tilde{z}}^0)\bar{n}^0 + H(\bar{\tilde{z}}^1)\bar{n}^1$

26. Resource Constraint

$$Y_t = C_t + av_t$$
$$\bar{y}\hat{y}_t = \bar{c}\hat{c}_t + a\bar{v}\hat{v}_t \tag{92}$$

27. Money Growth Rate Shock

$$\hat{\phi}_t = \rho_m\hat{\phi}_{t-1} + \epsilon_{m,t} \tag{93}$$

28. Productivity Shock

$$\hat{A}_t = \rho_A\hat{A}_{t-1} + \epsilon_{A,t} \tag{94}$$

28 equations and 28 variables:

$$(C_t, R_t, \pi_t, m_t, \mathcal{M}_t, u_t, v_t, \theta_t, q_t, n_t, n_t^0, n_t^1, \rho_t^0, \rho_t^1, \rho_t^{0,n}, \rho_t^{1,n}, \tilde{z}_t^0, \tilde{z}_t^1, A_t, \hat{\phi}_t, d_t, w_t^0, w_t^1, Y_t, jcr_t, jdr_t, jt_t, net_t)$$

C Appendix: Matlab Codes

C.1 SSsolve.m

```
function F=SS_solve(vari)
% Compute the steady state values for different
% values of f keeping the same values of parameters. It can be used separately or in combination with Graph_SS.m
% to get the solutions for a serie of f and plot them.
global firing rhox mu_z sig a % to activate when used with Graph_SS.m
%global mu_z sig  % to activate when calculating the values for one value for f
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Calibration
rho1=0.1; u_bar=0.15; q_bar=.7; firing_cal=0;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

betta=0.99; eta=0.5; A_bar=1; epsilon=11; d_bar=(epsilon-1)/epsilon;
mu=0.4;
mu_z=0;  % parameter of the distribution of z
sig=.2;  % parameter of the distribution of z
rhox=0.68*rho1;
%firing=0; % to activate when calculating the values for one value for f

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Calculating the parameters
z1=logninv((rho1-rhox)/(1-rhox),mu_z,sig);
z0=(A_bar*z1*d_bar+firing_cal)/(A_bar*d_bar);
a=q_bar*betta*(1-(rhox+(1-rhox)*logncdf(z0,mu_z,sig)))*(1-eta)*A_bar*d_bar*(quad('afa',z0,8)/(1-logncdf(z0,mu_z,sig))-z0);
v_bar=rho1*(1-u_bar)/((1-(rhox+(1-rhox)*logncdf(z0,mu_z,sig)))*q_bar);
m=q_bar/(u_bar/v_bar)^(mu);
b=A_bar*z0*d_bar+betta*(1-rho1)*A_bar*d_bar*(quad('afa',z1,8)/(1-logncdf(z1,mu_z,sig))-z1)-betta*firing_cal-(eta/(1-eta))*a*v_bar/u_bar;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

F=[(1-eta)*(A_bar*vari(1)*d_bar-b+betta*(1-(rhox+(1-rhox)*logncdf(vari(2),mu_z,sig)))*A_bar*d_bar*(quad('afa',vari(2),8)/(1-logncdf(vari(2),mu_z,sig))-vari(2))-betta*firing)-eta*a*vari(3)/vari(5);
   A_bar*vari(2)*d_bar-A_bar*vari(1)*d_bar+firing;
   a/vari(4)-betta*(1-(rhox+(1-rhox)*logncdf(vari(1),mu_z,sig)))*(1-eta)*A_bar*d_bar*(quad('afa',vari(1),8)/(1-logncdf(vari(1),mu_z,sig))-vari(1));
   1-vari(5)-(1-(rhox+(1-rhox)*logncdf(vari(1),mu_z,sig)))*vari(4)*vari(3)-(1-(rhox+(1-rhox)*logncdf(vari(2),mu_z,sig)))*(1-vari(5));
```

```
   vari(4)-m*(vari(5)/vari(3))^(mu);
   vari(6)-(1-eta)*b-eta*(A_bar*d_bar*quad('afa',vari(1),8)/(1-logncdf(vari(1),mu_z,sig))+a*vari(3)/vari(5)-betta*firing);
   vari(7)-(1-eta)*b-eta*(A_bar*d_bar*quad('afa',vari(2),8)/(1-logncdf(vari(2),mu_z,sig))+a*vari(3)/vari(5)+firing-betta*firing)];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%vari(1)=z0; vari(2)=z1; vari(3)=v_bar; vari(4)=q_bar; vari(5)=u_bar; x(6)=w0; x(7)=w1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

C.2 SSGraph.m

