# UNEMPLOYMENT AND PRODUCTIVITY OVER THE BUSINESS CYCLE: EVIDENCE FROM OECD COUNTRIES

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**Abstract**

This paper examines the low correlation between cyclical productivity and unemployment: from significantly negative before 1980's, it has switched sign in several OECD countries and became positive. By using a New Keynesian model with sticky prices, search frictions and variable effort, I find that in the U.S. technology shocks can generate positive correlation between productivity and unemployment, while in Europe non-technology shocks generate the same effect. My results suggest that the increase in size of technology shocks and the reduction of the procyclicality of productivity after a non-technology shock in the U.S. can account for changes in correlation. On the other hand, aggregate demand shocks have gained weight in Europe in the last 20 years and explain the positive sign in the unemployment-productivity correlation in these economies.

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# 1 Introduction

Since the seminal work of Galí (1999), where he pointed out the almost-zero unconditional correlation between productivity and unemployment, there has existed a debate on whether Real Business Cycle models can account for the cyclical fluctuations of these variables in the economies, especially the U.S and developed countries.

In particular, there has been certain criticism in the empirical properties of Search Models. These models (Mortensen & Pissarides, 1994) predict that labor productivity and employment should be positively correlated. There, changes in productivity produce shifts in labor demand, leading to a reduction in the level of unemployment of the economy. The effect is summarized as follows: an increase in productivity increases the surplus of the worker-firm match. This extra surplus motivates firms to post more vacancies as the demand of labor is increased, and consequently, as vacancies are filled, unemployment in the economy is reduced.

This master thesis tries to provide the literature with estimates of these relationships for a larger sample of OECD countries than the US for which quarterly data on both unemployment and employment, productivity, total hours and vacancies is collected and report the results. The analysis will also be replicated for a larger group of countries drawn from the Total Economy Database of the Conference Board.

Initially, I describe the sources of the data and time period covered. I have estimated the correlation of cyclical fluctuations between productivity, unemployment, employment, vacancies, and vacancies unemployment (v-u) ratio. As a remarkable finding, correlation in the US has switched sign in the mid 1980's: from being -0.45 between 1970 and 1984, in the last 20 years it has increased an exhibits a correlation of 0.07. This result is not isolated for the US, and it is also present in UK, Sweden or Spain. In fact in Spain, it is significantly positive for all the 40 years covered, resulting in a strong correlation coefficient after 1984. By performing a graphical analysis of the evolution of these cyclical components in each of the economies , the sign of the correlation can be more easily identified.

Changes in correlation might be the result of the counteracting effects of technology and non-technology shocks in the economy. By performing a bivariate VAR for productivity and unemployment in the countries chosen, I can account for the effect of technology and non-technology shocks on the previous labor market measures. In the U.S., a technology shock, which is assumed to have a permanent effect on productivity, increases unemployment temporarily, generating a positive correlation between these two variables. On the other hand, a non-technology shock, while increasing productivity, decreases unemployment, generating a negative correlation. In Europe, the effects of both shocks are opposed to the U.S. scenario. A non-technology shock is responsible for generating a positive correlation between productivity and unemployment, while a technology shocks results in a negative correlation.

In order to provide an explanation to these facts, I present a New Keynesian model as in Barnichon (2010) with three important elements: sticky prices, variable hours and effort, and search frictions. I have calibrated this model for the U.S. as well as for other OECD countries, and I present the matching of the model and the data for these economies. While the model is able to replicate quite accurately the impulse response from the data in the U.S., it is not very successful in matching the European empirical evidence. By simulating 40 years of data, I can account for more than 50% of the change in correlation in the U.S. and Sweden, but in Germany or Spain it is again away from the data. As a result, I can conclude that technology shocks have increasing importance in the U.S. given that they generate the positive correlation between productivity and unemployment. Therefore, the size of non-technology shocks with respect to technology shocks in the U.S. might have reduced after 1984.

In Europe, where the model fails to replicate the impulse response of the data, aggregate demand shocks are the driving force of the positive correlation observed after 1984. In fact, by examining impulse responses after 1984 for the U.S., the cyclical response of productivity to non-technology shocks has became less negative, approaching the effect observed in Europe. This also provides an explanation besides the relative increase in the size of technology shocks of why correlation between productivity and unemployment has increased.

Although limited, the empirical work that has accounted for the relationship between unemployment and productivity, has also recognized the low correlation found in the data and highlighted the existing criticisim to business cycle models. Shimer (2005) sustains that the Pissarides model cannot account for the volatility of labor market variables as observed in US data. Galí and Gambetti (2009) report a decline in the correlation between total hours in productivity starting in the 1980's. Moreover, Barnichon (2010) defends that in the U.S. the low correlation between cyclical unemployment and productivity hides a large sign switch in the mid-1980's: from significantly negative the correlation became significantly positive over the business cycle. His claim is that some structural changes can account for the vanishing procyclicality of labor productivity starting in the 1980's: increasing hours per worker elasticity and a more flexible labor market. These changes, together with the fact that volatility of employment has increased relative to the volatility of output but has decreased relative to hours, are Barnichon's argument against RBC theories. However, his analysis is reduced to a single country, the US, and it is not performed in other economies in order to test its generality. My contribution, therefore, lies in the extension of this analysis to a larger number of countries, such that this relationship can be further investigated.

Regarding the structure of the paper, in section 2 I provide a description of the data used, descriptive statistics, and I present the correlation between productivity, unemployment, employment, vacancies and v-u ratio for OECD as well as Latin American countries. In section 3, I present the empirical approach and the model. In section 4 I provide a comparison of the responses of the model and the data and the main findings. Finally in section 5 presents my conclusions of the topic.

## 2 Data description

In order to test whether search models can account for the correlations implied by the data and to be able to compare cross-countries differences, I will first start by describing the different sources of my data set. I will also develop a descriptive analysis of some of the variables of the data set to illustrate the labor market differences across countries, and finally some evidence on correlations between productivity, employment and unemployment will be presented. This will be the starting point for the rest of the paper, as heterogeneity across countries provides a rationale for the study of the behavior of these variables over the cycle.

### 2.1 Data sources

This paper is mainly focused on a quarterly analysis of the labor market outcome, although some yearly basis results are presented.

Firstly I will describe the sources chosen for the quarterly analysis. The countries selected for this purpose are Australia, Canada, France, Germany, Italy, Japan, Norway, Portugal, Spain, Sweden, United Kingdom and United States. Quarterly data on GDP, employment, unemployment, hours worked, vacancies and other variables of interest is compiled from the OECD. In order for results to be as much comparable and reliable as possible, I tried not to used a different source unless it was necessary. Hence, the following data were not available in the OECD database, and I obtained them from the indicated sources: vacancies from the US and Canada is the Help-Wanted Index (from JOLTS and Statistics Canada, respectively); unemployment in France comes from the INSÉE (National Institute of Statistics and Economic Studies). Unemployment Rate in Spain is obtained from the INE, and GDP in Sweden is available since Statistics

Sweden covers the whole period (in the OECD database started in 1993). The selection of countries is based also on this issue, as it is difficult to find series that cover long time spans (1970-2010) even for countries of the OECD. Therefore the time period has to be reduced in some of them due to unavailability of certain variables.

Following the definition of each variable in the OECD database, unemployment is the harmonized unemployment level, seasonally adjusted series from the Labor Force Statistics (MEI). The unemployment rate is defined as the level of unemployed in the economy divided by the labor force of the country, this is, the employed and the unemployed. The employment level is also from the Labor Force Statistics (MEI) database of the OECD, and it is seasonally adjusted. In this paper I use two different definitions of productivity. The first one is GDP per employee as a natural measure of productivity. However, as I want my results to be comparable to those in Barnichon (2010) for the US. I need to construct a series for productivity in terms of output per hour. Hours worked is not available at the quarterly level, so I imputed a value for output per hour using productivity per hour annually, as well as production and GDP/Employment, available at a quarterly frequency. In order to check the robustness of this imputation I compare the resulting series for the US with the quarterly productivity per hour series available at the BLS and extend the imputation for the rest of countries.

Secondly, I have also constructed an annual database starting in 1950 for a larger set of countries, so I could perform my analysis in developing countries, as well as compare the results available at a quarterly frequency level with those at an annual level. Data on GDP, hours worked, employment, productivity per hour, and productivity per worker is drawn from the Total Economy Database (TED) from the Conference Board, and data on unemployment from the OECD. Due to the unavailability of unemployment data prior to the 1990's for Latin American countries, I have performed a partial analysis for Argentina, Brazil, Peru, Chile and Mexico. I have also analyzed the previous OECD countries with annual data, in order to ensure that my results are not driven by short-term fluctuations.

## 2.2 Descriptive Statistics

The sample periods are 1970I-2010IV for the US, 1971I-2010IV for the UK, 1972III-2010IV for Spain, 1970I-2010IV for Sweden, 1983II-2010IV for Portugal, 1972I-2010IV for Norway, 1970I-2010IV for Japan, 1970I-2010IV for Italy, 1970I-2010IV for Germany, 1970I-2010IV for France, 1970I-2010IV for Canada and 1970I-2010IV for Australia.

Table 1: Time covered by country

| Country | Starting Quarter | Last Quarter |
|---|---|---|
| U.S | 1970I | 2010IV |
| U.K. | 1971I | 2010IV |
| Spain | 1972III | 2010IV |
| Sweden | 1970I | 2010IV |
| Portugal | 1983II | 2010IV |
| Germany | 1970I | 2010IV |
| Norway | 1972I | 2010IV |
| France | 1970I | 2010IV |
| Canada | 1970I | 2010IV |
| Japan | 1970I | 2010IV |
| Italy | 1970I | 2010IV |

As mentioned above, sample coverage is reduced for some countries due to unavailability of some series. Vacancies are unavailable for Italy, and in France they start in 1989I. In the United Kingdom vacancies end in 2007IV, in Canada in 2003I and in Spain they go from 1977I to 2005I.

