Monetary Policy and Resource Mobility

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Abstract

The imperfect nature of resource mobility plays a surprisingly small role in most policy models. In the standard benchmark new Keynesian model, for example, it is costly for firms to adjust their selling prices, but these same firms can costlessly hire and fire workers and both workers and capital can costlessly shift from one firm to another. In this paper, I review some of the implications for monetary policy of imperfect resource mobility, distinguishing between its role in altering the transmission mechanism of monetary policy and its role in affecting the goals of policy.

(JEL E52, E58, J64).

1 Introduction

Over the past twenty years, economists have developed a rich set of tools for studying the design of monetary policy in dynamic and stochastic environments. We know how to build macro models consistent with optimizing behavior by households, firms, and the central bank. Most of these models are highly stylized, more appropriate for gaining basic insights into policy issues than they are for actually guiding the implementation of policy, but these models have also been extended in a wide variety of ways to better incorporate macroeconomic dynamics, to improve their forecasting ability, and to make them more useful in the practice of monetary policy.

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Despite these advances, the financial crisis, the Great Recession, and the ongoing fiscal crises serve as painful reminders of how inadequate our models are in understanding the role of financial frictions, the sources of potential shocks, and the manner in which shocks can be amplified and propagated throughout not just the economy in which the shock originates but throughout the international economic system. Fortunately, monetary policy models are rapidly evolving to incorporate many important insights gained from the past two years.

While the theme of this celebration of the 200th anniversary of the Bank of Finland is *Monetary policy under resource mobility*, most of my focus will be on resource *immobility*. The reason is that the basic new Keynesian framework that is at the heart of most modern DSGE policy models gives center stage to nominal price and wage rigidities, yet underlying this structure are some very extreme assumptions about the ability of labor and capital to swiftly move among alternative uses. For example, the baseline version of the new Keynesian model has a continuum of firms producing differentiated goods. These firms find it costly to adjust their selling prices, but these same firms can hire and fire workers at zero cost, and both workers and capital can instantly shift from one firm to another. Baseline models are poor at matching macroeconomic dynamics, and the versions of the models taken to the data generally incorporate features that are often ad hoc but are necessary to capture the types of sluggish adjustments seen in the data. A more careful treatment of the costs that limit rapid movement of labor and capital among alternative uses is likely to be useful in understanding the way monetary policy actions affect the behavior of the economy as well as critical in assessing the costs associate with economic fluctuations.

Ignoring potential costs associated with shifting real economic resources is consistent with standard one-sector, one-good models of the aggregate economy. However, economies consist of multiple sectors, and different sectors of the economy behave differently over the course of a business cycles. Durable goods producing sectors are, for example, more cyclically sensitive than service sectors. Economic fluctuations may be associated with shifts in relative prices across sectors or with persistent shifts in relative demand that may require labor (and capital) to shift from contracting to expanding sectors of the economy. These shifts require resource to move, yet differences in the labor skills or the types of capital employed in different occupations or sectors may made sectoral reallocations costly. And the costs that arise because resources are not fully mobile may have consequences for aggregate demand polices.

In this paper, therefore, I explore some of the implications of imperfect resource mobility for monetary policy. To undertake this exploration, my discussion is organized around two distinct but closely related questions. First, how does imperfect resource mobility affect the transmission process of monetary policy? Second, how does it affect the goals of monetary policy? A key conclusion is that resource mobility matters for both – it affects the transmission mechanism that links monetary policy instruments to inflation and the real economy, thereby affecting the trade-offs faced by the policy authority, and it affects the way policy makers should weigh their objectives.

My chief focus will be on labor mobility. This is an issue of particular importance for the U.S., where the Great Recession was associated with what is likely to be a very persistent shift of resources out of construction. Labor mobility is also relevant in the European Union, as the ability to efficiently respond to asymmetric shocks across member states is limited when labor mobility is itself quite limited.

The rest of the paper is organized as follows. Section 2 briefly reviews the assumptions concerning resource mobility that are common in current policy models and looks at some evidence related to sectoral reallocations. Then, in sections 3 - 6, I work through four examples that imbed the assumption of costly labor and employment adjustment as a form of imperfect resource mobility. The examples highlight how the transmission channels of policy are affected by different assumptions about the ability to reallocate resources in the face of economic shocks. If it is costly to reallocate real resources, then real rigidities arise. If these rigidities generate distortions that interact with nominal rigidities, they can affect the objectives a central bank should pursue. Section (7) summarizes the lessons for monetary policy.

2 Sectoral shifts and reallocation

Large sectoral shifts and reallocations of resources are continuously occurring within individual economies, or, for that matter, within monetary unions. While these shifts are related to differences in secular trends and differences in sensitivity to the aggregate business cycle, the ease or difficult with which resources may move in response to these shifts may play a role in macroeconomic dynamics and affect measures such as potential output, or the flexible-price output level, that serve as benchmarks for gauging the cyclical state of the economy. Costly adjustments may generate distortions in the economy that may be independent of the distortions associated with nominal rigidities – and therefore irrelevant for monetary policy – but if real rigidities hinder the efficient reallocation of resources in the face of shocks and structural shifts, nominal and real distortions may interact in ways that have implications for monetary policy. In this section, I first examine some of the evidence on the relationship between sectoral reallocations and unemployment and then very briefly review some of the alternative assumptions concerning resource mobility that have been made in the literature.

2.1 Sectoral reallocations

If labor and other resources can be shifted from slow growing sectors of the economy to rapidly growing sectors easily, then sectoral reallocations may have no macro implications for monetary policy makers. However, at least in the U.S, the sharp drop in employment in sectors such as construction, and the likelihood that construction activity will not return to the bubble-driven levels of 2004-2006, have raised questions about whether the natural rate of unemployment in the U.S. – the level relevant for policy makers in judging the state of the economy and the pressures on inflation – may be higher now then before the Great Recession (Weidner and Williams 2011). This is an important issue from the central bank's perspective, as the natural rate of unemployment is a key benchmark for assessing the state of the economy and the likely inflation implications of actual unemployment. How plausible it is that employment declines in one sector accompanied by job growth in another affects the natural rate of unemployment depends, in part, on how easily it is for labor resources to shift from one sector to another. If labor and capital mobility is high, it is less likely that the natural rate of unemployment will be affected by shifts in employment patterns across industries, occupations, or sectors.

Different sectors display different patterns of growth and employment growth. Figure 1 illustrates employment shares in six sectors of the U.S. economy (construction, manufacturing, finance, trade, mining, and government). The data for each sector are normalized to equal one in January 1985. These six sectors contain just under 70% of all U.S. employment. It is clear that they display quite different secular trends, with the declining share of employment in manufacturing balanced by the growth in professional and business services and educational and health services, and, to a lesser degree, leisure and hospitality employment. Employment in construction and government display the least evidence of longer term trends, but construction has also experienced the largest swings, seeing a sharp decline during the 1990 recession and an even larger one during the

Great Recession, while remaining flat during the 2000 recession. In contrast, employment in the educational and health services and government sectors appears to be procyclical.

More generally, economists have long debated whether these sorts of sectoral shifts are relevant for aggregate variables such as unemployment. The law of large numbers would suggest that shocks occurring at the sectoral level cancel out as one aggregates across sectors (Lucas 1987). However, some work has been done to show how this need not be the case when sectors are linked via input-output relationships (e.g., Horvath 1998, 2000). Huang and Liu (2006) construct a two sector model in which one sector produces intermediate goods used in the other sector to produce final goods, and show that optimal monetary policy must consider more than just an aggregate output gap and aggregate measure inflation. If cyclical movements of the employment shares in different industries or occupations are transitory, they may imply little for monetary policy. On the other hand, if the mobility of resources, particularly labor, is imperfect, then shifts in the sectoral composition of output will generate a rise in structural unemployment, and policy authorities would need to be able to distinguish between such induced variations in the natural rate of unemployment and possibility correlated movements in cyclical unemployment.

In a famous article that pre-dated the Great Moderation, David Lilien (1982) argued that a large share of unemployment fluctuations normally thought of as cyclical in nature could instead be attributed to fluctuations in the natural rate of unemployment. He claimed these natural rate movements at business cycle frequencies were due to sectoral shifts in employment. Lilien (1982) constructed a measure of the sectoral dispersion of employment growth and concluded that sectoral reallocations associated with a widening of the dispersion of growth rates across industries lead to a rise in the overall unemployment rate.

Lilien's index was defined as

$$\sigma_t = \left[\sum_{i=1}^{K} \left(\frac{e_{i,t}}{e_t} \right) (\Delta \log e_{i,t} - \Delta \log e_t)^2 \right]^{1/2},$$

where $e_{i,t}$ is employment in sector i and e_t is total employment. Figure 2 shows Lilien's sectoral employment dispersion index using employment in 11 sectors of the U.S. economy (mining, construction, manufacturing, trade, information, finance, professional services, education and health services, leisure and hospitality, other services, and government).

Because σ_t is very volatile at a monthly frequency, the figure shows a twelve-month moving average of σ_t. The figure also shows the monthly civilian unemployment rate and (since December 2000), the vacancy rate measured from the JOLTs survey. The Great Recession in the U.S. has seen a tremendous increase in the overall unemployment rate, and a parallel jump in the measure of sectoral dispersion of employment growth.

Lilien's argument that sectoral dispersion caused a rise in the natural rate of unemployment was criticized, however, in an influential paper by Abraham and Katz (1986). Abraham and Katz made two arguments. First, they noted that Lilien's measure of sector dispersion would automatically rise and fall with the business cycle if industries exhibit different sensitivities to the business cycle. Thus, Lilien's measure of dispersion potentially was correlated with the level of unemployment simply because both were moving in response to aggregate fluctuations. Second, Abraham and Katz argued that if Lilien's measure was in fact reflecting sectoral reallocations, then it should be positively correlated with vacancies, while if it was just measuring changes in the composition of output associated with aggregate demand fluctuations, then it should be negatively correlated with vacancies. Their empirical work found a negative such correlation, a correlation apparent in figure 2.