```
% Plot the solutions of the system for different firing costs provided by SS_solve
z0=[]; z1=[]; rho0=[]; rho1=[]; v=[]; u=[]; w0=[]; w1=[]; f=[];
c=[]; yy=[]; jc=[]; nn0=[]; nn1=[]; global firing rhox mu_z sig a
options=optimset; for  firing=[0,0.5]
     vari0=[.8;.8;.1;.7;.1;.9;.9];
     [vari] = fsolve('SS_solve',vari0,options);
     z0   =[z0;vari(1)];
     z1   =[z1;vari(2)];
     rho0 =[rho0;rhox+(1-rhox)*logncdf(vari(1),mu_z,sig)];
     rho1 =[rho1;rhox+(1-rhox)*logncdf(vari(2),mu_z,sig)];
     v    =[v;vari(3)];
     u    =[u;vari(5)];
     w0   =[w0;vari(6)];
     w1   =[w1;vari(7)];
     n0   =(1-rhox-(1-rhox)*logncdf(vari(1),mu_z,sig))*vari(4)*vari(3);
     n1   =(1-rhox-(1-rhox)*logncdf(vari(2),mu_z,sig))*(1-vari(5));
     y    =n0*quad('afa',vari(1),8)/(1-logncdf(vari(1),mu_z,sig))+n1*quad('afa',vari(2),8)/(1-logncdf(vari(2),mu_z,sig));
     yy   =[yy,y];
     c    =[c;y-a*vari(3)];
     jc   =[jc;(1-rhox)*logncdf(vari(2),mu_z,sig)];
     nn0  =[nn0;n0];
     nn1  =[nn1;n1];
     f    =[f;firing];
end for firing=[0.5:0.05:0.9]
    vari0=[.8;.1;.01;.9;.15;.5;.9];
    [vari] = fsolve('SS_solve',vari0,options);
    z0   =[z0;vari(1)];
    z1   =[z1;vari(2)];
    rho0 =[rho0;rhox+(1-rhox)*logncdf(vari(1),mu_z,sig)];
    rho1 =[rho1;rhox+(1-rhox)*logncdf(vari(2),mu_z,sig)];
    v    =[v;vari(3)];
```

```
    u    =[u;vari(5)];
    w0   =[w0;vari(6)];
    w1   =[w1;vari(7)];
    n0   =(1-rhox-(1-rhox)*logncdf(vari(1),mu_z,sig))*vari(4)*vari(3);
    n1   =(1-rhox-(1-rhox)*logncdf(vari(2),mu_z,sig))*(1-vari(5));
    y    =n0*quad('afa',vari(1),8)/(1-logncdf(vari(1),mu_z,sig))+n1*quad('afa',vari(2),8)/(1-logncdf(vari(2),mu_z,sig));
    c    =[c;y-a*vari(3)];
    jc   =[jc;(1-rhox)*logncdf(vari(2),mu_z,sig)];
    nn0  =[nn0;n0];
    nn1  =[nn1;n1];
    f    =[f;firing];
end

figure(1) pl_z=plot(f,z0,'-r',f,z1,'--bo'); grid;
set(pl_z,'LineWidth',2) xlabel('firing cost','FontSize',20);
ylabel('z_bar','FontSize',20); leg_z = legend('z0','z1',2);
leg_z_text = findobj(leg_z,'type','text');
set(leg_z_text,'FontUnits','points','FontSize',20); hold; title('SS
change to variation in f','FontSize',20);

figure(2) pl_rho=plot(f,rho0,'-r',f,rho1,'--bo'); grid;
set(pl_rho,'LineWidth',2) xlabel('firing cost','FontSize',20);
ylabel('rho_{bar}','FontSize',20); leg_rho =
legend('rho0','rho1',2); leg_rho_text =
findobj(leg_rho,'type','text');
set(leg_rho_text,'FontUnits','points','FontSize',20); hold;
title('SS change to variation in f','FontSize',20);

figure(3) pl_v=plot(f,v,'b'); grid; set(pl_v,'LineWidth',2)
xlabel('firing cost','FontSize',20); ylabel('v','FontSize',20);
hold; title('SS change to variation in f','FontSize',20);