For the analysis, data are expressed in logs (except for the unemployment rate) and are detrended using a Hodrick-Prescott filter with smoothing parameter $10^5$ for quarterly data (as in Shimer, 2005) and for annual data, using a corresponding parameter $\lambda = 6250$.

In order to emphasize the diversity of labor markets across OECD countries, Table 2 describes the main descriptive statistics for the sample. Panel A reports the mean of the unemployment rate, employment, GDP and hours worked across countries. Continental European countries (Germany, France) as well as the UK present higher unemployment rates compared to the US. But in Europe there are wide differences across Northern and Southern countries. While Norway and Sweden present the lowest unemployment rates of the sample of countries analyzed, except for Japan; south european countries (Italy, Portugal and Spain), have high unemployment rates for the whole time period selected.

Table 2: Descriptive Statistics

| Country | | U.S | U.K. | Spain | Sweden | Norway | Germany | Italy | France | Canada | Japan | Portugal | Australia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A) Mean (%) | Unemployment Rate | 6.28 | 6.78 | 14.19 | 4.78 | 3.42 | 6.54 | 8.81 | 7.43 | 8.16 | 3.02 | 6.53 | 6.42 |
| | Log Employment | 8.05 | 7.42 | 7.14 | 6.62 | 6.31 | 7.55 | 7.32 | 7.37 | 7.09 | 7.78 | 6.66 | 6.88 |
| | GDP | 6.90 | 6.12 | 5.88 | 5.32 | 5.14 | 6.29 | 6.10 | 6.13 | 5.86 | 6.44 | 5.18 | 5.62 |
| | Hours per worker | 1735.95 | 1789.14 | 1803.18 | 1574.21 | 1540.57 | 1618.57 | 1876.31 | 1623.96 | 1794.51 | 1978.96 | 1898.24 | 1786.29 |
| B) St.Deviation (%) | Unemployment Level | 0.116 | 0.117 | 0.085 | 0.153 | 0.163 | 0.127 | 0.051 | 0.054 | 0.089 | 0.066 | 0.098 | 0.113 |
| | Log Employment | 0.006 | 0.005 | 0.008 | 0.006 | 0.006 | 0.005 | 0.004 | 0.004 | 0.006 | 0.003 | 0.008 | 0.006 |
| | GDP | 0.007 | 0.007 | 0.006 | 0.007 | 0.007 | 0.007 | 0.007 | 0.005 | 0.007 | 0.008 | 0.009 | 0.006 |
| | Hours per worker | 15.204 | 23.588 | 32.116 | 36.268 | 32.069 | 18.429 | 27.777 | 31.117 | 24.733 | 36.173 | 40.812 | 16.421 |
| C) Relative SD (%) | Unemployment Level | 1.000 | 1.010 | 0.738 | 1.320 | 1.407 | 1.100 | 0.440 | 0.463 | 0.769 | 0.573 | 0.850 | 0.976 |
| | Log Employment | 1.000 | 0.952 | 1.418 | 1.102 | 1.083 | 0.959 | 0.695 | 0.636 | 0.980 | 0.598 | 1.453 | 1.023 |
| | GDP | 1.000 | 1.004 | 0.840 | 0.989 | 0.880 | 0.992 | 0.950 | 0.688 | 0.930 | 1.034 | 1.246 | 0.786 |
| | Hours per worker | 1.000 | 1.551 | 2.112 | 2.385 | 2.109 | 1.212 | 1.827 | 2.047 | 1.627 | 2.379 | 2.684 | 1.080 |
| D) Autocorrelation | Unemployment Level | 0.91 | 0.93 | 0.93 | 0.90 | 0.77 | 0.87 | 0.77 | 0.92 | 0.87 | 0.82 | 0.90 | 0.86 |
| | Log Employment | 0.70 | 0.76 | 0.79 | 0.75 | 0.68 | 0.76 | 0.50 | 0.60 | 0.61 | 0.58 | 0.73 | 0.70 |
| | GDP | 0.74 | 0.64 | 0.66 | 0.62 | 0.50 | 0.62 | 0.72 | 0.63 | 0.69 | 0.68 | 0.78 | 0.53 |
| | Hours per worker | 0.75 | 0.75 | 0.93 | 0.81 | 0.84 | 0.59 | 0.73 | 0.81 | 0.81 | 0.86 | 0.68 | 0.67 |

It is especially shocking the case of Spain, where the mean of its unemployment rate (14.19%) almost doubles the rest of the countries. The standard deviation of each variable for each country is presented in panel B, and the volatility with respect to the US in panel C. The main conclusions we can draw from these two panels are that unemployment is more volatile than the other variables, and, in particular, that the US exhibits less volatility than Southern Europe in employment and employment, but higher in unemployment. However, the opposite picture emerges when we pay attention to GDP, which is definitely more volatile in the US than in Europe, Canada and Australia.

Finally, panel D exhibits the first order autocorrelation for each of the variables. Unemployment is very persistent in all countries, with a coefficient above 0.85 for almost every country, except for Norway, Italy and Japan. Employment, GDP and hours worked are less persistent, and the degree of persistency relative to other countries is usually maintained across variables. In other words, Spain presents a higher autocorrelation in all these variables, compared to Italy. Nevertheless, major differences are not present across countries and all the coefficients are similar.

### 2.3 Correlations between labor productivity and labor input measures

Table 3 presents a correlation analysis between hourly productivity, employment (e), unemployment (u), vacancies (v) and the labor market tightness ratio v/u for the quarterly data of US, Spain and Germany[1]. Data are detrended using a Hodrick-Prescott filter with smoothing parameter $10^5$, and the results are not changed by using different smoothing parameters. Labor productivity measured either as output per hour or as output per worker is negatively correlated with unemployment in the 1970-1984 period[2] in most OECD countries.

These results initially document the degree of heterogeneity present in labor markets across countries. Especially in the U.S. the estimate (-0.45) is in line with Shimer (2005) result for a longer period 1948-2003. However, this correlation is very weak compared to what search models suggest. In a similar fashion, employment exhibits a weak positive correlation with productivity, becoming even negative for some countries.

It is even more shocking that after 1984, in line to Barnichon's finding for the U.S., these correlations have become even weaker and have switched sign for several countries. Besides the U.S., Sweden, Norway, U.K. or Italy are some examples of this fact, for

[1] Data are in log base and the analysis for the whole database can be found in Appendix A

[2] The decision to choose 1984 as the end of the first time period is based on comparability of the results to those in Barnichon (2010) and also on the break implied in McConnel & Pérez-Quiros (2000).

both employment and unemployment. An special case to mention is Spain, where the correlation between productivity and unemployment (employment) has traditionally been positive (negative), and after 1984 it has increase, so that cyclical components of both variables co-move positively (negatively). In fact, correlation between productivity and unemployment for 1985-2007 is 0.80, with the opposite sign if employment is used. Vacancies and labor market tightness are also negative, suggesting that the predictions of search models in this economy will not be validated by the data. These results are maintained when performing analysis with output per employee as a measure of productivity, and also with annual data for OECD, as well as Latin American countries.

Table 3: Correlations using GDP per hour

| | | ρ(p,u) | ρ(p,e) | ρ(p,v) | ρ(p,v/u) |
|---|---|---|---|---|---|
| U.S. | 1970I-1984IV | -0.45** | 0.37** | 0.56** | 0.56** |
| | | (0.10) | (0.11) | (0.09) | (0.09) |
| | 1985I-2007IV | 0.07 | 0.02 | -0.38** | -0.37** |
| | | (0.10) | (0.10) | (0.09) | (0.09) |
| | 1970I-2007IV | -0.23** | 0.22** | 0.11 | 0.15* |
| | | (0.08) | (0.08) | (0.08) | (0.08) |
| Spain | 1972IV-1984IV | 0.36** | -0.33** | -0.19 | -0.48** |
| | | (0.13) | (0.13) | (0.17) | (0.15) |
| | 1985I-2007IV | 0.80** | -0.80** | -0.11 | -0.28** |
| | | (0.04) | (0.04) | (0.11) | (0.10) |
| | 1972IV-2007IV | 0.69** | -0.68** | -0.08 | -0.28** |
| | | (0.04) | (0.05) | (0.09) | (0.09) |
| Germany | 1970I-1984IV | -0.21* | -0.58** | 0.13 | 0.56** |
| | | (0.12) | (0.09) | (0.13) | (0.13) |
| | 1985I-2007IV | -0.18* | 0.08 | 0.20** | 0.21** |
| | | (0.10) | (0.10) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.19** | -0.31** | 0.14* | 0.40** |
| | | (0.08) | (0.07) | (0.08) | (0.08) |