Table 1 reports regressions similar to those of Lilien and Abraham and Katz. Column 1 parallels Lilien's regression of the unemployment rate on the current and lagged dispersion index. Lilien used an estimate of unanticipated money growth to control for the aggregate business cycle; I use four lags of industrial production detrended using a linear trend. Consistent with Lilien's results, an increase in the sectoral dispersion index is associated with a rise in unemployment. But the coefficient of near one on the lagged unemployment rate and the fact the coefficient on σ_{t-1} is approximately equal but of opposite sign to the coefficient on σ_t suggests re-estimating the equation in first differences. The results of doing so are reported in column 3. Now, industrial production is negatively related to unemployment (as expected), but the sector dispersion measure continues to have a significant positive effect on aggregate unemployment.

Abraham and Katz argued that if sectoral dispersion was increasing overall unemployment, it should be associated with a rise in job vacancies because of an increase in the mismatch between workers and job vacancies. If σ_t was simply capturing aggregate business cycle effects, it should be negatively related to vacancies. Columns 2 and 4 report regressions similar to those of Abraham and Katz for the JOLTs measure of job openings in levels and first differences. The coefficient on σ_t in the levels regressions (col.

2) is negative, consistent with the earlier findings of Abraham and Katz and inconsistent with the sectoral shift story. When re-estimated in first differences, the coefficient on σ_t is statistically insignificant.

Thus, even with the large increase in Lilien's index of sectoral dispersion and the huge rise in U.S. unemployment, both variables appear to reflect the general severity of the Great Recession rather than a suggesting a causal connection running from sectoral reallocation to an increase in the natural rate of unemployment. The work by Abraham and Katz strengthened the view that business cycles were driven by aggregate fluctuations. As a consequence, it strengthened the case for aggregate, one-sector models and, implicitly, for the view that the natural rate of unemployment is relatively stable. The more recent data, and the improved job vacancy data provided by the JOLTs survey, appear to be consistent with this earlier conclusion.

However, the apparent shift during the past two years in the U.S. Beveridge Curve, , the relationship between job vacancies and unemployment, may suggest that structural shifts associated with the Great Recession have in fact affected the U.S. labor market. Figure 3 plots the Beveridge Curve for the U.S., based on the monthly civilian unemployment rate and the job openings rate from the JOLTS survey. The recent increase in the vacancy rate without a corresponding reduction in unemployment since the beginning of 2010 is suggestive of a structural mismatch between job openings and unemployment workers. The figure is based on data up through January 2011, and the final observation does suggest the Beveridge Curve may be returning to its pre-recession position.

Barnichon, Elsby, Hobjin, and Şahin (2010) have investigated the factors that have contributed to the recent shifts in the Beveridge Curve. They report (see their Table 2) that there is a 3.1% unemployment rate gap between the Beveridge Curve fitted to data from Dec. 2000 to Nov. 2007 and the average for Aug. 2010 to Oct. 2010. Decomposing this gap into the parts associated with deviations of the vacancy yield (hires per vacancy), layoffs, quits, and labor force growth, they find that a drop in hires per vacancy is by far the largest contributor to the gap. In fact, the vacancy yield itself would account for a 3.8% gap, with the net effect of lower layoffs and quits and the contribution of higher labor force growth reducing the gap by 0.7%. Figure 4 shows the marked decline in the vacancy yield since the end of the recession in 2009. The drop in hires per vacancy, reflecting a deterioration in the efficiency of the labor market matching process, is consistent with the hypothesis that there has been at least temporarily a rise in structural unemployment, itself a reflection of the imperfect mobility of labor.

The standard Mortensen-Pissarides search and matching model of the labor force assumes that total hires are a constant returns to scale function of unemployment and vacancies. This implies that the vacancy yield is a (negative) function of labor market tightness as measured by the vacancy to unemployment ratio. Using the JOLTs data up to 2009:12, I regressed the vacancy yield on a constant and labor market tightness and then generated the implied forecast for the yield in 2010. Figure 5 shows the actual yield (solid line) and the forecast from the regression (dotted line). Both the during the Great Recession contraction and during 2010, the yield has been consistently less than the level that the degree of labor market tightness would have predicted.

Imperfect labor mobility across locations, skill categories or occupations can cause an increase in average unemployment – that is, in the natural rate of unemployment – during periods of sectoral reallocations. Measures such as Lilien's dispersion index, however, seem primarily to reflect cyclical factors associated with the variations in sensitivity to the business cycle of different employment categories. The recent behavior of the Beveridge Curve for the U.S., however, hints at possible changes in the labor market that are affecting macroeconomic developments. If these developments are, in part, a reflection of the fact that resources, and particularly labor, do not adjust as quickly or as smoothly as monetary policy models assume they do, then we need to investigate the consequences that costly labor adjustment may have for macro dynamics and macro policy goals.

2.2 Resource mobility in policy models

Existing macro policy models do not provide much insight into the effects of sectoral reallocation of resources. The prototypical monetary policy model is of a one-sector, closed economy. While firms produce individual goods that are slightly differentiated from the perspective of households, it is commonly assumed that factors of production can freely and instantly be reallocated across firms. If imperfect resource mobility plays a role, it is via firm specific capital and/or investment adjustment costs. The standard assumptions about resource mobility are illustrated by the well-known Smets and Wouter (2003) model of the Euro Area. This model was one of the very first estimated DSGE models and includes many of the features that are now typical in such models. These features include sticky prices and wages, variable capital utilization, and investment installation costs, as well as a variety of shocks that produce fluctuations even with flexible wages and prices, as well as shocks that lead to inefficient fluctuations in output and inflation. However, in this model labor can move instantly from contracting to expanding firms without regard to whether the contracting firm is in Portugal or the expanding firm is in Finland. As a model of the Euro Area, the Smets and Wouter model implicitly assumes labor and capital are perfectly mobile and country specific shocks have no implications for aggregate, euro-wide behavior or for macroeconomic policy.

Investment installation costs are present in Smets and Wouter and are a common feature of other estimated policy models (e.g., Smets and Wouter 2007, Christiano, Eichenbaum, and Evans 2005, Adolfson, Laséen, Lindé, and Villani 2007, Altig, Christiano, Eichenbaum, and Lindé 2011). They are the only friction in standard DSGE models that one might associate with the idea that there are costs of reallocating resources. However, except for affecting the impact of Tobin's Q on investment demand, these adjustment costs are of second order, so they disappear from the first-order approximation to the model that is actually fit to the data. As a consequence, adjustment costs affect the behavior of the estimated model primarily through an aggregate demand channel via Tobin's Q and not through any aggregate supply effect that might limit the resources available for consumption or investment or the ability of resources to shift between firms.

Incorporating firm specific capital is a common way of allowing for imperfect mobility of capital (Woodford 2005, Sveen and Weinke 2007, 2009, Altig, Christiano, Eichenbaum, and Lindé 2011). Another way to recognize the imperfect mobility of factors of production is to introduce multiple sectors explicitly into a model, with resources unable to shift between sectors. Examples of closed economy multiple sector models with at least some resources completely sector specific include the durables and nondurables model of Erceg and Levin (2006), the model of tradeable and nontradeable goods of Monacelli (2005), and the intermediate and final goods sectors of Huang and Liu (2005). For example, in their two sector model, Erceg and Levin assume each sector has a fixed stock of capital and that workers are permanently allocated to a particular sector. Since each sector has a continuum of firms, labor resources are completely mobile within a sector but completely immobile across sectors. This is likely to affect the relative volatility of the two sectors – since expenditures on durables are more cyclically sensitive, sector specific output gaps fluctuate more than they would if resources could shift out of (into) durables and into (out of) nondurables production during aggregate contractions (expansions).

Huang and Liu (2005) also study a two sector model, thought they employ an input-output structure in which one sectors produces an input used by the other sector. In contrast to Erceg and Levin (2006), Huang and Liu assume labor is completely transferable between firms and across sectors.

Open economy models represent another class of models that are inherently multi-sector. The estimated DSGE model of Adolfson, Laséen, Lindé, and Villani (2007), for example, has a continuum of domestic firms producing a final consumption good using labor and capital. Both factors can be reallocated among firms with zero cost, while these same firms are limited in their ability to change prices. The foreign sector also produces a consumption good purchased by domestic households. de Resende, Dib, and Kichian (2010) estimate a multi-sector model of the Canadian economy. Three sectors – manufacturing, non-tradable, and commodity – are identified. Capital is sector-specific but freely transportable between firms within the sector, and new investment is subject to adjustment costs. As in Smets and Wouter, these costs are zero in the steady-state, and of second-order outside the steady state. Labor is freely mobile among firms within sectors and across sectors, though the representative household views hours worked in different sectors as imperfect substitutes.

Models of a currency union, such as those of Benigno (2004) and Galí and Monacelli (2008), assume perfect factor mobility within each member of the currency union but perfect immobility of resources across borders within the union. In both these models, optimal policy depends only on an aggregate union-wide measure of output; the distribution of output levels across member countries is irrelevant for monetary policy. Benigno (2004), for example, assumes initial holdings of interregional bonds equal zero, in which case, consumption is equalized across all member states. Since maximizing the welfare of the representative union household depends on the gap between consumption and its efficient level, and consumption is the same in all members, there is no need for monetary policy to be concerned with output fluctuations in individual countries.