figure(4) pl_u=plot(f,u); grid; set(pl_u,'LineWidth',2)
xlabel('firing cost','FontSize',20); ylabel('u','FontSize',20);
hold; title('SS change to variation in f','FontSize',20);

figure(5) pl_w=plot(f,w0,'-r',f,w1,'--bo'); grid;
set(pl_w,'LineWidth',2); xlabel('firing cost','FontSize',20);
ylabel('wages','FontSize',20); leg_w = legend('w0','w1',2);
leg_w_text = findobj(leg_w,'type','text');
set(leg_w_text,'FontUnits','points','FontSize',20); hold; h =
```

```
hline(0.8197,'m','b'); set(h,'LineWidth',2); title('SS change to
variation in f','FontSize',20);

figure(6) pl_c=plot(f,c); grid; set(pl_c,'LineWidth',2)
xlabel('firing cost','FontSize',20);
ylabel('c_{bar}','FontSize',20); hold; title('SS change to variation
in f','FontSize',20);

figure(7) pl_jc=plot(f,jc); grid; set(pl_jc,'LineWidth',2)
xlabel('firing cost','FontSize',20); ylabel('jd-jc','FontSize',20);
hold; title('SS change to variation in f','FontSize',20);
```

C.3 dynamics.m

```
disp('A New Keynesian model with matching frictions'); disp('Money
growth rule');



disp('Hit any key when ready...'); pause;



% Setting parameters:

global mu_z sig
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Calibration
rho1=0.1; u_bar=0.15; q_bar=.7; firing_cal=0;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
betta=0.99; eta=0.5; A_bar=1; epsilon=11; d_bar=(epsilon-1)/epsilon;
mu=0.4; sigma=2; mu_z=0; sig=.2; rhox=0.68*rho1;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Calculating the parameters
z1=logninv((rho1-rhox)/(1-rhox),mu_z,sig);
z0=(A_bar*z1*d_bar+firing_cal)/(A_bar*d_bar);
a=q_bar*betta*(1-(rhox+(1-rhox)*logncdf(z0,mu_z,sig)))*(1-eta)*A_bar*d_bar*(quad('afa',z0,8)/(1-logncdf(z0,mu_z,sig))-z0);
v_bar=rho1*(1-u_bar)/((1-(rhox+(1-rhox)*logncdf(z0,mu_z,sig)))*q_bar);
```

```
m=q_bar/(u_bar/v_bar)^(mu);

b=A_bar*z0*d_bar+betta*(1-rho1)*A_bar*d_bar*(quad('afa',z1,8)/(1-logncdf(z1,mu_z,sig))-z1)-betta*firing_cal-(eta/(1-eta))*a*v_bar/u_bar;

w0=(1-eta)*b+eta*(A_bar*d_bar*quad('afa',z0,8)/(1-logncdf(z0,mu_z,sig))+a*v_bar/u_bar-betta*firing_cal);

w1=(1-eta)*b+eta*(A_bar*d_bar*quad('afa',z1,8)/(1-logncdf(z1,mu_z,sig))+a*v_bar/u_bar+firing_cal-betta*firing_cal);


phi=.5; phi_d=(1-betta*phi)*(1-phi)/phi;


psi_A=0.95; psi_M=0.49; sigma_A=0.00712; sigma_M=0.01;


mu_z=0; sig=.2;


firing=0; % choose the value for firing costs



if firing ==0.05
    z0=0.70099989837468;
    z1=0.64599989837468;
    v_bar=0.11096218569564;
    q_bar=0.71300512104683;
    u_bar=0.12917384776996;
    w0=0.89670853236379;
    w1=0.91784539660036;
end

if firing==0.1
    z0=0.70650116649291;
    z1=0.59650116649291;
    v_bar=0.09860507644134;
    q_bar=0.72493155636480;
    u_bar=0.11964913598774;
    w0=0.87080583551678;
    w1=0.91466665721721;
end

if firing==0.2
    z0=0.71699726452854;
    z1=0.49699726452853;
    v_bar=0.09048418985926;
    q_bar=0.74869908513133;
    u_bar=0.11901692929255;
    w0=0.81931255520466;
```