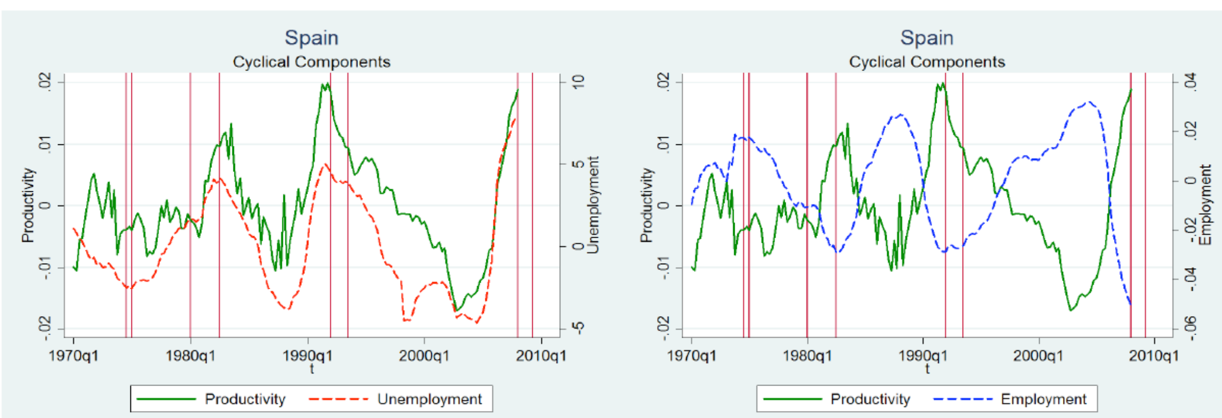
Note: For data s.e. are in parenthesis and significance is indicated by one asterisk (10-percent level) or two asterisks (5-percent level)
Data is detrended using a HP filter with smoothing parameter $10^5$

Tables can be found in the appendix, but the main claim is that the Southern European, as well as Latin American evidence is hard to reconcile with the predictions of the traditional search models. Productivity and unemployment tend to move together, with an even higher positive correlation after 1984. In order to go deeper into these results, by comparing the cyclical components of productivity, employment and unemployment, a clearer view arises.

In Figure 1, I present these cyclical fluctuations for Spain. The vertical lines represent CEPR recession dates.[3], and it is noticeably how productivity and unemployment move together after 1980, and specially the last 5 years of data, the magnitude of the fluctuation is the same. Moreover, these fluctuations for productivity are, for 2000-2010, countercyclical. While in the 2000's Spain was experiencing a boom in its economy, productivity exhibits a decreasing pattern, and only it starts to increase in 2007, when the recession had already started.

These findings are again confirmed by repeating the exercise with annual data. In particular, Latin American countries exhibit a similar pattern, that coincides with the one found in Spain. In this same group, Portugal and Italy could be included. Labor markets of these countries may have common features that lead to this result. However, different liberalization and regulatory processes lead to differences in labor market institutions that cannot solely account for these facts. Some common cultural or unobserved component could be a plausible explanation. However, this exercise requires further research to obtain accurate conclusions.

Figure 1: Cyclical Components of Productivity, Employment and Unemployment in Spain




[3]These cyclical fluctuations have been plotted for several countries in this exercise and can be found in Appendix B, also with CEPR recession dates for European countries, and NBER recession dates for the US

# 3 Empirical Strategy

After finding that the correlation between productivity and unemployment ( denoted from now on as $\rho$) has switched sign after 1984, it is necessary to understand what force is driving such a change. Using a bivariate VAR for productivity and unemployment, and imposing the long run restriction that technology shocks have a permanent effect on productivity, I can identify which shock has an outstanding presence in each of the economies. Previous findings by Barnichon (2010) suggest that in the U.S. positive technology shocks that increase productivity affect unemployment in the same direction, while demand shocks have the counteracting effect. However, the analysis of a greater number of countries with heterogeneous labor market outcomes will draw additional information to account for the change in $\rho$.

## 3.1 The effects of technology and non-technology shocks on productivity and unemployment

In order to understand how the impact of different technology and non-technology shocks affect on labor correlations, I proceed as in Galí (1999)[4] and I estimate a bivariate VAR with unemployment and productivity:

$$\begin{pmatrix} \Delta x_t \\ u_t \end{pmatrix} = C\left(L\right) \begin{pmatrix} \varepsilon_t^a \\ \varepsilon_t^m \end{pmatrix} = C(L)\varepsilon_t$$

where $x_t$ is (logged) labor productivity, $u_t$ unemployment, $C(L)$ an invertible matrix polynomial and $\varepsilon_t$ the vector of structural orthogonal innovations, where $\varepsilon_t^a$ denotes technology shocks and $\varepsilon_t^m$ denotes non-technology shocks. A long run restriction is imposed on technology shocks to have permanent effects on labor productivity, while non-technology shocks have temporary effects. Hence, technology shocks are the only shocks to have a long run effect on productivity.

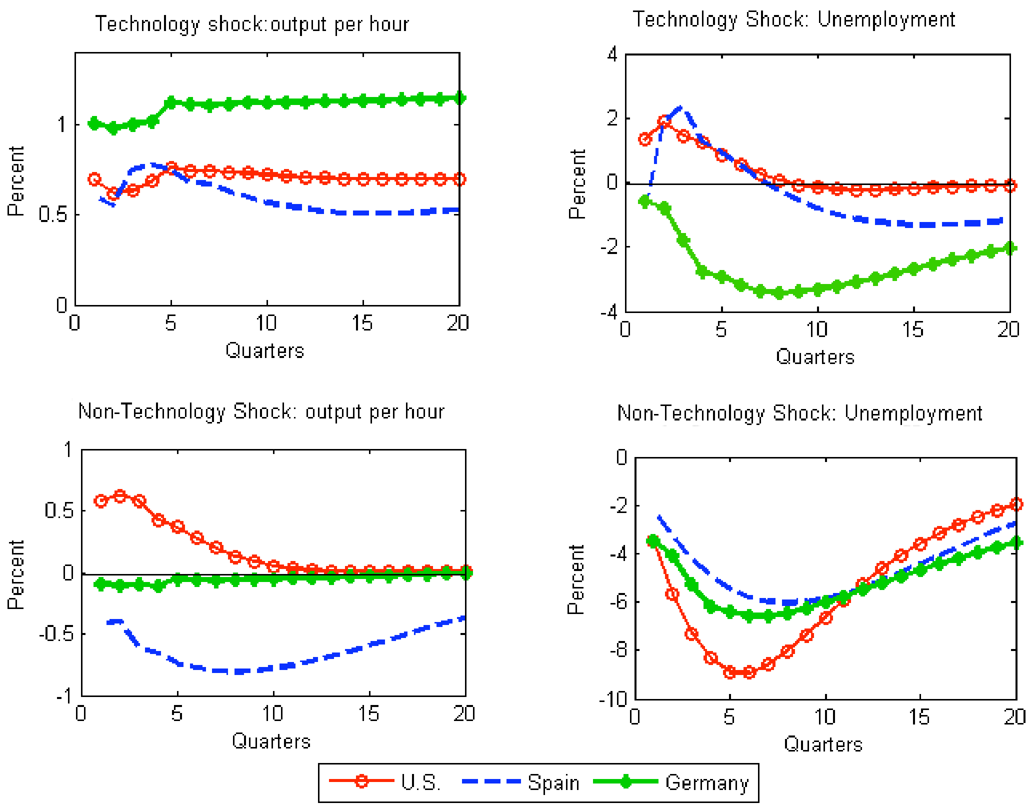
So as to obtain comparable results, I repeat this exercise for both measures of productivity (per hour and per employee), resulting in similar responses [5]. Effects of technology and non-technology shocks show how countries differ in their productivity

[4] I am aware of the criticisms of this approach, especially by Chari , Kehoe, and McGrattan (2008), and mine may suffer from identical comments. In particular, a VAR with a small number of lags is a poor approximation to the model's VAR.

[5] From now on, I am going to focus my explanations in productivity as GDP per hour, as it is the way it is modeled later, and what other authors have used, i.e. Barnichon or Shimer.

and unemployment reaction. Figure 2 plots the impulse response functions for the US, Spain and Germany following both a technology and a non-technology shock. It shows that following a positive technology shock in the US , productivity initially undershoots its long value level by 15% and then it reaches after 5 quarters its long run value.

Figure 2: Empirical impulse response functions for the U.S., Spain and Germany




On the other hand, following a technology shock, unemployment exhibits a hump-shaped form, peaking after 3 periods and returning to its initial level two and a half years later (10 quarters). Therefore, quantitatively, a 0.7% increase in productivity is correlated with a 0.15% increase in unemployment. Second row of Figure 2 plots the effect on productivity and unemployment following a non-technology shock. Quantitatively, a 0.5% increase in productivity is associated with a 0.3% decrease in unemployment, and the effects are temporary and revert to their long run value. This result for the U.S. is in line with findings by Galí and Gambetti (2009), who report a shrinking contribution of non-technology shocks to output volatility after 1980's, and to Barnichon (2010), who attributes the effect to both structural changes in the early 1980s and to a decline on the procyclicality of productivity. Therefore, technology shocks generate positive unemployment-productivity correlations.

In Europe these patterns do not necessarily appear. Except for some countries, such as Sweden, in Spain and Germany, a non-technology shock has an effect on unemployment of the same sign. Following the shock, productivity initially decreases, reaches its trough and returns to its initial level. Similarly, unemployment mimics productivity, and goes initially down. Non technology shocks in Europe result in positive unemployment-productivity correlations.

These differences seem hard to reconcile with the initial scenario in the U.S.. Most importantly, these result suggests that, in order to account for the increasing correlation of productivity and unemployment over the years, technology shocks will have a higher importance in the U.S., while demand shocks will be the driving force underlying in Europe for changes in correlations.

### 3.2 A New-Keynesian Model with Unemployment

The interaction between technology and non-technology shocks is driving, up to an important extent, the changes in correlation between productivity and unemployment across countries. This section contains a New Keynesian model with search unemployment as in Barnichon (2010), that will be tested not only for the US, but also for the OECD countries analysed in the previous section. Non-technology shocks are interpreted as aggregate demand or, more concretely, as monetary shocks[6]and technology shocks are orthogonal to monetary shocks . The economy is characterized by three agents: households, firms and a monetary authority, and relies on three important pillars: sticky prices, search unemployment, and variable effort and labor hours.