A focus on aggregate output rather than sectoral output arises due to the preference structure that is common in the literature. For example, many DSGE models assume utility depends on an aggregate C_t defined as CES function of the, say, two types of consumption goods:

$$\mathcal{C}_t \equiv \left[\gamma^{\frac{1}{a}} \left(C_{1,t}\right)^{\frac{a-1}{a}} + (1-\gamma)^{\frac{1}{a}} \left(C_{2,t}\right)^{\frac{a-1}{a}}\right]^{\frac{a}{a-1}}, \, a > 1.$$

Assuming the flexible price equilibrium is efficient, welfare will depend on the volatility of $\mathcal{C}_t$ and any deviation from the efficiency composition of $\mathcal{C}_t$ in terms of the individual $C_{1,t}$

and $C_{2,t}$. These in turn would usually be specified as Dixit-Stiglitz aggregates of individual goods produced in each sector. Given this specification, the objectives of monetary policy will only involve an aggregate "*consumption gap*", reflecting deviations of $\mathcal{C}_t$ from the flexible-price, efficient level. It will not depend on the outputs of the individual sectors except to the extent that the relative prices of $C_{1,t}$ and $C_{2,t}$, or the relative prices of the individual goods that make up $C_{1,t}$ and $C_{2,t}$, differ from their efficient values. In standard models, such deviations arise as a result of sticky prices. If the degree of price stickiness differs across member states, then the monetary authority needs to stabilize union-wide inflation and variation in any inflation differentials among the different countries. Since deviations of $C_{1,t}$ and $C_{2,t}$ from their efficient values depends only on inflation, policy should depend on sector-specific inflation rates along with aggregate consumption. Only if frictions other than sticky prices or wages also lead to $C_{1,t}$ and $C_{2,t}$ being produced in an inefficient combination should aggregate policy be concerned with sectoral output fluctuations as distinct from the aggregate consumption gap.

Standard models that underlie most DSGE models used in policy analysis are based on assumptions about resource mobility that limit their usefulness for investigating the role of resource mobility in affecting macro dynamics and monetary policy. In the next four sections, I will provide some simple examples of models that incorporate aspects of labor markets that offer the potential to help understand how costs associated with the adjustment of labor markets may affect dynamics and policy objectives.

3 Costly labor adjustment

Modern macro-labor economics emphasizes that labor reallocations involve a costly process in which unemployed workers forgo income and firms with job openings forgo profits. Yet most models in the new Keynesian tradition ignore these costs and instead assume labor can be reallocated across firms instantly. So my first example is designed to illustrate how costs associated with adjusting one factor of production, such as labor, can alter both the monetary policy transmission mechanism and the welfare implications of alternative policies. Modern treatments of the labor market and unemployment in new Keynesian models have build on the search and matching framework of Mortensen and Pissarides (1994), an approach I will adopt in sections 4, 5, and 6.[1] However, the example developed

[1] Earlier examples include Walsh (2003, 2005) and Trigari (2009). See also Ravenna and Walsh (2011). Estimated DSGE models with sticky prices and search matching include ertler, Sala, and Trigari

in this section takes a simpler approach, borrowing from Lechthaler and Snower (2011) who show that incorporating quadratic costs of labor adjustment helps improve the ability of a new Keynesian model to match some standard business cycle statistics. Because a single parameter in their model measures costs associated with adjusting employment, it offers a convenient framework for illustrating how imperfect mobility of labor affects the transmission of monetary policy.

The basic model due to Lechthaler and Snower (2011) is set out in an online appendix.[2] The key assumptions are that intermediate goods producing firms face quadratic costs of adjusting their employment and final goods producing firms face quadratic costs of adjusting their price (i.e., ala Rotemberg 1983). The cost to firm i of changing its price is equal to

$$\left(\frac{\Phi}{2}\right)\left[\left(\frac{P_{i,t}}{P_{i,t-1}}\right)-1\right]^2 .$$

The resulting reduced form condition for aggregate inflation can be summarized in terms of a forward-looking Phillips curve given by

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} + \left(\frac{1}{\Phi}\right)(q_t + \mu_t) \tag{1}$$

where π_t is the inflation rate, q_t is the price of the intermediate good relative to the final good, and μ_t is a shock to the markup in the final goods sector. Equation (1) represents a first-order approximation to the optimal price setting behavior of firms around a zero-inflation steady state. The parameter Φ measures the cost of adjusting prices; the greater these costs, the less responsive is inflation to changes in real marginal cost or to the markup shock.

The second equation of the model links the price of intermediate goods with employment in that sector and is obtained from the representative firm's first order condition for employment. Lechthaler and Snower assume labor adjustment costs are equal to

$$\Psi\left(\frac{L_{i,t}}{L_{i,t-1}}-1\right)^2 Y_t, \tag{2}$$

where $L_{i,t}$ is employment at firm i, $Y_t = A_t L_t = A_t \int L_{i,t} di$ is aggregate output, and A_t is

(2008), and Sodertrom, Sala, and Trigari (2008). Blanchard and Galí (2010) focus on hiring costs. Faia, Lechthaler, and Merkl (200X) emphasize firing and hiring costs. See Galí (2011) for a survey.

[2] http://people.ucsc.edu/~walshc/mprm_appendix.pdf

an exogenous productivity variable. Since all firms are identical, the first order condition for employment takes the form

$$Q_t = \frac{W_t/P_t}{A_t} + \Psi\left(\frac{L_t}{L_{t-1}} - 1\right)\frac{L_t}{L_{t-1}} - \beta \mathrm{E}_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\Psi\left(\frac{L_{t+1}}{L_t} - 1\right)\left(\frac{L_{t+1}}{L_t}\right)^2\left(\frac{A_{t+1}}{A_t}\right), \tag{3}$$

where Q_t is the relative price of the intermediate good. The first term on the right, $(W_t/P_t)/A_t$, is the measure of real marginal cost in a standard NK model without labor adjustment costs. The second two terms arise from the existence of adjustment costs. Log linearizing this condition yields

$$q_t = (\sigma + \varphi)x_t + \Psi\Delta x_t - \beta\Psi\mathrm{E}_t\Delta x_{t+1}, \tag{4}$$

where x_t is the output gap (output relative to the flexible-price output level), σ is the representative household's coefficient of relative risk aversion and φ is the inverse wage elasticity of labor supply. In a standard new Keynesian model, $\Psi = 0$ and real marginal cost is simply proportional to the output gap. What is interesting about (4) when $\Psi > 0$ is that it illustrates directly how costs associated with adjusting employment also affect marginal cost. Faster employment growth increases adjustment costs and pushes up real marginal costs and inflation.[3] However output and employment today reduces expected adjustment costs in the future and lowers real marginal cost.

Combining (1) and (4) yields

$$\pi_t = \beta\mathrm{E}_t\pi_{t+1} + \left(\frac{\sigma+\varphi}{\Phi}\right)x_t + \left(\frac{\Psi}{\Phi}\right)\Delta x_t - \beta\left(\frac{\Psi}{\Phi}\right)\mathrm{E}_t\Delta x_{t+1} + \left(\frac{1}{\Phi}\right)\mu_t, \tag{5}$$

which shows how, when adjusting labor resources is costly, inflation is affected by the output gap, changes in the output gap, and expected future changes in the output gap. What is interesting about (5) is that it shows how it is the costs of adjusting labor relative to the costs of adjusting prices, that is Ψ/Φ, that is critical for how inflation is affected by employment growth and expected employment growth. If resources can be freely adjusted ($\Psi = 0$), one obtains a standard new Keynesian Phillips curve, with current inflation dependent on the level of the output gap (and expected future inflation).

Lechthaler and Snower (2010) calibrate their model and argue that it does a reasonable

[3] In this model, employment relative to the flexible-price equilibrium and the output gap move one-for-one with each other.

job in matching basic U.S. business cycle data. Using their parameter values, of $\beta = 0.99$, $\sigma = 2$, $\varphi = 1$, $\varepsilon = 11$, and $\Phi = 40$, Table 2 shows the standard deviations of inflation and the output gap for different values of Ψ when policy is given by a basic Taylor rule of the form

$$i_t = 1.5\pi_t + \left(\frac{0.5}{4}\right) x_t.$$

The standard deviation of the markup shock μ_t is taken set at 0.12 with a first order serial correlation coefficient of 0.96, based on Ireland (2004). Row one has $\Psi = 0$ and so corresponds to a standard new Keynesian model with no labor adjustment costs. Row two uses $\Psi = 1.85$, the value employed by Lechthaler and Snower, based on estimated by Dib (2003). Row three set $\Psi = 4$ to illustrate the effects of much larger adjustment costs.

Also shown in the Table 2 are the standard deviations of inflation and the output gap under optimal discretion and optimal commitment. Since optimal policy depends on the specification of the loss function, Table 2 employs a standard loss given by

$$L_t \equiv \Phi\pi_t^2 + (\sigma + \varphi)x_t^2. \tag{6}$$

It can be shown that this loss function is the correct second order approximation to the welfare of the representative household when $\Psi = 0$, that is, when adjustment costs are ignored as is the case in the basic NK model. Labor adjustment costs improve the trade-off between output volatility and inflation volatility, leading both σ_x and σ_π to fall as Ψ increases. The relative performance of the Taylor rule improves as Ψ increases, a finding that is confirmed by calculating the present value of the loss function under each policy.

Adjustment costs will also affect the objectives that the monetary authority should pursue. In the online appendix, it is shown that ignoring terms independent of monetary policy, the second-order approximation to the welfare of the representative household around the steady state is given by

$$-\left(\frac{1}{2}\right)\bar{U}_C\bar{Y}\mathrm{E}_t\sum_{i=0}^{\infty}\beta^i\mathcal{L}_{t+i}$$

where

$$\mathcal{L}_t \equiv \left[\Phi\pi_t^2 + (\sigma + \varphi)x_t^2 + \Psi\Delta l_t^2\right]. \tag{7}$$

Thus, the appropriate objectives of policy are also affected by Ψ. When $\Psi > 0$, minimizing the volatility of changes in employment becomes a relevant goal of policy. Interestingly, smoothing employment volatility and inflation volatility are legitimate objectives exactly to the degree that adjustment costs are nonzero.[4] Since $x_t = l_t$ in this model, we can equivalently say that both the volatility of the output gap and of changes in the output gap matter for welfare.

Figures 6 and 7 show the impulse responses of the output gap and inflation under optimal commitment and discretion. The solid line corresponds to the standard case of no labor adjustment costs $\Psi = 0$. Not surprisingly, labor adjustment costs dampen the responses of both inflation and the output gap to the markup shock. Output behaves similarly under either commitment or discretion, though it is stabilized somewhat more under discretion. Optimal commitment, in contrast, succeeds in stabilizing inflation much more.