```
    w1=0.91113398139778;
end

if firing==0.3
    z0=0.72784015079317;
    z1=0.39784015079327;
    v_bar=0.08729950555755;
    q_bar=0.77471756035429;
    u_bar=0.12506565887390;
    w0=0.76804153762165;
    w1=0.90858569481218;
end

m_bar=q_bar*v_bar; theta_bar=v_bar/u_bar; R_bar=1/betta;
n_bar=1-u_bar; rho0=rhox+(1-rhox)*logncdf(z0,mu_z,sig);
rho1=rhox+(1-rhox)*logncdf(z1,mu_z,sig); n0_bar=(1-rho0)*m_bar;
n1_bar=(1-rho1)*n_bar; H0=quad('afa',z0,8)/(1-logncdf(z0,mu_z,sig));
H1=quad('afa',z1,8)/(1-logncdf(z1,mu_z,sig));
dH0=lognpdf(z0,mu_z,sig)*(H0-z0)/(1-logncdf(z0,mu_z,sig));
dH1=lognpdf(z1,mu_z,sig)*(H1-z1)/(1-logncdf(z1,mu_z,sig));
nu=H0*n0_bar+H1*n1_bar; y_bar=A_bar*nu; c_bar=y_bar-a*v_bar;
e_z0=lognpdf(z0,mu_z,sig)*z0/logncdf(z0,mu_z,sig);
e_z1=lognpdf(z1,mu_z,sig)*z1/logncdf(z1,mu_z,sig); H=H1-H0;
zeta=(1-rho1)*A_bar*d_bar*(H1-z1); rhon0=(rho0-rhox)/(1-rhox);
rhon1=(rho1-rhox)/(1-rhox);


% Declaring the matrices.


VARNAMES = ['new workers           ',  %1
            'old workers           ',
            'vacancy               ',
            'real money            ',
            'aggregate new wage    ',   %5
            'aggregate old wage    ',
            'marginal cost         ',
            'net employment change ',
            'consumption           ',
            'output                ',   %10
            'gross nominal return  ',
```

```
            'inflation             ',
            'unemployment          ',
            'tightness             ',
            'match separation rate ',  %15
            'job separation rate   ',
            'total employment      ',
            'job creation rate     ',
            'job destruction rate  ',
            'threshold for new jobs',   %20
            'threshold for old jobs',
            'endo match separ rate ',
            'endo job separ rate   ',
            'job turnover          ',
            'productivity          ',   %25
            'money growth rate     '];

% CHECK: 26 equations, 26 variables.
% Endogenous state variables "x(t)": n0(t), n1(t), v(t), m(t), w0(t), w1(t), d(t), net(t)
% Endogenous other variables "y(t)": c(t), y(t), R(t), pi(t), u(t), theta(t), rho0(t), rho1(t), jc(t),jdr(t), z0(t), z1(t), rhon0(t), rhon1(t), jt(t)
% Exogenous state variables  "z(t)": A(t), psi(t)


% for           n0(t),          n1(t),    v(t),m(t), w0(t), w1(t),             d(t),net(t)
AA = [              0,              0,       0,   1,     0,     0,                0, 0   %1.
                    0,              0,      -1,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0
             -n0_bar,        -n1_bar,       0,   0,     0,     0,                0, 0
                    1,              0,       0,   0,     0,     0,                0, 0  %5
                    0,              1,       0,   0,     0,     0,                0, 0
        -H0*n0_bar/nu,  -H1*n1_bar/nu,       0,   0,     0,     0,                0, 0
                    0,              0, a*v_bar,   0,     0,     0,                0, 0
                    0,              0,       0,   1,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,          (z0-z1), 0  %10
                    0,              0,       0,   0,    w0,   -w1, eta*A_bar*d_bar*H, 0
                    0,              0,       0,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0   %15
                    0,              0,       0,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0
                    0,              0,       0,   0,     0,     0,                0, 0
```

```
                 0,            0,      0,   0,     0,     0,               0, 1];

% for                        n0(t-1),                        n1(t-1),  v(t-1), m(t-1), w0(t-1), w1(t-1), d(t-1),net(t-1)
BB = [                             0,                              0,       0,      0,       0,       0,      0, 0  %1
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                   mu*n0_bar/u_bar,                mu*n1_bar/u_bar, -(1-mu),      0,       0,       0,      0, 0  %5
                    -n0_bar/n_bar,                  -n1_bar/n_bar,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,     -1,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0  %10
                                   0,                              0,       0,      0,       0,       0,      0, 0
      (mu*n_bar/u_bar+1)*n0_bar/n_bar,(mu*n_bar/u_bar+1)*n1_bar/n_bar, -(1-mu),      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0  %15
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0
                                   0,                              0,       0,      0,       0,       0,      0, 0];