#### 3.2.1 Households

The economy is characterized by the existence of a continuum of households of measure one. Families make decisions on consumption and money holdings in order to maximize their expected lifetime utility, as in Merz (1995) and Andolfatto (1996). There are $n_t$ employed workers who receive the wage payment $w_{it}$ from firm $i$ for providing hours $h_{it}$ and effort per hour $e_{it}$, and $1 - n_t$ unemployed workers who receive unemployment benefits $b_t$. The individual disutility from working is $g(h_{it}, e_{it})$.

The representative family maximizes:

[6]This is claimed by Barnichon (2010) to be a parsimonious and tractable way of introducing demand shocks. He shows that monetary policy shocks display a similar volatility drop to the one experienced by non-technology shocks in the mid-1980‘s.

$$E_o \sum_{t=0}^{\infty} \beta^t \left[ ln\left(C_t\right) + \lambda_m ln\left(\frac{M_t}{P_t}\right) - n_t \int_0^1 g(h_{it}, e_{it}) di \right]$$

$$subject\ to$$

$$\int_0^1 P_{jt} C_{jt} dj + M_t = \int_0^1 n_t w_{it} di + (1 - n_t) b_t + \Pi_t + M_{t-1}$$

with $\lambda_m$ is a positive constant, $M_t$ nominal money holdings, $\Pi_t$ total transfers to the family, $C_t$ a composite consumption good index, and $P_t$ the aggregate price level.

Barnichon (2010) imposes on the consumption good index the following structure $C_t = \left(\int_0^1 C_{it}^{(\epsilon-1)/\epsilon} di\right)^{\epsilon/\epsilon-1}$, where $C_{it}$ is the consumption of good $i$ in period $t$. Similarly, the aggregate price level is $P_t = \left(\int_0^1 P_{it}^{1-\epsilon} di\right)^{1/1-\epsilon}$. Finally, the functional form of the disutility of working is as in Bils and Cho (1994) $g(h_{it}, e_{it}) = \left(\frac{\lambda_h}{1+\sigma_h}\right) h_{it}^{1+\sigma_h} + h_{it} \left(\frac{\lambda_e}{1+\sigma_e}\right) e_{it}^{1+\sigma_e}$. $\lambda_e$, $\lambda_h$ are positive constants to be calibrated. The (inverse) of worker per hour elasticity is given by $\sigma_h$, and $\sigma_e$ is the elasticity with respect to effort. An infinite value for $\sigma_e$ generates an inelastic response of effort.

### 3.2.2 Firms

In this economy, a monopolistically competitive firm which uses labor as an input produces each variety of a good. Therefore, there exists a continuum of firms distributed on the unit interval. In period $t$, each firm $i$ hires $n_{it}$ workers to produce output $y_{it} = A_t n_{it} L_{it}^{\alpha}$. $A_t$ is an aggregate technology index, $L_{it}$ is the labor supply, and $0 < \alpha < 1$. Labor supply is a function of hours and effort with $L_{it} = h_{it} e_{it}$.

As each firm is a monopolist in the production of each good, it faces a downward sloping demand $y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\epsilon} Y_t$, and they choose prices $P_{it}$, to maximize profits taking into account aggregate price level $P_t$ and aggregate output $Y_t$. We assume that there are sticky prices (as in Calvo (1983)), so firms cannot adjust prices immediately in response to shocks.

The labor market is modeled as in a search and matching framework (Mortensen and Pissarides (1994)), where unemployed workers search for jobs and firms post vacancies at cost $c_t$. The measure of successful matches in a period is given by the usual matching function with a Cobb-Douglas form $m_t = m_0 u_t^{\eta} v_t^{1-\eta}$. $\eta$ represents the elasticity of the matching function with respect to unemployment, $m_0$ is a positive constant, $u_t$ the level of unemployment in the economy and $v_t$ the level of vacancies posted by all the firms. We can also define $\theta_t = \frac{v_t}{u_t}$ as the labor market tightness, $q(\theta_t) = m_t/v_t$ the probability of a vacancy being filled in the next period, and $\lambda$ is the job separation rate in the economy. Finally, the law of motion of employment is given by $n_{it+1} = (1-\lambda)n_{it} + q(\theta_t)v_{it}$.

#### 3.2.3 Monetary authority

This economy is modeled to be non-stationary, with zero inflation in "steady-state" and money supply that evolves according to $M_t = \bar{A}_t e^{mt}$. The monetary rule is implied in terms of money growth $\Delta m_t = \rho_m \Delta m_{t-1} + \varepsilon_t^m + \tau^{cb}\varepsilon_t^a$ with autocorrelation parameter $\rho_m \in [0,1]$ and $\varepsilon_t^m$ is interpreted as an aggregate demand shock, and $\varepsilon_t^a$ as a technology shock. As in Gali (1999), if $\tau^{cb} \neq 0$, the Central Bank responds in a systematic fashion to technology shocks.

The technology index series is non stationary with a unit root, this is, technology shocks have a permanent effect on productivity. This is consistent with the long run restriction imposed in subsection 3.1 on the VAR for persistence of technology shocks. The evolution of technology is denoted by $A_t = \bar{A}_t e^{a_t}$ with deterministic component $\bar{A}_t = (1+g_a)\bar{A}_{t-1}$, and stochastic component $a_t = a_{t-1} + \varepsilon_t^a$ with $\varepsilon_t^a \sim N(0, \sigma^a)$.

#### 3.2.4 Closing the model

Assuming that firms and individuals are homogeneous, we can average the firms' employment and define the law of motion for total employment as $n_{t+1} = (1-\lambda)n_t + v_t q(\theta_t)$, with the labor force normalized to 1, so that $u_t = 1 - n_t$. In this non-stationary economy, vacancy posting costs as well as unemployment benefits grow in line with technology, then $c_t = cA_t$ and $b_t = bA_t$. Finally, in equilibrium $C_t = Y_t$ as vacancy posting costs are distributed to the aggregate households (Krause and Lubik, 2007).

### 3.3 Equilibrium conditions

As the details of the solution of this model can be found in Barnichon (2010), I just will summarize the first order conditions as well as define the (non-stationary) equilibrium for this economy.

**Household first order conditions**

The first order condition for consumption is the usual Euler equation

$$\frac{1}{C_t} = \beta E_t (1+i_t) \frac{P_t}{P_{t+1}} \frac{1}{C_{t+1}}$$

and for money holdings takes the following form

$$\frac{M_t}{P_t} = \frac{1}{C_t}\frac{i_t}{1+i_t}$$

**Firms' maximization**

Firm $i$ will choose a sequence of prices $\{P_{it}\}$ and vacancies $\{v_{it}\}$, given the aggregate price level, in order to maximize the expected present discounted value of future profits, subject to the demand constraint, the Calvo price setting condition, the law of motion of employment and the hours/effort choice.

$$E_t \sum_j \beta^j \frac{u'(C_{t+j})}{u'(C_t)} \left[ \frac{P_{i,t+j}}{P_{t+j}} y^d_{i,t+j} - n_{i,t+j} w_{i,t+j} - c_{t+j} v_{i,t+j} \right]$$

subject to

$$\begin{cases} y^d_{it} = \left(\frac{P_{i,t}}{P_t}\right)^{-\epsilon} Y_t \\ y_{it} = y_o A_t n_{it} h^{\varphi}_{it} \\ n_{it+1} = (1-\lambda) n_{it} + q(\theta_t) v_{it} \\ w_{it} = \gamma c_t \theta_t + (1-\gamma) b_t + (1-\gamma) \varkappa \frac{h^{1+\sigma_h}_{it}}{\lambda_t} \end{cases}$$

**Vacancy posting condition**

The optimal vacancy posting condition is

$$\frac{c_t}{q(\theta_t)} = E_t \beta_{t+1} \left[ \chi_{it+1} + \frac{c_{t+1}}{q(\theta_{t+1})}(1-\lambda) \right]$$

where the shadow value of a marginal worker is given by

$$\chi_{it} = -\gamma \frac{c}{\lambda_t} \theta_t - (1-\gamma)\frac{b}{\lambda_t} + (1-\gamma)\left(\frac{1+\sigma_h}{\varphi} - 1\right) \varkappa h^{1+\sigma_h}_{it} Y_t$$

Hours per worker is the mechanism driving the incentives of the firms to post more vacancies. When $\varphi < 1 + \sigma_h$, the more hours, the larger will be the reduction in the bill for hiring an extra worker[7]. Following a demand shock, hours grow to satisfy demand,

[7]With $\varphi > 1$, the production functions exhibits short run increasing returns to hours. This condition is imposed to generate procyclical response of productivity to aggregate demand shocks.

leading to an increase in the marginal value of a worker. Firms will post more vacancies and employment will grow.

**Calvo price setting condition**

A firm $i$ resetting its price at $t$ will satisfy

$$E_t \sum_{j=0}^{\infty} \nu^j \beta_j \left[ \frac{P^*_{it}}{P_{t+j}} - \mu s_{it+j} \right] Y_{t+j} P^{\epsilon}_{t+j} = 0$$

where the optimal mark-up is $\mu = \frac{\epsilon}{\epsilon - 1}$ and the firm's marginal cost is $s_{it}$[8].