Table 3 repeats the exercise of Table 1, but now the correct loss function (7) is used in deriving optimal policy. The responses of the output gap and inflation to a markup shock under optimal commitment and optimal discretion are illustrated in figures 6 and 7.

The specification of labor adjustment costs in Lechthaler and Snower, given by (2), gives rise to an externality that makes the private market outcome inefficient, even when prices are fully flexible. The reason for this inefficiency is that adjustment costs are proportional to aggregate output but each individual firm takes Y_t as given in deciding on their own level of employment. A decision to increase employment raises adjustment costs for all other firms. When the economy experiences a productivity shock and prices are sticky, the monetary authority faces a trade-off , even in the absence of markup shocks. The private sector adjustment is inefficient, so it is not feasible to keep inflation at zero and have output adjust efficiently. Optimal policy should allow inflation to deviate from zero to offset partially this labor adjustment inefficiency. But notice that according to (7)

[4] If $\mu_t \equiv 0$ so that the markup is constant, (5) and the loss function would imply that optimal policy would ensure $\pi_t = x_t = 0$ for all t. This might seem at odds with the fact that adjustment costs are a function of aggregate output, which individual firms take as given in chosing their employment. A social planner would take this dependence into account. The flexible-price output level is therefore inefficient, as Lechthaler and Snower (2011) show. However, in the steady state, adjustment costs are zero so as long as a subsidy is available to offset the steady-state effects of imperfect competition, the steady-state flexible price output is equal to the efficient output level. Productivity shocks will cause flex-price output and the efficient output to deviate, but the gap betwen them is of second order. If x^* is the efficient output (relative to steady state), then $x_t^2 = (x_t^* + \zeta_t)^2 = (x_t^*)^2 + \mathcal{O}\left(\| a \|^3\right)$. The connection between model specification and policy objectives is the focus of Walsh (2005b).

and (5), in the absence of markup shock, the policy authority *can* keep $\pi_t = 0$ and $x_t = 0$ for all t. That is, while there is an inefficiency due to costly labor adjustment, the linear quadratic version of the policy problem calls for keeping inflation at zero and allowing output to follow the path of the flexible-price output level, even though the latter is socially inefficient. The reason is that the distortion due to the adjustment costs is itself of second order, implying that terms involving deviations of the flexible-price equilibrium from the efficient equilibrium that appear in the welfare approximation are of order three or higher.[5] This is a consequence of the common assumptions that adjustment costs are quadratic and zero in the steady state, two assumptions that characterize the way capital installation costs are commonly modeled in empirical DSGE policy models.

Three lessons emerge from this simple example. First, costs associated with adjusting employment can have a direct impact on the firm's real marginal cost and therefore on inflation. This alters the impact of policy on both employment and on inflation. Second, the presence of real adjustment costs affects the goals of policy as reflected in social welfare. But third, even if adjustment costs generate externalities that make the private market outcome inefficient, the resulting distortion does not affect the quadratic approximation to the welfare of the representative household when, as is standard in the literature, adjustment costs (whether with respect to labor or capital) are themselves quadratic and equal to zero when evaluated at the steady state.

4 Costly search

A model with quadratic costs of adjusting employment and prices is useful for highlighting the role of adjustment costs, but as a theory of employment adjustment it is inadequate. It lacks, for example, any unemployment. Modern approaches to unemployment generally build on the search and matching approach of Mortensen and Pissarides (1994). For example, Ravenna and Walsh (2011) provide an example of how both the monetary policy transmission mechanism and the appropriate objectives of monetary policy are affected by costly labor adjustment within a search and matching framework (see also Walsh 2003, 2005a, Thomas 2008, Trigari 2009).

[5] Thus, if $\hat{y}_t^{flex}$ is flexible-price output and $\hat{y}_t^*$ is the efficient output, then $\hat{y}_t - \hat{y}_t^* = \left(\hat{y}_t - \hat{y}_t^{flex}\right) + \left(\hat{y}_t^{flex} - \hat{y}_t^*\right)$ and since $\left(\hat{y}_t^{flex} - \hat{y}_t^*\right)$ is of second order, $(\hat{y}_t - \hat{y}_t^*)^2 = \left(\hat{y}_t - \hat{y}_t^{flex}\right)^2 + 2\left(\hat{y}_t - \hat{y}_t^{flex}\right)\left(\hat{y}_t^{flex} - \hat{y}_t^*\right) + \left(\hat{y}_t^{flex} - \hat{y}_t^*\right)^2 \approx \left(\hat{y}_t - \hat{y}_t^{flex}\right)^2 = x_t^2$ up to order two.

The Ravenna-Walsh (henceforth RW) model intentionally stays as close to the standard new Keynesian model as possible, deviating only in the specification of the labor market. The model consists of households whose utility depends on the consumption of market and home produced goods, competitive firms who employ labor to produce a homogeneous wholesale good, and retail firms who transform the wholesale good into differentiated final goods sold to households. Households members are either employed or searching for a new job match. Prices of retail firms are sticky and adjust according to a standard Calvo specification.

The number of job-worker matches that produce in period t is

$$N_t = (1 - \rho) N_{t-1} + h_t, \tag{8}$$

where ρ is an exogenous separation rate and h_t is the number of new hires, assumed to be a constant returns to scale function of unemployment u_t and the number of vacancies v_t:

$$h_t = \chi v_t^{\alpha} u_t^{1-\alpha} = \chi \theta_t^{\alpha} u_t \tag{9}$$

where $\theta_t \equiv v_t/u_t$ is the measure of labor market tightness and $0 < \alpha < 1$.

To hire workers, wholesale firms must post vacancies. With free entry, the value of a vacancy must equal zero in equilibrium. This so-called *job posting condition* implies that the expected value of a filled job will equal the cost of posting a vacancy, or

$$q_t J_t = \kappa, \tag{10}$$

where J_t is the real value of a filled job, $q_t \equiv h_t/v_t$ is the probability a firm with a vacancy will fill it, and κ is the per vacancy cost of posting a job opening.

As is standard in the search and matching literature (paralleling the assumption of flexible wags in the basic NK model), assume workers and firms in a match engage in Nash bargaining so that the wage ensures the share of the joint match surplus received by the worker is b_t. Given this theory of wages and the Calvo model of price adjustment, RW show that the resulting reduced form equation for inflation can be written as

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} - \delta \left(a_1 \tilde{u}_t - \delta a_2 \tilde{r}_t - \delta a_3 \hat{b}_t \right), \tag{11}$$

where $\delta = (1 - \omega)(1 - \beta\omega)/\omega$ is the elasticity of inflation with respect to real marginal cost that is familiar in the Calvo model, where $1-\omega$ is the fraction of firms adjusting price each period.[6] Each variable in (11) is expressed relative to the (efficient) steady-state equilibrium, and the parameters a_i depend on structural characteristics of the labor market. The real interest rate has a direct impact on inflation because their is a surplus earned by ongoing job matches. An increase in the real interest rate reduces the present discounted value of these future surplus and increases the firm's labor costs. This leads to higher inflation.

In this model, efficiency requires flexible prices, a fiscal subsidy to ensure the steady-state markup equals 1; and the Hosios (1990) condition must hold ($b = 1 - \alpha$). Under these conditions, the second order approximation to welfare is

$$\sum_{i=0}^{\infty} \beta^i U(C_{t+i}) = \frac{U(\bar{C})}{1-\beta} - \frac{\varepsilon}{2\delta} U_c \bar{C} \sum_{i=0}^{\infty} \beta^i L_{t+i} + t.i.p. \tag{12}$$

where $t.i.p.$ denotes terms independent of policy, and the period-loss function is

$$L_t = \pi_t^2 + \lambda_0 \tilde{x}_t^2 + \lambda_1 \tilde{\theta}_t^2. \tag{13}$$

RW show that the weight on the output gap is exactly the same as that obtained in a standard NK model if utility is linear in hours worked.

Just as in the case of the welfare approximation obtained from the example with quadratic adjustment costs (7), a search and matching view of the labor market also implies policy makers should care about the labor market and not just inflation and the output gap. If $\kappa = 0$ so that firms can hire at zero cost, then $\lambda_1 = 0$ in (13) and one obtains the standard loss function.

To understand why labor market tightness matters, recall that utility is reduced in a standard NK model by inefficient volatility of consumption (measured by the output gap) and by inflation that generates a dispersion of relative prices. This dispersion of prices leads to an inefficient composition of consumption. That is, even if total consumption is equal to its efficient level, up to first order, the composition of consumption across individual goods is inefficient in the presence of inflation. Efficient fluctuations in hours also reduce welfare in the standard NK model because of diminishing marginal utility with

[6] The timing convention in RW is slightly different than employed here, so what I have called $\tilde{u}_t$ corresponds to $\tilde{u}_{t+1}$ in RW. Marginal cost depends on both current and expected labor marekt conditions, but R-W show how the Euler condition can be used to eliminate expected future terms to arrive at (11).

respect to leisure, but from the aggregate production function, hours can be expressed in terms of consumption so that total loss can be written solely as a function of inflation volatility and consumption (output) volatility.

The marginal disutility of working is constant in RW, but to transfer workers from home production to market production involves the matching function, which is characterized by search costs and diminishing marginal productivity with respect to labor market tightness as long as $0 < \alpha < 1$. The costs of job posting rise more when vacancies increase than they fall when vacancies decrease. Thus, volatility in vacancies relative to their efficient level reduces welfare and accounts for the separate term in labor market tightness that appears in the loss function (13).

Even if inflation is zero and market consumption is obtained through an efficient combination of the differentiated market goods, the composition of total consumption between market goods and home production can be inefficient if vacancy postings, and thus the aggregate cost of search deviate from their efficient value. This result does not hinge on the particular specification of home production or search frictions used in RW (as long as they are not linear) but simply on the fact that an alternative way of generating utility (home production) is available to unemployed agents, and this alternative does not suffer from the search friction necessary to produce matches and market consumption. Expressed alternatively, $\tilde{x}_t^2$ captures the welfare loss due to fluctuations in total consumption when households are risk averse, while π_t^2 represents losses arising from an inefficient composition of market goods, and $\tilde{\theta}_t^2$ represents losses due to an inefficient composition of market and non-market activities.