% For   c(t),    y(t),         R(t),pi(t), u(t),theta(t),       rho0(t),         rho1(t),    n(t),         jcr(t),jdr(t),                z0(t),                z1(t),            rhon0(t),              rhon1(t),jt(t):
CC = [-sigma,     0,   1/(R_bar-1),     0,     0,       0,            0,               0,       0,             0,    0,                   0,                   0,                   0,                      0,  0 % 1
          0,     0,            0,     0,     1,       1,            0,               0,       0,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     0, u_bar,       0,            0,               0,   n_bar,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     0,     0,       0,            0,               0,   n_bar,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     0,     0,       0, rho0/(1-rho0),              0,       0,             0,    0,                   0,                   0,                   0,                      0,  0 % 5
          0,     0,            0,     0,     0,       0,            0,   rho1/(1-rho1),       0,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     1,            0,     0,     0,       0,            0,               0,       0,             0,    0,      -dH0*z0*n0_bar/nu,      -dH1*z1*n1_bar/nu,                   0,                      0,  0
      c_bar,-y_bar,            0,     0,     0,       0,            0,               0,       0,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     1,     0,       0,            0,               0,       0,             0,    0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     0,     0,       0,            0,               0,       0,             0,    0,                  z0,                 -z1,                   0,                      0,  0 % 10
          0,     0,            0,     0,     0,       0,            0,               0,       0,             0,    0,-eta*A_bar*d_bar*dH0*z0, eta*A_bar*d_bar*dH1*z1,                   0,                      0,  0
          0,     0,            0,     0,     0,       0, rho0/(1-rho0),              0,       0,(rho1-rhox)/rho1,  0,                   0,                   0,                   0,                      0,  0
          0,     0,            0,     0,     0,       0,            0,               0,       0,             0,    0,               -e_z0,                   0,                   1,                      0,  0
          0,     0,            0,     0,     0,       0,            0,               0,       0,             0,    0,                   0,               -e_z1,                   0,                      1,  0
          0,     0,            0,     0,     0,       0,            1,               0,       0,             0,    0,                   0,                   0,  -(1-rhox)*rhon0/rho0,                   0,  0 % 15
          0,     0,            0,     0,     0,       0,            0,               1,       0,             0,    0,                   0,                   0,                   0,  -(1-rhox)*rhon1/rho1,  0
          0,     0,            0,     0,     0,       0,            0,-rho1/(rho1-rhox),      0,             0,    1,                   0,                   0,                   0,                      0,  0
```

```
      0,   0,       0,   0,   0,    0,       0,         0,    0,        -1,  -1,           0,           0,           0,           0,  1
      0,   0,       0,   0,   0,    0,       0,         0,    0,        -1,   1,           0,           0,           0,           0,  0];

% For          A(t), psi(t):
DD = [            0,   0  %1
                  0,   0
                  0,   0
                  0,   0
                  0,   0  %5
                  0,   0
                 -1,   0
                  0,   0
                  0,  -1
            (z0-z1),   0  %10
   eta*A_bar*d_bar*H,  0
                  0,   0
                  0,   0
                  0,   0
                  0,   0  %15
                  0,   0
                  0,   0
                  0,   0
                  0,   0];

% EXPECTATIONAL EQUATIONS:

% For  n0(t+1),n1(t+1),v(t+1),m(t+1),w0(t+1),w1(t+1),d(t+1),net(t+1)
FF = [   0,    0,     0,     0,     0,     0,   betta,   0
         0,    0,     0      0,     0,     0,       1,   0
         0,    0,     0,     0,     0,     0,       0,   0
         0,    0,     0,     0,     0,     0,       0,   0
         0,    0,     0,     0,     0,     0,       0,   0];

% For  n0(t),n1(t),v(t), m(t),  w0(t),   w1(t),             d(t),net(t)
GG = [  0,   0,   0,      0,     0,       0,
A_bar*z0*d_bar/zeta,   0
        0,   0,   0,      0,     0,       0,                  0,   0
        0,   0,   0,      0,    w0,       0, -eta*A_bar*d_bar*H0,   0
        0,   0,   0,      0,     0,       0,                  0,   0
        0,   0,   0,      0,     0,       0,             -phi_d,   0];
```