**Non-Stationary Equilibrium**

The economy is described by the following system of equations and 5 unknowns $\theta^*,\ y^*,\ h^*, e^* and\, n^*$:

$$y^* = y_0 n^* h^{*\varphi} \tag{1}$$

$$e^* = e_0 (h^*)^{\frac{\sigma_h}{1+\sigma_e}} \tag{2}$$

$$\beta \chi^* = \frac{c}{q(\theta^*)} (1 - \beta(1 - \lambda)) \tag{3}$$

$$\chi^* = -\gamma c \theta^* - (1-\gamma) b + (1-\gamma) \left( \frac{1+\sigma_h}{\varphi} - 1 \right) \varkappa h^{*1+\sigma_h} y^* \tag{4}$$

$$1 = \mu \frac{1+\sigma_h}{\varphi} (1-\gamma) \varkappa h^{*1+\sigma_h - \varphi} y^* \tag{5}$$

$$n^* = \frac{\theta^* q(\theta^*)}{\lambda + \theta^* q(\theta^*)} \tag{6}$$

where $y_0$,$e_0$ and $\varkappa$ are positive constants[9].

Variables have been rescaled with technology index $A_t$ and are denoted by lower-case letters.

[8] By log-linearizing the Calvo price setting condition, I obtain a standard New-Keynesian Phillips Curve.

[9] $y_0 = e_0^{\alpha}$, $e_0 = \left( \frac{1+\sigma_e}{\sigma e} \frac{\lambda_h}{\lambda_e} \right)^{\frac{1}{1+\sigma_e}}$ and $\varkappa = \frac{\lambda_h^{\frac{1+\sigma_h+\sigma_e}{(1+\sigma_h)\sigma_e}}}{1 - \frac{\gamma}{\rho}(1+\sigma_h)}$

# 4 Confronting the Model with the Data

The impulse response functions from the VAR lead to the evidence that technology shocks could account for the increase in correlation between productivity and unemployment in the U.S., while in European countries demand shocks were those producing positive comovements of both variables. In order to see to what extent the model I have presented can account for these different outcomes across OECD countries, I need to calibrate it with parameters characterizing each labor market. By simulating data with the model, its empirical performance can be assessed and I can test whether the prevalence of each of the shocks for each economy can quantitatively account for the change in $\rho$ over time.

## 4.1 Calibration and impulse responses

I have calibrated the model for 7 countries: the US, the UK, Spain, Sweden, Norway, Germany and Japan, which essentially capture the heterogeneity of the different correlations from Section 2. Initially, I have calibrated the US as in Barnichon (2010), to obtain a reliable comparison of the results, taking into account the time period covered here differs from his. After completing this exercise, I have simulated 40 years of data for this economy, and compared the response of productivity and unemployment following technology and demand shocks with the responses in the VAR.

I have proceed in a similar fashion for the rest of the economies, and I have analyzed the implications of these results for the success of the model and its capacity to match the data.

### 4.1.1 Solving the model for the U.S.

The calibration choice for the U.S. is solely based on Barnichon (2010), although some changes have been made in order to satisfy certain properties of the model and empirical studies. As in Kydland and Prescott (1982), the quarterly discount factor $\beta$ is set to 0.99, and returns to labor parameter $\alpha$ is 0.64. Assuming that the markup of prices over marginal costs is 10%, this leads to a parameter $\epsilon = 11$. Firms reset prices every 2 quarters, so the price adjustment cost parameter $\nu = 100$ is set to match the Phillips Curve coefficient $\delta = 0.10$. The growth rates of technology and money supply are set to be 0.5% each quarter (2% annually). The autocorrelation parameter of money growth is $\rho^m = 0.5$ (in order to match the autocorrelations of M1 and M2 in the U.S. and Europe). The matching function elasticity is $\eta = 0.4$ as in Blanchard and Diamond (1989) and I also set $\eta = \gamma$ in order to satisfy Hosios' Condition, although other studies suggest this value is very low and should be around 0.7 (Justiniano and Michelacci, 2011). A firm fills a vacancy with quarter by probability $q(\theta) = 0.6$, and as in Shimer (2005), the job finding probability is $\theta q(\theta) = 0.6$. The separation rate is set to $\lambda = 0.10$, also as in Shimer (2005), so the jobs last for 2.5 years on average. I have chosen an hours per worker elasticity of 0.31 ($\sigma_h = 3.2$), so as to obtain $\varphi > 1$, as in Bils and Cho (1994) and in the range of Basu and Kimball (1997).

Finally, Barnichon (2010) sets hiring costs equal to 1% of GDP, and the degree of accommodation of monetary policy to technology shocks $\tau^{cb} = -0.4$. The decision to do this is based on the fact that, as explained in Galí and Rabanal (2004), the policymaker has difficulties in observing potential output, so technology shocks suffer the risk of being misinterpreted. In such a case, the Central Bank implements a contractionary policy, resulting in the negative sign present in this calibration.

Table 4: Benchmark calibration parameters for the U.S.

| Description | Parameter Value |
|---|---|
| Quarterly discount factor ($\beta$) | 0.99 |
| Returns to labor ($\alpha$) | 0.64 |
| Matching function elasticity ($\eta$) | 0.4 |
| Quarterly job separation rate ($\lambda$) | 0.1 |
| Job finding rate ($q(\theta)$) | 0.6 |
| Hours per worker elasticity ($1/\sigma_h$) | 0.5 |
| Elasticity of effort with respect to hours ($\sigma_h/(1+\sigma_e)$) | 0.5 |
| Hiring costs ( c ) | 1% GDP |
| Degree of monetary policy accomodation ($\tau_{cb}$) | -0.4 |

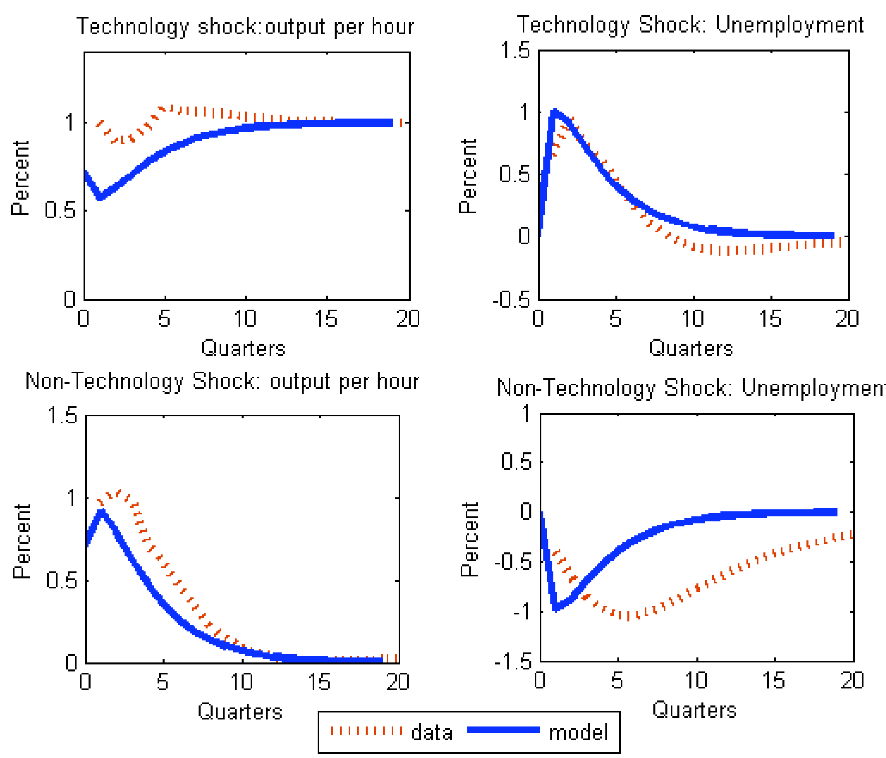
In Figure 3, I present the impulse response functions following a technology and a non-technology shock for the U.S. and I compare it with the response of a shock that increases productivity by 1%, previously obtained from the VAR. Except for deviations in the response of unemployment following a non-technology shock (it takes longer to reach the trough), the model is quite successful in replicating the responses of the data conditional on each shock.

In particular, following a technology shock, initially demand does not increase as much as productivity because prices are sticky in the short run. Besides, the Central Bank does not accommodate the shock. In order to satisfy demand, firms rely in the intensive margin because they cannot fire workers, and they reduce hours and effort.

The value of a marginal worker goes down, and so does the value of posting a vacancy. Firms post less vacancies, and progressively unemployment increases. Productivity undershoots its long run level due to the existence of increasing returns to hours.

On the other hand, the effects of an aggregate demand shock (monetary shock) are the following. Firms need to increase labor to satisfy demand. However in the short-run, labor is subject to hiring frictions, so firms initially increase effort and hours. By doing this, the value of a marginal worker goes up, and firms post more vacancies. This leads to a reduction of unemployment in the economy. As productivity and prices adjust to the new equilibrium, unemployment also returns to its long run level.

Figure 3: Impulse response functions: Empirical and Model




#### 4.1.2 Empirical response of the model in OECD countries

The interest now relies on testing whether the model can account for the considerable level of heterogeneity in labor markets across OECD countries. The model may do well in matching the evidence in U.S., but its capacity to explain other economies might be limited. For that reason, I calibrate the model again for different countries[10], allowing

[10] Calibration for the US is from Barnichon (2010), the UK, Sweden, Norway and Germany are calibrated following Justiniano and Michelacci (2011), Spain on Sala and Silva (2005) and Japan on Miyamoto (2009).

for variations in labor market parameters, leaving everything else unchanged. A relation of the different parameters can be found in Table 5. Except for Sweden, the model is not able to replicate accurately the empirical evidence[11]. The impulse response functions of the model exhibit large deviations from the data. However, this is not unexpected. From the analysis of the VAR it was already pointed out that following a demand shock, U.S., Germany and Spain behaved in different ways with respect to the response in unemployment.