One advantage of the search and matching framework is its potential for investigating the effects of different labor market structures on macro dynamics and monetary policy. For example, one can use the model to ask how differences between U.S. and European labor markets might affect the design of optimal policy. While the U.S. and Euro Area economies differ in many ways, a very stylized comparison would highlight the lower job turnover and higher average rates of unemployment in Europe. Blanchard and Galí (2010), for example, argue that Europe is characterized by a lower separation rate and level of steady-state employment than the U.S. They suggest setting $\rho = 0.025$ to capture the lower turnover in Europe, compared to a calibration of $\rho = 0.10$ for the U.S. Over the period 1983-2007, U.S. unemployment has averaged 5.84 percent while that in the Euro Area has averaged 10.11%. Unemployment benefits tend to be more generous in Europe, with OECD evidence on average unemployment benefit replacement ratios suggesting a value of 0.54 for the U.S. and 0.65 for Euro area countries.[7] Assuming other parameters of the model are the same across the U.S. and EU versions of the model Ravenna and Walsh find that the labor market structure has a significant impact on the Phillips curve and therefore on the trade-offs faced by policy authorities. Specifically, (11) for the U.S. is

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} - 0.087\tilde{u}_t + 0.103\tilde{r}_t + e_t \tag{14}$$

while that for the EU calibration it is

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} - 0.065\tilde{u}_t + 0.845\tilde{r}_t + e_t. \tag{15}$$

There are two important differences in the inflation adjustment equations for the U.S. and EU calibrations. First, the interest rate channel on inflation is much larger in the EU calibration. Second, inflation is less sensitive to the unemployment gap under the EU calibration. Both these differences reflect the higher persistence of unemployment under the EU calibration as a result of the much lower separation rate observed in Europe. The higher degree of persistence of employment matches reduces the impact of employment on inflation. If unemployment is highly persistent, current and expected future labor market conditions move together, so the impact of current conditions on firms' labor costs are offset to some degree by the co-movement of expected future conditions. In more flexible labor markets, persistence is smaller and current unemployment conditions induce a smaller co-movement in expected future conditions.

The greater persistence of matches also explains why changes in the interest rate, which affect the present value of the match surplus, have a bigger impact under the EU calibration. When employment is more persistent, the expected discounted future labor market conditions have a bigger impact on marginal cost and therefore on inflation, so changes in the rate used to discount the future have a correspondingly larger impact on current inflation.

Figure 8 plots the responses of output, inflation, and labor market tightness to a serially correlated shock to labor's bargaining share for the U.S. and EU calibrations. The EU calibration leads to less volatility in the inflation rate and in labor market variables.

[7] This is in line with Stephen J. Nickell (1997) who reports an average replacement ratio for EU countries of 0.6 and 0.5 for the U.S. The average duration of unemployment benefits is also shorter in the U.S. than in EU countries. It is important to note that the differences between our U.S. and EU calibrations is restricted *only* to different values of the labor market parameters. Other parameters, including the frequency of price adjustment, are held constant across the two calibrations.

This greater stability is the result of two factors. First, with the EU calibration reflecting a less flexible labor market, the steady-state share of output devoted to vacancy posting costs is smaller, reducing the welfare loss from inefficient fluctuations in the labor market. This results in a smaller weight on reducing labor market fluctuations in the loss function (13). To understand why the reduction in the rate of exogenous job destruction ρ from 0.1 under the U.S. calibration to 0.025 for the EU calibration leads to greater stabilization of inflation, consider the limit as $\rho \rightarrow 0$. With no employment turnover and no vacancies, unemployment is constant, and optimal policy reduces to stabilizing the inflation rate at zero. Thus, optimal policy under the EU calibration assigns relatively more weight to achieving inflation stability than would be the case under the US calibration. Second, the effect of the interest rate on inflation is much stronger under the EU calibration, and this improves the inflation-unemployment trade-off. When matches persist with greater probability, as is the case under the EU calibration, the expected savings in future vacancy costs from having an existing match is larger, and changes in the interest rate that affect the present value of these savings have a bigger impact on the effective cost of labor. A positive bargaining shock increases inflation and increases unemployment, but reducing the interest rate to boost employment through the standard demand channel also acts to significantly reduce inflation through its direct effect on labor costs, improving the inflation-unemployment trade-off.

This second example, focusing on search frictions in the labor market, again illustrates that frictions associated with labor mobility – in this case, the ease with which workers can transition between unemployment and employment – affects the dynamics of the economy's responses to shocks but also the appropriate objectives that optimal policy makers should pursue.

5 Skill heterogeneity and monetary policy

Figure 1 illustrated that employment declines during the Great Recession in the U.S. were felt unevenly across occupational sectors. One consequence of this shift in employment patterns is that it causes changes in the skill composition of the unemployed. If job growth returns but occurs in sectors that differ in their skill needs or location than characterized the sectors and locations that lost jobs during the recession, there can be a mismatch between vacancies and workers (Shimer 2007). Such a mismatch could account for the decline in hires per vacancy reported by Barnichon, et. al (2010).

Ravenna and Walsh (2010) examine the effects of skill heterogeneity in a new Keynesian model to assess the impact that changes in the composition of the pool of unemployed workers has on employment dynamics. In their model, workers are either of high-skill or low-skill. Firms post vacancies and are randomly matched with unemployed workers. For simplicity, assume high skill workers are sufficiently productive that they are always hired whenever they meet a firm with a vacancy. Low-skill workers are drawn from a distribution of skill levels, and firms will only hire those whose productivity exceeds a critical cutoff level. Thus, low-skill workers may find a firm with a vacancy but may be screened out and not hired. Think of the standard matching function determining the number of interviewers that occur, with the number of workers actually hired being less than or equal to the number of interviews. Thus, the hiring rate, which is equal to one in a standard matching model, will be less than one as some low-skill workers obtain interviews but are not hired.

Assume a fraction $1-\rho_t^n$ of type l (low skill) workers receive productivity levels that exceed the time t cutoff level $\bar{a}_t$ necessary to generate a positive job surplus. New hires H_t are given by the number of interviewees who are high skill, all of whom are hired, plus the number of interviewees who are low skill times the fraction of these with productivity levels that exceed $\bar{a}_t$. If k_t^w is the probability an unemployed workers gets an interview and the fraction of low-skill workers among the unemployed is γ_t, then new hires will equal

$$H_t = (1-\gamma_t)k_t^w U_t + (1-\rho_t^n)\,\gamma_t k_t^w U_t = (1-\rho_t^n\gamma_t)\,k_t^w U_t,$$

where U_t is the number of unemployed. Note that fewer workers are hired than are interviewed: $H_t = (1-\gamma_t\rho_t^n)\,k_t^w U_t < k_t^w U_t$. The probability a randomly selected unemployed worker is screened out in the interview process (i.e., actually gets interviewed with a firm but has productivity less than $\bar{a}_t$ and so is not hired) is $\gamma_t\rho_t^n$. In standard matching models, new hires equal $k_t^w U_t$. Screening implies new hires are less than this level and depend on the average skill quality of the pool of unemployed workers γ_t and the aggregate productivity level which will affect $\tilde{a}_t$ and therefore ρ_t^n. The job finding probability, $H_t/U_t = (1-\rho_t^n\gamma_t)\,k_t^w$ depends on the skill composition of the unemployed and on the distribution of productivity across unemployed workers.

In a recession, the cutoff productivity level $\bar{a}_t$ that determines whether a firm would hire (or retain) a low skill worker rises, and low skill workers are laid off. This changes the composition of the pool of unemployed workers, lowering the average skill level of the unemployed. Combined with the rise in the cutoff productivity level necessary for a firm to hire a low skill worker, fewer vacancies result in hires.

A firm that posts a vacancy is also more likely to interview a low skill worker, reducing the probability of forming a match, and reducing the expected surplus from a match. Let k_t^f be the probability a firm with a vacancy meets a worker to interview. With wages determined by Nash bargaining and the worker's share equal to η, the job posting condition for the firm takes the form

$$k_t^f(1-\eta)\left[(1-\gamma_t)s_t^h+\gamma_t\int_{\bar{a}_t}^1 s_{i,t}^l f(a_i)da_i\right]=\kappa, \tag{16}$$

where s_t^h is the surplus from a match with a high-skill worker, $s_{i,t}^l$ is the surplus of a match with a low-skill worker, $f(a)$ is the distribution of skill levels, and κ is the cost of posting a vacancy. With $s^h > s^l$, a rise in γ_t – that is, a shift in the composition of the unemployed to low-skilled workers – reduces the incentive to post new job vacancies. The vacancy yield rate falls. All unemployed workers are less able to gain interviews and be rehired.

The direct composition effect can be illustrated through the dynamic behavior of the job finding probability. The probability of finding a job for a low-skill worker depends only on the interviewing rate k_t^w and on the endogenous separation rate ρ_t^n. Both will fall in a recession, so the job finding probability falls by more (and the unemployment duration increases by more) for a low-skill worker than for a high-skill worker. Thus, the unconditional probability that an unemployed worker enters into a match falls by more when the unemployed pool worsens. The top panel of figure 9 shows the behavior of the unconditional worker job finding probability. The unconditional probability falls in part because both job finding probabilities fall for both worker types, but it also falls because fraction of low-skill workers in the unemployment pool increases as these workers swell the pool of unemployed. The figure is based on EU calibration discussed in Ravenna and Walsh (2010).