```
% For n0(t-1),n1(t-1),v(t-1),m(t-1),w0(t-1),w1(t-1),d(t-1),net(t-1)
HH = [      0,      0,     0,     0,      0,     0,    0,   0
            0,      0,     0,     0,      0,     0,    0,   0
            0,      0,     0,     0,      0,     0,    0,   0
            0,      0,     0,     0,      0,     0,    0,   0
            0,      0,     0,     0,      0,     0,    0,   0];

% For [                      c(t+1),y(t+1),R(t+1),pi(t+1),u(t+1),theta(t+1), rho0(t+1),           rho1(t+1),n(t+1),jcr(t),jdr(t),        z0(t+1),                  z1(t+1), rhon0(t+1),rhon1,  jt(t+1)
JJ = [  betta*sigma*(firing/zeta-1),    0,      0,       0,    0,
0,              0, -betta*rho1/(1-rho1),      0,   0,  0,
0, betta*(dH1*z1-z1)/(H1-z1),       0,      0,     0
                             -sigma,    0,      0,       0,    0,   0,  -rho0/(1-rho0),                    0,      0,   0,  0, (dH0*z0-z0)/(H0-z0),                        0,       0,      0,     0
            -sigma*eta*betta*firing,    0,      0,       0,    0,   0,               0,                    0,      0,   0,  0,                  0,                        0,       0,      0,     0
                             -sigma,    0,      0,      -1,    0,   0,               0,                    0,      0,   0,  0,                  0,                        0,       0,      0,     0
                                  0,    0,      0,  -betta,    0,   0,               0,                    0,      0,   0,  0,                  0,                        0,       0,      0,     0];

% For [                       c(t), y(t),   R(t),pi(t),  u(t),                        theta(t) rho0(t),rho1(t),n(t)),jc(t),jdr(t),              z0(t),    z1(t), rhon0(t), rhon1(t),jt(t):
KK = [-betta*sigma*(firing/zeta-1),    0,      0,    0,    0,
-eta*a*theta_bar/((1-eta)*zeta),       0,     0,      0,  0,  0,
A_bar*z0*d_bar/zeta,       0,       0,      0,       0
                             sigma,    0,      0,    0,    0,                           -mu,       0,     0,      0,   0,  0,                     0,       0,       0,      0,       0
            sigma*eta*betta*firing,    0,      0,    0,    0,              -eta*a*theta_bar,       0,     0,      0,   0,  0,-eta*A_bar*d_bar*dH0*z0,      0,       0,      0,       0
                             sigma,    0,      1,    0,    0,                             0,       0,     0,      0,   0,  0,                     0,       0,       0,      0,       0
                                 0,    0,      0,    1,    0,                             0,       0,     0,      0,   0,  0,                     0,       0,       0,      0,       0];

LL = [betta,         0
          1,         0
          0,         0
          0,         0
          0,         0];

% For                 A(t),psi(t):
MM = [ A_bar*z0*d_bar/zeta,    0
                        0,    0
       -eta*A_bar*d_bar*H0,    0
                        0,    0
                        0,    0];

% AUTOREGRESSIVE MATRIX FOR z(t)

NN = [psi_A,     0
```

```
          0, psi_M];

Sigma = [ sigma_A^2,           0
                  0,   sigma_M^2];

% Setting the options:

[l_equ,m_states] = size(AA); [l_equ,n_endog ] = size(CC);
[l_equ,k_exog  ] = size(DD);


PERIOD     = 4; GNP_INDEX  = 10; IMP_SELECT = [10,12,25];
DO_HP_FILTER = 1; HP_SELECT  = 1:(m_states+n_endog+k_exog);
DO_MOMENTS = 1; HORIZON      = 48; INIT_DATE = 4; DO_HP_GRAPH = 0;
DO_STATE_RESP = 0;

DISPLAY_AT_THE_END = 0;

do_it;
```

Declaration of Authorship

I hereby confirm that I have written this diploma thesis independently and without use of other than the indicated resources. All passages, which are literally or in general matter taken out of publications or other resources, are marked as such.

Rong Sun

Berlin, September 1st, 2006