Table 5: Cross-country labor-market parameters

| | U.S. | U.K. | Germany | Spain | Sweden | Norway | Japan |
|---|---|---|---|---|---|---|---|
| Quarterly Job Separation Rate ($\lambda$) | 0.1 | 0.03 | 0.02 | 0.16 | 0.04 | 0.05 | 0.004 |
| Matching Function Elasticity ($\eta$) | 0.4 | 0.7 | 0.7 | 0.7 | 0.8 | 0.74 | 0.65 |
| Job Finding Rate ($q(\theta)$) | 0.6 | 0.25 | 0.15 | 0.25 | 0.43 | 0.52 | 0.131 |
| Labor Market Tightness ($\theta$) | 0.86 | 0.86 | 0.8 | 0.67 | 0.8 | 0.8 | 0.68 |

While following a demand shock that increased productivity in all countries, in the U.S. unemployment decreased, in Germany and Spain unemployment also increased as productivity. These differences cannot only be achieved by calibration, as there must be an underlying element not included in the model (some kind of adjustment costs) that is driving the positive comovement of productivity and unemployment in Europe.

Table 6: Correlations using GDP per hour for the model and data in different OECD countries

| | U.S. | | Germany | | Spain | | Sweden | |
|---|---|---|---|---|---|---|---|---|
| | Data | Model | Data | Model | Data | Model | Data | Model |
| 1970I-1984IV | -0.45** | -0.25 | -0.21* | -0.5 | 0.36** | -0.37 | -0.39** | -0.26 |
| | (0.10) | (0.11) | (0.12) | (0.09) | (0.13) | (0.10) | (0.11) | (0.11) |
| 1985I-2007IV | 0.07 | -0.004 | -0.18* | -0.003 | 0.80** | -0.01 | 0.02 | -0.02 |
| | (0.10) | (0.10) | (0.10) | (0.09) | (0.04) | (0.10) | (0.10) | (0.10) |
| 1970I-2007IV | -0.23** | -0.11 | -0.19** | -0.25 | 0.69** | -0.17 | -0.04 | -0.11 |
| | (0.08) | (0.08) | (0.08) | (0.07) | (0.04) | (0.08) | (0.08) | (0.08) |
| % Change Explained | *0.56* | | *15.67* | | *0.82* | | *0.59* | |

Note: For data, s.e. are in parenthesis and significance is indicated by one asterisk (10-percent level) or two asterisks (5-percent level).
For model, s.e. (standard deviation across 5000 simulations) are reported in parenthesis.

[11] Impulse response functions for relevant economies are in Appendix B

Nevertheless, there are still other features of the model that can be tested. The initial reason for developing such a model was to see if it could replicate the change in correlations experienced by countries after 1980's, and make an improvement in the prediction of traditional search models. In order to study the sign of the correlation between productivity and unemployment, I simulate 40 years of data with the model calibrated for each of the economies. For precision, I calculated the correlation between productivity and unemployment over 5000 simulations of the data. I present the results of this exercise in Table 6, comparing them with the correlations from Section 2. The last row, which presents the change explained by the model is calculated in the following way: in the U.S., correlation increases 0.52 and 0.21 in data and model respectively. Hence, the variation in the correlation in the model accounts for 56% of the increase in correlation in data for the same period. Moreover, in the data simulated for Sweden, correlation increases 0.24, almost a 60% of the total change in correlation. On the other hand, for Germany and Spain the model fails to replicate again the empirical evidence. While in Spain the absolute increase in correlation is high, it does not succeed in achieving the highly positive correlation between productivity and unemployment. And as for Germany, it overestimates the magnitude of the change, which was quite small.

Finally I compare the standard deviation of employment [12] and the autocorrelation generated by the model with those values obtained from the data. Once again, the model matches pretty well the volatility of employment and its autocorrelation in the U.S., and also in Germany. Autocorrelation estimates from the model are remarkably close to those in data, but the model fails to replicate the volatility of labor outcome measures in Europe. As it is shown in Table 7, in Spain and Sweden, the standard deviation of employment is much lower in the model than in data.

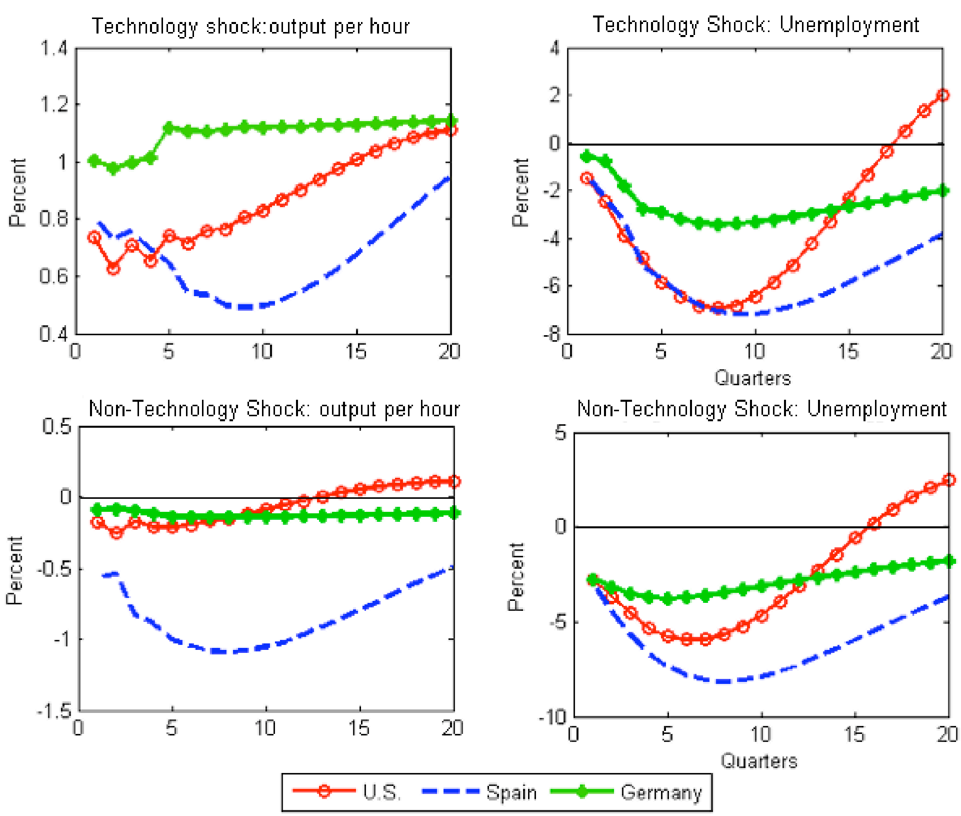
Table 7: Summary statistics of employment for countries and model data 1973-2007

| | U.S. | | Germany | | Spain | | Sweden | |
|---|---|---|---|---|---|---|---|---|
| | Data | Model | Data | Model | Data | Model | Data | Model |
| Standard deviation | 0.006 | 0.007 | 0.005 | 0.004 | 0.008 | 0.002 | 0.006 | 0.001 |
| Autocorrelation | 0.70 | 0.75 | 0.76 | 0.77 | 0.79 | 0.72 | 0.75 | 0.75 |

[12] I have chosen to use employment in t+1 because it is a predetermined variable in the solution of the system of equations of the model. However, unemployment, which is a state variable, could be obtained using the fact that labor force is normalized to 1 and results are not affected by these measures. In fact, the correlations are very similar (this is change is just a vertical translation).

All these results confirm that the heterogeneity of labor markets across OECD countries is responsible for the different correlations observed between productivity of unemployment. The relative size of technology shocks versus aggregate demand shocks in these economies accounts for the changes in correlation observed after 1984. On the one hand, in the U.S. (and possibly Sweden) an increase in the size of technology shocks relative to demand shocks, is able to produce joint fluctuations of the cyclical components of productivity and unemployment. In Europe we find the opposite picture: demand shocks have gained relatively more importance after 1984, given that following a non-technology shock that increases productivity, the effect on unemployment is also positive. This could potentially explain the differences in correlations across countries.

Figure 4: Empirical impulse response functions for the U.S., Spain and Germany after 1984




By further examining the differences between the U.S. and Europe, the impulse response functions of the former after 1984 draw an interesting fact. In Figure 4, following a positive technology shock, now the effect on unemployment is ambiguous, it initially decreases, but after 10 quarters it returns to its initial level and increases again. But more interestingly, the impulse response of productivity and unemployment following a non-technology shock is more similar to Spain and Germany, compared to the whole sample period. The cyclical response of productivity has diminished significantly, and therefore, this also leads to an increase in the conditional unemployment-productivity correlation.

Some authors[13] have examined a reduction in the response of labor productivity, and the explanation of this finding could go in their direction. However, further research would be needed in this area, that is beyond the scope of this thesis. However, a simple analysis for the model, in which effort is completely removed from it (calibrating it to be zero), reveals that the matching of the model for Europe, although still large from perfect, shows an improvement. In this case, workers could only change hours after the occurrence of a shock, so productivity does not increase or decrease as much as in the case with effort. This solution will (partially) conciliate the evidence that in countries such as Spain, U.K. or Germany, unemployment and productivity move together in response to a non-technology shock, and will better replicate the correlations observed in data.