The presence of heterogenous skills among workers also implies that a firm with a low-skill worker may terminate the match in hopes of finding a high-skill replacement. This leads to an increase in worker reallocation. Additionally, some low-skill applicants who are interviewed are not hired since the firm does not wish to forego the opportunity of finding a high-skill worker if the position is kept open. Both these margins are affected as the composition of the pool of job seekers changes. In a recession, the quality of the unemployment pool deteriorates, and this reduces the likelihood a firm will find a high-skill worker to hire. The composition effect then dampens the incentive to terminate existing low-skill matches and helps limit the inflow to unemployment. At the same time, by reducing the incentive to post vacancies, the composition effect acts to reduce the outflow from unemployment. In equilibrium, unemployment composition changes will impact employment flows, and the ratio of the duration of unemployment spells between high and low-skill workers.[8]

Finally, screening has a negative externality on other firms. Since an individual firm hires with a higher probability a high skill worker it interviews compared to a low skill worker, a decision by the firm to hire tends to deteriorate the average skill level of the pool of unemployed, making it less likely other firms will successfully fill vacancies.

6 Labor mobility, sectoral shocks, and monetary policy

So far, my examples have focused on costly adjustment of homogenous labor, search costs associated with moving between employment and unemployment, and worker skill heterogeneity that captures a form of resource immobility in that low skill workers cannot be transformed into high skill workers. None of these examples capture the notion of sectoral reallocations that were discussed in section 2 and that are of concern in the U.S. Nor could they address issues of policies such as those in a currency union where imperfect labor mobility results in segmented economies sharing a common monetary policy. These issues are more naturally thought of within the context of multi-sector models where resources cannot flow easily across sectors due to their specificity. Macro models almost exclusively rely on aggregate shocks to generate aggregate fluctuations, in part on the assumption that while sectoral shocks are undoubtedly important, the law of large numbers suggests that independent sector-specific shocks will tend to cancel out at the aggregate level. However, as Horvath (1998, 2000) demonstrated, this may not be the case, and because sectoral shocks require adjustments in relative prices, there may be implications for aggregate inflation and therefore for monetary policy.

[8] The composition effect and incentive effect may work in opposite direction. Assume a marginal increase in the share of h-workers in the labor force. The composition effect will drive down the unconditional job finding probability: there is less churning of workers since the share of employed workers who can separate endogenously is smaller. The incentive effect though may drive up the unconditional job finding probability, since the likelihood that an open vacancy will be filled with a high skill worker increases, leading possibly to a higher endogenous separation rate.

Discussions of sector reallocation and the labor market often focus on the potential mismatch between the job skills of the unemployed and those needed to fill job openings (Shimer 2007). In this section, I want to sketch a model that incorporates sector specific shocks and captures in a simple way the idea that workers who lose jobs in one sector may, because of skill or locational reasons, not be good matches with job openings that might exist in another sector. The basic model has two sectors, assumed to be identical in a symmetric non-stochastic steady state. The labor market not sector specific, but a firm in sector s that hires a worker last employed in sector $k \neq s$ faces higher management and/or training costs in hiring the worker than if the worker had last been employed in the firm's own sector. One consequence of this is that the incentives for firms to post vacancies will be affected by the composition of the pool of unemployed workers. A contraction in one sector swells the pool of unemployed, but the incentives for firms in the other sector to post vacancies is reduced because they know they are more likely to be matched with a worker who initially generates a smaller surplus. While I will focus on how this structure effects the dynamic response of the aggregate economy to sector specific shocks, it should also be recognized that the model has implications for policy objectives as well. Since individual firms take the composition of the unemployed as given, there are externalities in addition to the standard ones arising in search and matching models. A firm in sector s that hires a worker last employed in sector s both reduces the probability another firm in the same sector will make a match (by reducing the number of unemployed workers) and reduces the expected surplus from a match (by affecting the composition of the unemployed).

The details of the model are provided in an online appendix.[9] I follow Thomas (2008) in dropping the standard dichotomy between perfectly competitive intermediate goods producing firms that hire labor via a matching process and imperfectly competitive firms selling final goods and whose prices are sticky. Instead, there are a continuum of goods producing firms that produce differentiated final goods that are imperfect substitutes from the perspective of households, hire workers, and have sticky prices. Labor is firm specific. As with models of firm specific capital subject to adjustment costs (Woodford 2005, Sveen and Weinke 2007, 2009), making labor firm specific affects the sensitivity of inflation to movements in output. The contribution of the model is to extend Thomas's model to two sectors and to employ a new matching function that allows hiring costs to

[9] http://people.ucsc.edu/~walshc/mprm_appendix.pdf

depend on the composition of the unemployed.

The sectors are denoted 1 and 2. The key aspect of the model is the matching function. Standard models assume that new hires are a function of aggregate unemployment and the aggregate number of job openings. Assume instead that the number of matches (hires) in sector s is equal to,

$$M_t^s = (v_t^s)^a \, u_t^{1-a} g(\lambda_t^s); \; g' \geq 0, \tag{17}$$

with $\lambda^s \equiv u^s/u$ equal to the fraction of the unemployed who last worked in sector s. Given the number of vacancies in the sector and the total number of unemployed, the number of matches actually successfully made is increasing in the fraction of the unemployment with sector appropriate skills (measured by sector of last employment). Sector s matches can be written as

$$M_t^s = (v_t^s)^a \, u_t^{1-a} g(\lambda_t^s) = (v_t)^a \, u_t^{1-a} g\left(\lambda_t^s\right) \left(\frac{v_t^s}{v_t}\right)^a,$$

total matches are

$$M_t = M_t^1 + M_t^2 = (v_t)^a \, u_t^{1-a} \left[g\left(\lambda_t^1\right) \left(\frac{v_t^1}{v_t}\right)^a + g\left(\lambda_t^2\right) \left(\frac{v_t^2}{v_t}\right)^a \right],$$

and the probability a firm with a vacancy in sector s fills a job opening is

$$q_t^s = \frac{M_t^s}{v_t^s} = \frac{(v_t)^a \, u_t^{1-a} g\left(\lambda_t^s\right)}{v_t^s} \left(\frac{v_t^s}{v_t}\right)^a = \theta_t^{a-1} g\left(\lambda_t^s\right) \left(\frac{v_t^s}{v_t}\right)^{a-1} \tag{18}$$

where $\theta_t = v_t/u_t$ is the aggregate measure of labor market tightness. The matching function (17) captures in a simple manner the idea that the hiring yield in a sector rises if more of the unemployed have recently worked in that sector. I assume that, when log-linearized around the steady state,

$$\hat{q}_t^s = (a-1)\hat{\theta}_t^s + (1-\zeta)\hat{\lambda}_t^s; \; 0 < \zeta \leq 1.$$

The profits of firm j in sector s are

$$\left(\frac{P_{j,t}^s}{P_t}\right) C_{j,t}^s - w(h_{j,t}^s) N_{j,t}^s - \kappa v_{j,t}^s - \Phi_t^s H_{j,t}^s, \tag{19}$$

where it's price is $P^s_{j,t}$, its output is $C^s_{j,t}$, $N^s_{j,t}$ is its number of employees, $w(h^s_{j,t})$ is the wage schedule as a function of hours worked per employee, $v^s_{j,t}$ is the number of job openings, κ is the cost per period per opening, $H^s_{j,t}$ are new hires and Φ^s_j is the cost per hire. The including of hiring costs is the second modification to the model, and, again expressed in terms of the log-linearized form of the model, I assume

$$\hat{\phi}^s_t = \epsilon\hat{\lambda}^{k\neq s}_t$$

to capture the idea that an increase in the share of the unemployed who last worked in a sector other than s increase the firm's costs of hiring.

The rest of the model is fairly standard. Wages are Nash bargained, with hours chosen to maximize the joint surplus. Labor is specific to each firm; this affects the optimal pricing decision of firms when they do adjust prices. In contrast to the models of the previous two sections, I allow for adjustment along both the intensive (hours) margin and the extensive (worker) margin. For each sector, the linearized condition for inflation takes the form

$$\pi^s_t = \left(\frac{\kappa^s}{1+\bar{\eta}^s}\right)[\widehat{mc}^s_t + (p_t - p^s_t)] + \beta \mathrm{E}_t \pi^s_{t+1},$$

where π^s_t is inflation in sector s prices, p^s_t is the sector s price index, p_t is the aggregate (CPI) price index, $\widehat{mc}^s_t$ is real marginal cost in sector s, and κ^s and $\bar{\eta}^s$ are sector specific parameters. The first, κ^s is the standard elasticity of inflation with respect to real marginal cost; the second $\bar{\eta}^s$ arises from the specificity of labor. Given that firms can adjust along the intensive (hours) margin, real marginal cost is equal to is

$$\widehat{mc}^s_t = (\sigma+\eta)\hat{y}_t - (1+\eta)\hat{a}_t - \eta\hat{n}_t,$$

where σ is the coefficient of relative risk averse and η is the inverse of the hours labor supply wage elasticity characterizing the representative household.

Calibration is standard for most parameters: $\beta = 0,9967$, $\sigma = 2$, $\eta = 3$, the elasticity of demand faced by individual firms is 7.67 implying a steady state markup of 1.15. The Calvo parameter for price adjustment is set at 0.78 and $a = 0.6$ with the Hosios condition for efficient matching imposed. The exogenous separation rate for matches is set at 0.10 and the steady-state job filling probably equals 0.7, a common value in the literature although too low based on the evidence of Davis, R. Jason Faberman, and Haltiwanger

(2009).[10]

To represent monetary policy, I assume a standard Taylor rule of the form

$$i_t = 1.5\pi_t + \left(\frac{0.5}{4}\right) y_t,$$

where y is aggregate output.

Figure 10 shows the response to the economy in the face of an aggregate productivity shock that affects both sectors. the solid line shows the responses when $\zeta = 1$, the steady-state hiring cost $\Phi = 0$, and $\epsilon = 0$, corresponding to a standard matching model with job posting costs but no hiring costs and the probability of filling a vacancy depending only on aggregate unemployment and vacancy levels. As is common in sticky price models, a positive productivity shock reduces labor demand as output is demand determined. The dashed line shows the impulse responses when hiring costs and spillover effects on vacancy yields are present ($\zeta = 0.25$, $\Phi = 1$, and $\epsilon = 2$). Since the two sectors are calibrated to be symmetric, they respond identically to an aggregate shock so only aggregate variables are shown in the figure.

Consistent with the simple quadratic cost model, adding labor adjustment costs beyond the standard job posting cost tends to dampen the movement of employment and unemployment. Hours, though, respond more to the aggregate productivity shock than in the baseline case. This occurs as the additional adjustment costs only affect the firm's labor choice at the extensive margin and so adjustment along the intensive margin becomes more prominent.

Now consider an asymmetric negative productivity shock that affects only sector one. The impulse responses of hours and employment in the two sectors are shown in figure 11. As in the previous figure, the solid line represents the case in which only job posting costs are present. Hours in the sector experiencing the negative productivity shock, sector one, rise immediately to offset the fall in labor productivity. Employment also rises. Both hours and employment also rise in sector two as the price of sector one output rises relative to sector two and demand shifts in favor of sector two.

The dashed lines show the impulse responses in the face of hiring costs and the

[10] den Haan, Ramey, and Watson (2000) cite data from Davis, et.al. (1996) to calibrate q at 0.71. Cooley and Quadrini (1999) and Walsh (2005) also set $q = 0.7$. Davis, R. Jason Faberman, and Haltiwanger (2009) estimate a daily job-filling probability of around 5 percent. Assuming an average of 26 working days per month, or three times that per quarter, a daily rate of f would imply the probability a vacancy is filled over a quarter to be roughly $1 - (1 - f)^{3*26} = 0.98$.

hiring yield depend on the composition of unemployment. As expected, in sector one more of the adjustment is in the form of hours, less along the extensive margin. The effects of costly labor adjustment are more pronounced in the sector not experiencing the productivity shock. Employment actually falls eventually in this sector. The reason for this effect is probably more instructive about the model than about actual labor markets. As firms in sector one expand employment to compensate for the fall in productivity, the inflow to unemployment shifts to become increasingly from sector one. This is a result of the exogenous separate rate that is the only source of an inflow to unemployment in this model in which endogenous separation is absent. Consequently, this change in the composition of the pool of the unemployed makes hiring more costly for firms in sector two. Job openings and employment in sector two fall.

The model of this last section is the least developed of my four examples illustrating the effects of moving away from standard assumptions that allow labor to be costlessly shifted among firms and across sectors. It does, however, provide a further illustration of how macro dynamics can be dependent on the costs associated with labor market adjustment.

7 Summary

When economists discuss globalization, it is usually in terms of the increasing mobility of capital and the international integration of financial and goods markets. Less frequently discussed are the consequences of imperfect labor mobility, the topic that has been the focus of this paper. Standard models that assume perfect labor mobility cannot capture the effects that sectoral shifts, mismatches between worker skills or locations and new job openings, or changes in the ability of labor to move within a monetary union may have for macroeconomic dynamics.

I have provided four examples of models in which there are costs in shifting labor resources among alternative uses. In all four cases, I show how the costs associated with labor adjustment affected the dynamics of the model economy. In two of the cases, I showed how these costs also affected the objectives that should guide the implementation of monetary policy. These examples illustrate that the factors that affect the mobility of labor may be important for macro dynamics and for policy objectives. They are also important therefore for designing monetary policy. These general conclusions will apply to other factors of production and to other situations in which there are costs of adjustment.

While the past sixty years have seen a tremendous expansion in the ties that link economies together, and the ability of resources to move globally, factor specificity and skill and locational specialization mean that labor, arguably the most important resource, is not as mobile as is typically assumed in macroeconomic models. However, while adjustment costs are important for understanding macro dynamics, their implications for policy objectives is less clear. Limitations on mobility may or may not give rise to economic distortions. These distortions may or may not be relevant for monetary policy objectives.

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Table 1

U.S. Unemployment and Vacancy Rate Equations: Monthly 2000:12-2010:09

	$z_t = \bar{c} + a_0\sigma_t + a_1\sigma_{t-1} + b_1 z_{t-1} + \sum_{i=1}^{4} c_i ip_{t-i}$		$\Delta z_t = \bar{c} + a_0\Delta\sigma_t + \sum_{i=1}^{4} c_i \Delta ip_{t-i}$	
	Unemployment rate	Vacancy rate	Unemployment rate	Vacancy rate
a_0	0.31^{**}	-0.16	0.24^{**}	-0.04
a_1	-0.29^{**}	0.09		
b_1	1.01^{**}	0.82^{**}		
$\sum_{i=1}^{4} c_i$	0.01	-0.00	-0.17^{**}	0.06^{*}

** Significant at the 5% level; * Significant at the 10% level.

Table 2: Effects of Ψ: Fixed loss

	Taylor rule		Discretion		Commitment	
Ψ	σ_x	σ_π	σ_x	σ_π	σ_x	σ_π
0	4.57	1.73	3.44	3.44	4.74	0.49
1.85	2.35	0.89	2.08	1.76	2.38	0.16
4.0	1.50	0.56	1.44	0.80	1.50	0.08

Table 3: Effects of Ψ: Welfare loss

	Taylor rule		Discretion		Commitment	
Ψ	σ_x	σ_π	σ_x	σ_π	σ_x	σ_π
0	4.57	1.73	3.44	3.44	4.74	0.49
1.85	2.35	0.89	2.21	1.18	2.37	0.17
4.0	1.50	0.56	1.47	0.46	1.49	0.09

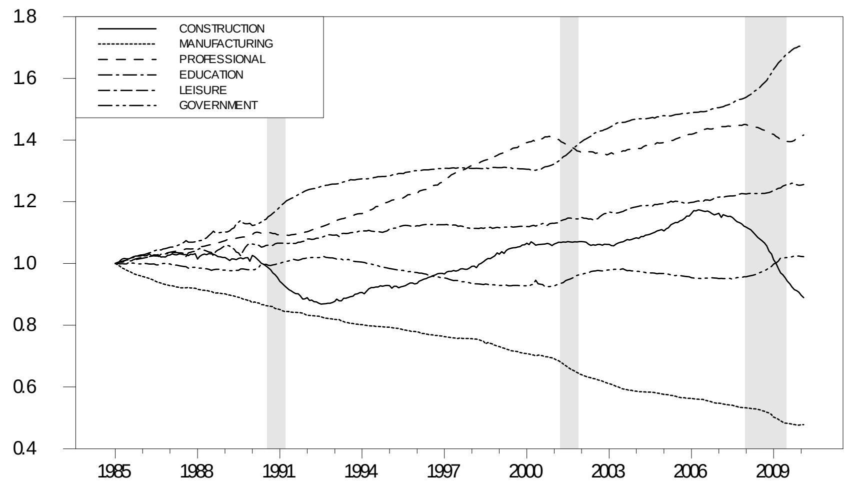

Figure 1: Employment shares in construction, manufacturing, professional and business services, educational and health services, leisure and hospitality services, and government (1985:1 = 1). These sectors account for just under 70% of U.S. total employment. Shaded regions denote NBER business cycle recessions.

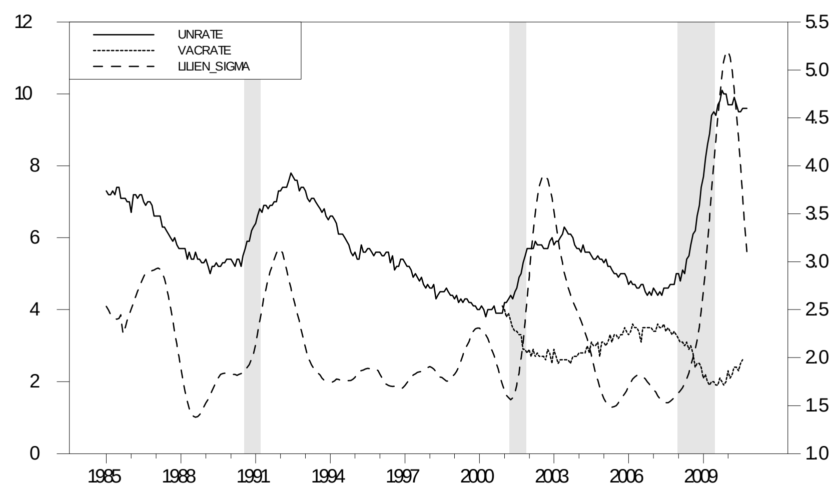

Figure 2: The civilian unemployment rate, the vacancy rate, and sectorial dispersion (right scale); monthly, U.S. data, 1985:1-2010:1. The dispersion measure is a 12-month moving average.

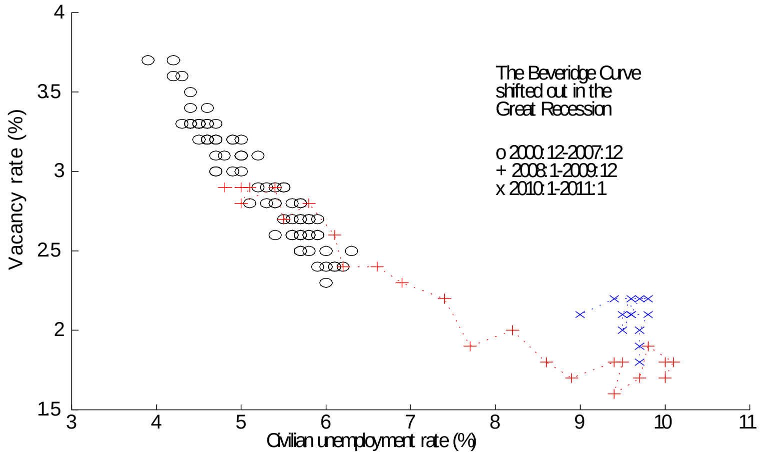

Figure 3: The U. S. Beveridge Curve

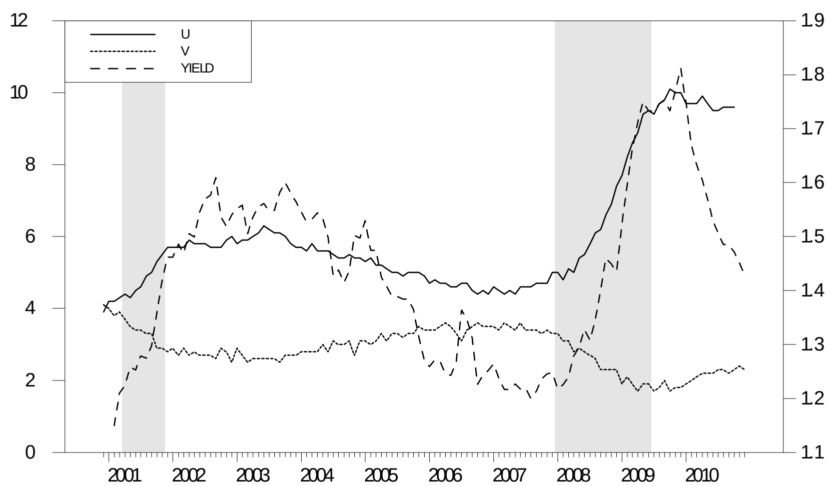

Figure 4: The U.S. unemployment rate, the vacancy rate, and the hiring yield (right scale).