## 5 Conclusions

In this master thesis I have exploited the departure of the evidence in correlations between productivity and unemployment from traditional search and matching models. By constructing a data set with quarterly data from the OECD and annual data from the Total Economy database, compiled by the Conference Board, I have performed an analysis of the correlations in the cyclical components of productivity, employment and unemployment in different OECD countries, as well as Latin American countries. The results indicate that the negative correlation predicted by Mortensen and Pissarides between productivity and unemployment is not that strong, and that it has even become positive after 1984. Especially, in Southern Europe and Latin countries, this correlation has been positive before the 1980's.

In order to evaluate the sources of changes of correlations over time and the heterogeneity in labor markets over countries, I have first estimated the impulse response functions of a bivariate VAR with productivity and unemployment. The results that arise from this analysis show that in the U.S., following a positive technology shock that has a permanent effect on productivity, unemployment rises temporarily and moves in

[13] Galí and Gambetti (2009) report an smooth and progressive decline in the procyclicality of productivity starting in 1970s. Barnichon (2010) attributes these effects to two structural changes: Central Banks became more accommodating technology shocks after 1984, and also to the decline of procyclicality of productivity.

the same direction as productivity. However, a non-technology shock with also a positive effect on productivity, although temporary, will decrease unemployment. Therefore an increase in the correlation between productivity and unemployment can be explained by the increase in the relative size of technology over demand shocks in the US. Nevertheless, the picture that emerges in Europe is the opposite. Non-technology shocks produce shifts in labor productivity in the same direction as unemployment. In these economies, the change in correlation between these two variables lies in the increased importance of demand shocks over technology ones.

As an explanation to these facts, I present a New Keynesian model as in Barnichon (2010) with three important elements: sticky prices, variable hours and effort, and search frictions. I have calibrated this model for several OECD countries, and I present the matching of the model and the data for these economies. While the model is able to replicate quite accurately the impulse response from the data in the US, its empirical ability to match the evidence in Europe is limited. By simulating 40 years of data, I can account for more than 50% of the change in correlation in the US and Sweden, but in Germany or Spain it is again away from the evidence. The model replicates the prediction of the data, and the most important findings are that while technology shocks have an increasing importance in the US given that they generate the positive correlation between productivity and unemployment, while in those European countries that experienced a change in correlations, demand shocks play the biggest role. These results impose a constraint in business cycle theories, which claim that cyclical fluctuations of variables are a recurrent event with many similarities over time and across countries. In spite of this, these findings suggest that heterogeneity is remarkably important across countries that the evidence from business cycle and search models cannot be conciliated anymore.

Future lines of research arise when examining the picture in the US after 1984, as it seems that the response of productivity following a non-technology shock has fallen significantly. Some authors, as Galí and Rabanal (1994) have pointed out this fact, and Barnichon (2010) claims that the reduction in the procyclicality of productivity is due to a moderation in the volatility of employment with respect to the volatility of hours per worker, but an increase in the volatility with respect to output since 1984. He also suggests that structural changes have occurred in the labor market in the last two decades, such as a reduction in hiring frictions and more elastic hours per worker.

Moreover, this model is based on sticky prices and variable effort to generate a reduction in employment following an increase in productivity. Several modifications to this model may be introduced in order to better conciliate the evidence with Europe.

Shimer (2005) proposes including a higher wage rigidity into the model, as in Burdett and Mortensen (1998). As firms have incentives to increase wages, and attract better workers away from competitors, the link between productivity and v-u ratio is broken and this may affect wages and employment in equilibrium. Also introducing flexible prices would be interesting, and see how unemployment-productivity correlation is affected if we rule sticky prices out of the model. López-Salido and Michelacci (2007) also provide an explanation, where the introduction of new technologies leads to an Schumpeterian creative destruction, and obsolete technologies may disappear, leading to a temporary increase in unemployment.

Finally, the positive correlation between productivity and unemployment over the whole sample period in Southern Europe and Latin America, but especially in Spain, establishes a future goal for research. The boost of sectors that employed low-skilled workers, such as construction, followed by the Great Recession in 2007 may have had a role in the correlation in these economies, where productivity fluctuations exhibit a countercyclical pattern that mimics the cycles of unemployment. However, a common underlying pattern prevails labor markets in these economies and obtaining an explanation for this phenomenon is in the future research agenda.

## References


Andolfatto, David, 1996. "Business Cycles and Labor-Market Search," *American Economic Review*, vol. 86(1), 112-32.

Barnichon, R., 2010. "Productivity and unemployment over the business cycle", *Journal of Monetary Economics*, vol. 57(8), 1013-1025.

Barnichon, R. 2007. "The Shimer Puzzle and the Correct Identification of Productivity Shocks", *CEP Discussion Papers* dp0823, Centre for Economic Performance, LSE.

Basu, S., Kimball, M., 1997. "Cyclical Productivity with unobserved input variation", *NBER Working Papers*, 5915.

Bils, M., Cho, J., 1994. "Cyclical Factor Utilization", *Journal of Monetary Economics*, 33, 319-354.

Burdett, K., Mortensen, D. T., 1998. "Wage Differentials, Employer Size, and Unemployment", *International Economic Review*, vol. 39(2), 257-73.

Chari, V.V., Kehoe, Patrick J., McGrattan, Ellen R., 2008. "Are structural VARs with long-run restrictions useful in developing business cycle theory?", *Journal of Monetary Economics*, vol. 55(8), 1337-1352.

Cooley, T., and Prescott, E., (1995), "Economic Growth and Business Cycles", in *Frontiers of Business Cycle Research*, ed. by T. Cooley, chapter 1. Princeton University Press, Princeton.

Gali, J.,1999. "Technology, employment and the Business Cycle: do technology shocks explain aggregate fluctuations?", *American Economic Review*, 89(1), 249-271.

Gali, J., Gambetti,L., 2009. "On the sources of Great Moderation", *American Economic Journal: Macroeconomics* 1(1),26-57.

Justiniano, A., Michelacci,C., 2011. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies in the US and Europe", *NBER Working Papers* 17429, National Bureau of Economic Research, Inc.

Krause, Michael U. & Lubik, Thomas A., 2007. "The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions," *Journal of Monetary Economics,* vol. 54(3), 706-727.

Kydland, F. E., Prescott, E. C., 1982. "Time to Build and Aggregate Fluctuations", *Econometrica*, vol. 50(6), 1345-70.

López-Salido,D., Michelacci,C.,2007. "Technology Shocks and Job Flows", *Review of Economic Studies*, 74(4), 1195-1227.

McConnell, M. M. , Perez-Quiros, G., 2000. "Output Fluctuations in the United States: What Has Changed since the Early 1980's?," *American Economic Review*, vol. 90(5), 1464-1476.

Merz, M., 1995. "Search in the labor market and the real business cycle," *Journal of Monetary Economics*, vol. 36(2), 269-300.

Miyamoto, H., 2011. "Cyclical behavior of unemployment and job vacancies in Japan," *Japan and the World Economy*, vol. 23(3), 214-225.

Mortensen, D., Pissarides, C., 1994. "Job creation and job destruction in the theory of unemployment", *Review of Economic Studies*, 61,397-415.

Sala, H., Silva, J. 2005. "The Relevance of Post-Match LTC: Why Has the Spanish Labor Market Become as Volatile as the US One?", *IZA Discussion Papers 1823*, Institute for the Study of Labor (IZA).

Shimer, R.,2005. "The cyclical behavior of equilibrium unemployment and vacancies", *American Economic Review*, 95(1),25-49.

## Appendix A: Tables

Table A1: Quarterly correlations using GDP per hour worked

| | | ρ(p,u) | ρ(p,e) | ρ(p,v) | ρ(p,v/u) |
|---|---|---|---|---|---|
| | 1970I-1984IV | -0.45** | 0.37** | 0.56** | 0.56** |
| | | (0.10) | (0.11) | (0.09) | (0.09) |
| U.S. | 1985I-2007IV | 0.07 | 0.02 | -0.38** | -0.37** |
| | | (0.10) | (0.10) | (0.09) | (0.09) |
| | 1970I-2007IV | -0.23** | 0.22** | 0.11 | 0.15* |
| | | (0.08) | (0.08) | (0.08) | (0.08) |
| | 1970I-1984IV | 0.34** | -0.42** | 0.35** | 0.34** |
| | | (0.12) | (0.11) | (0.11) | (0.12) |
| U.K. | 1985I-2007IV | 0.05 | -0.18* | 0.64** | 0.51** |
| | | (0.10) | (0.10) | (0.06) | (0.08) |
| | 1970I-2007IV | 0.20** | -0.29** | 0.47** | 0.40* |
| | | (0.08) | (0.07) | (0.06) | (0.07) |
| | 1972IV-1984IV | 0.36** | -0.33** | -0.19 | -0.48** |
| | | (0.13) | (0.13) | (0.17) | (0.15) |
| Spain | 1985I-2007IV | 0.80** | -0.80** | -0.11 | -0.28** |
| | | (0.04) | (0.04) | (0.11) | (0.10) |
| | 1972IV-2007IV | 0.69** | -0.68** | -0.08 | -0.28** |
| | | (0.04) | (0.05) | (0.09) | (0.09) |
| | 1970I-1984IV | -0.21* | -0.58** | 0.13 | 0.56** |
| | | (0.12) | (0.09) | (0.13) | (0.13) |
| Germany | 1985I-2007IV | -0.18* | 0.08 | 0.20** | 0.21** |
| | | (0.10) | (0.10) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.19** | -0.31** | 0.14* | 0.40** |
| | | (0.08) | (0.07) | (0.08) | (0.08) |
| | 1970I-1984IV | -0.39** | -0.06 | 0.26** | 0.20 |
| | | (0.11) | (0.13) | (0.12) | (0.13) |
| Sweden | 1985I-2007IV | 0.02 | -0.12 | 0.16* | 0.10 |
| | | (0.10) | (0.10) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.04 | -0.09 | 0.19** | 0.16** |
| | | (0.08) | (0.08) | (0.08) | (0.08) |
| | 1970I-1984IV | -0.18 | 0.28** | -0.07 | -0.19 |
| | | (0.14) | (0.13) | (0.14) | (0.14) |
| Norway | 1985I-2007IV | -0.11 | -0.14 | -0.22** | -0.20** |
| | | (0.10) | (0.10) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.11 | -0.04 | -0.16** | -0.19** |
| | | (0.08) | (0.08) | (0.08) | (0.08) |
| | 1970I-1984IV | 0.02 | 0.13 | 0.46** | 0.35** |
| | | (0.13) | (0.13) | (0.10) | (0.11) |
| Japan | 1985I-2007IV | -0.19 | -0.04 | 0.40** | 0.33** |
| | | (0.10) | (0.10) | (0.09) | (0.09) |
| | 1970I-2007IV | -0.13 | 0.03 | 0.42** | 0.29** |
| | | (0.08) | (0.08) | (0.07) | (0.07) |