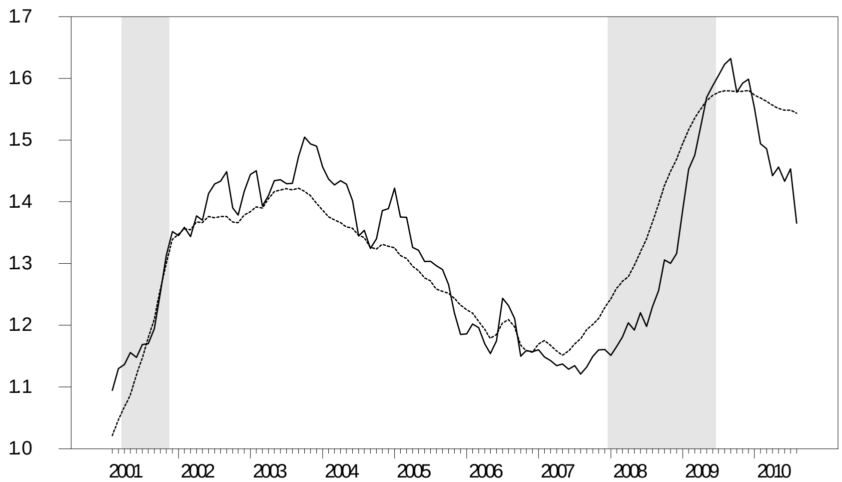

Figure 5: The hiring yield and forecasted yield based on labor market tightness (V/U). Forecast obtain from an OLS regreesion of the yield on a constant and V/U, 2000:12 - 2009:12.

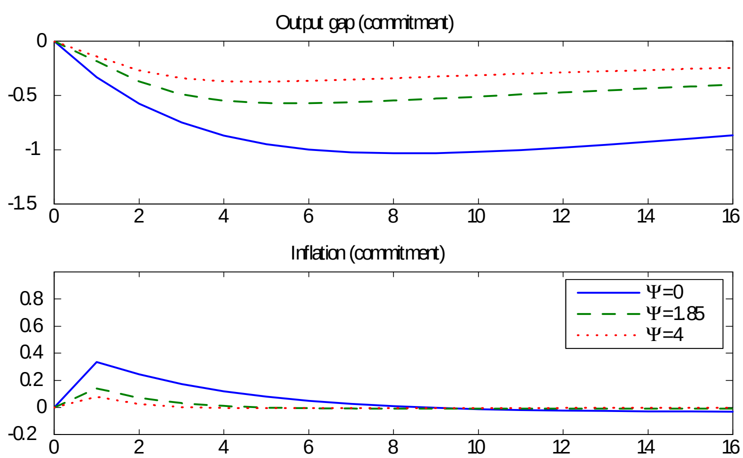

Figure 6: Optimal response under commitment to a markup shock in the quadratic costs of adjustment model.

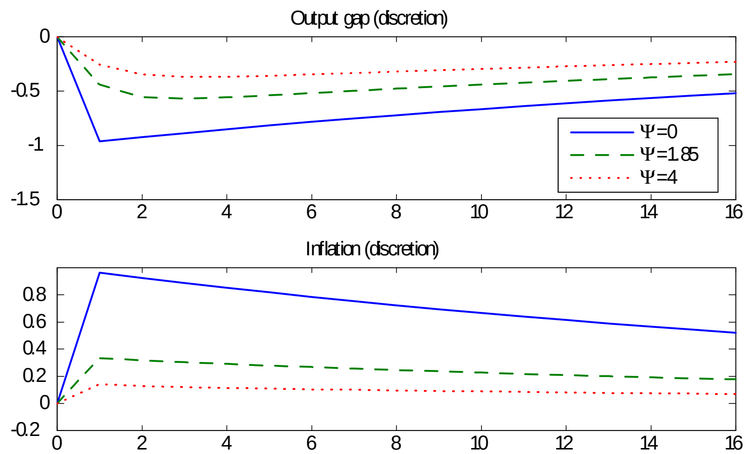

Figure 7: Optimal response under discretion to a markup shock in the quadratic costs of adjustment model

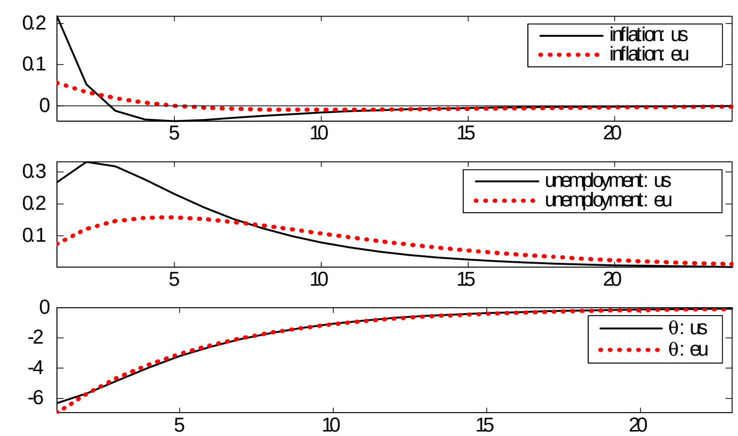

Figure 8: Responses to a one standard deviation bargaining shock for U.S. (solid line) and EU (dotted line) calibrations. (π and θ scaled in percentage point deviations from steady state; unemployment scaled as percentage points of total labor force).

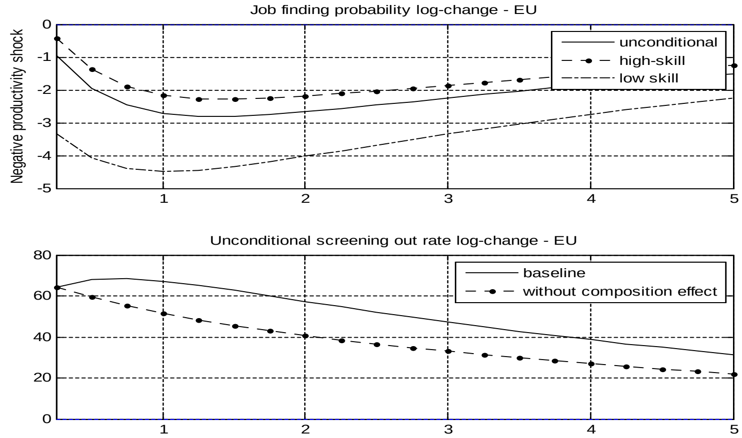

Figure 9: Skill heterogeneity: response to a negative productivity shock: Job finding and screening rates

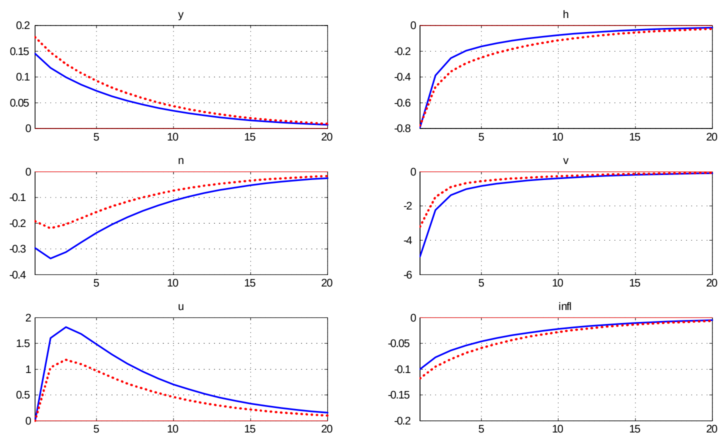

Figure 10: Impulse responses to a serially correlated productivity shock to both sectors.

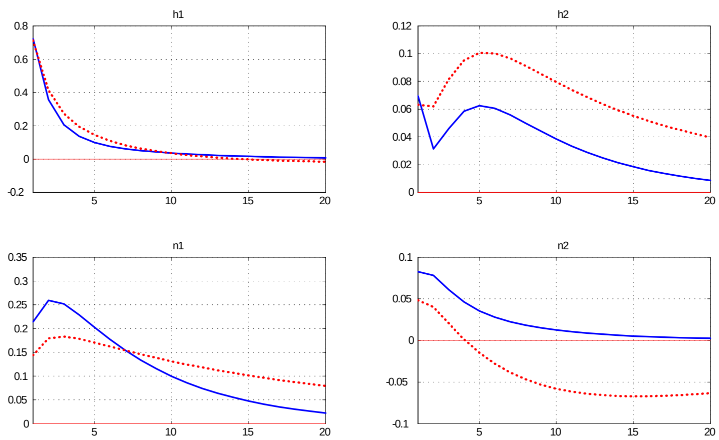

Figure 11: Impulse responses of hours and employment to a negative productivity shock only to sector 1.