Note: For data s.e. are in parenthesis and significance is indicated by one asterisk (10-percent level) or two asterisks (5-percent level)

Table A2: Quarterly correlations using GDP per employee

| | | ρ(p,u) | ρ(p,e) | ρ(p,v) | ρ(p,v/u) |
|---|---|---|---|---|---|
| U.S. | 1970I-1984IV | -0.59** | 0.32** | 0.58** | 0.57** |
| | | (0.08) | (0.12) | (0.09) | (0.09) |
| | 1985I-2007IV | -0.29** | 0.35** | 0.23** | 0.23** |
| | | (0.10) | (0.09) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.49** | 0.35** | 0.43** | 0.43** |
| | | (0.06) | (0.07) | (0.07) | (0.07) |
| U.K. | 1970I-1984IV | -0.11 | 0.09 | 0.66** | 0.49** |
| | | (0.13) | (0.13) | (0.07) | (0.10) |
| | 1985I-2007IV | -0.07 | 0.04 | 0.72** | 0.61** |
| | | (0.10) | (0.10) | (0.05) | (0.07) |
| | 1970I-2007IV | -0.09 | 0.08 | 0.70** | 0.54** |
| | | (0.08) | (0.08) | (0.04) | (0.06) |
| Spain | 1972IV-1984IV | 0.37** | -0.40** | -0.14 | -0.41** |
| | | (0.12) | (0.12) | (0.18) | (0.16) |
| | 1985I-2007IV | 0.89** | -0.92** | -0.54** | -0.61** |
| | | (0.02) | (0.02) | (0.08) | (0.07) |
| | 1972IV-2007IV | 0.81** | -0.84** | -0.42** | -0.57** |
| | | (0.03) | (0.02) | (0.08) | (0.06) |
| Germany | 1970I-1984IV | -0.27** | -0.55** | 0.22* | 0.64** |
| | | (0.12) | (0.09) | (0.12) | (0.11) |
| | 1985I-2007IV | -0.21** | -0.09 | 0.18* | 0.19* |
| | | (0.10) | (0.10) | (0.10) | (0.10) |
| | 1970I-2007IV | -0.23** | -0.35** | 0.20** | 0.44** |
| | | (0.08) | (0.07) | (0.08) | (0.07) |
| Sweden | 1970I-1984IV | -0.33** | 0.05 | 0.39** | 0.30** |
| | | (0.12) | (0.13) | (0.11) | (0.12) |
| | 1985I-2007IV | 0.19* | -0.41** | 0.23** | 0.03 |
| | | (0.10) | (0.09) | (0.10) | (0.10) |
| | 1970I-2007IV | 0.11 | -0.32** | 0.28** | 0.16* |
| | | (0.08) | (0.07) | (0.08) | (0.08) |
| Norway | 1970I-1984IV | -0.23* | -0.26** | 0.30** | 0.28** |
| | | (0.13) | (0.13) | (0.13) | (0.13) |
| | 1985I-2007IV | 0.19* | -0.47** | -0.36** | -0.33** |
| | | (0.10) | (0.08) | (0.09) | (0.09) |
| | 1970I-2007IV | 0.13 | -0.42** | -0.15* | -0.14* |
| | | (0.08) | (0.07) | (0.08) | (0.08) |
| Japan | 1970I-1984IV | -0.41** | 0.20* | 0.54** | 0.46** |
| | | (0.12) | (0.12) | (0.07) | (0.08) |
| | 1985I-2007IV | -0.69** | 0.24** | 0.80** | 0.89** |
| | | (0.08) | (0.10) | (0.05) | (0.06) |
| | 1970I-2007IV | -0.60** | 0.26** | 0.71** | 0.65** |
| | | (0.07) | (0.07) | (0.04) | (0.05) |

Table A3: Quarterly correlations using GDP per employee (Cont.)

| | | ρ(p,u) | ρ(p,e) | ρ(p,v) | ρ(p,v/u) |
|---|---|---|---|---|---|
| Canada | 1970I-1984IV | -0.17 | -0.15 | 0.30** | 0.34** |
| | | (0.12) | (0.13) | (0.12) | (0.12) |
| | 1985I-2007IV | -0.49** | 0.35** | 0.54** | 0.51** |
| | | (0.08) | (0.09) | (0.08) | (0.09) |
| | 1970I-2007IV | -0.36** | 0.12 | 0.45** | 0.43** |
| | | (0.07) | (0.08) | (0.07) | (0.07) |
| Italy | 1970I-1984IV | -0.29** | -0.08 | - | - |
| | | (0.12) | (0.13) | | |
| | 1985I-2007IV | 0.36** | -0.38** | - | - |
| | | (0.09) | (0.09) | | |
| | 1970I-2007IV | 0.12 | -0.24** | - | - |
| | | (0.08) | (0.08) | | |
| Portugal | 1972IV-1984IV | - | - | - | - |
| | 1985I-2007IV | 0.12 | -0.62** | 0.12 | 0.02 |
| | | (0.10) | (0.06) | (0.10) | (0.10) |
| | 1985I-2010IV | 0.11 | -0.56** | 0.09 | 0.01 |
| | | (0.10) | (0.07) | (0.10) | (0.10) |
| Australia | 1970I-1984IV | 0.02 | -0.31** | 0.65** | 0.44** |
| | | (0.13) | (0.12) | (0.12) | (0.18) |
| | 1985I-2007IV | 0.07 | -0.58** | 0.27** | -0.09 |
| | | (0.10) | (0.07) | (0.10) | (0.10) |
| | 1970I-2007IV | 0.06 | -0.50** | 0.27** | -0.06 |
| | | (0.08) | (0.06) | (0.09) | (0.08) |
| France | 1970I-1984IV | -0.73** | 0.67** | - | - |
| | | (0.06) | (0.07) | | |
| | 1985I-2007IV | -0.28** | 0.20** | -0.02 | 0.15 |
| | | (0.10) | (0.10) | (0.12) | (0.11) |
| | 1970I-2007IV | -0.38** | 0.29** | - | - |
| | | (0.07) | (0.07) | | |

Notes: All data is extracted from OECD database and seasonally adjusted. The cyclical component is obtained using HP filter with smoothing parameter $10^5$. Unemployment for U.K. starts in 1971I. Vacancies for Spain start n 1978I and the series ends in 2005I. v/u in Germany starts in 1978I. v starts in 1989I in France and in 1979II in Australia.
For data s.e. are in parenthesis and significance is indicated by one asterisk (10-percent level) or two asterisks (5-percent level).

Table A4: Correlations using GDP per hour worked (Anual)

| | | ρ(p,u) | ρ(p,e) |
|---|---|---|---|
| | 1955-1984 | -0.49** | -0.25 |
| | | (0.14) | (0.17) |
| U.S. | 1985-2010 | -0.12 | -0.22 |
| | | (0.20) | (0.19) |
| | 1955-2010 | -0.31** | -0.26 |
| | | (0.12) | (0.13) |
| | 1955-1984 | -0.33** | 0.56** |
| | | (0.17) | (0.13) |
| France | 1985-2010 | 0.47** | -0.34* |
| | | (0.16) | (0.18) |
| | 1955-2010 | -0.05 | 0.18 |
| | | (0.14) | (0.13) |
| | 1955-1984 | -0.64** | -0.81** |
| | | (0.12) | (0.07) |
| Italy | 1985-2010 | 0.70** | -0.45** |
| | | (0.10) | (0.17) |
| | 1955-2010 | -0.21 | -0.65** |
| | | (0.13) | (0.08) |
| | 1955-1984 | -0.14 | -0.72** |
| | | (0.19) | (0.09) |
| Portugal | 1985-2010 | -0.24 | 0.12 |
| | | (0.19) | (0.20) |
| | 1955-2010 | -0.12 | -0.46** |
| | | (0.13) | (0.11) |

Table A5: Correlations using GDP per hour worked (Anual) (Cont.)

| | | ρ(p,u) | ρ(p,e) |
|---|---|---|---|
| Spain | 1955-1984 | 0.03 | -0.23 |
| | | (0.14) | (0.18) |
| | 1985-2010 | 0.77** | -0.85** |
| | | (0.20) | (0.05) |
| | 1955-2010 | 0.43** | -0.55** |
| | | (0.12) | (0.09) |
| Argentina | 1955-1984 | - | -0.39** |
| | | | (0.16) |
| | 1985-2010 | - | -0.36** |
| | | | (0.17) |
| | 1955-2010 | - | -0.37** |
| | | | (0.12) |
| Brazil | 1955-1984 | - | 0.53** |
| | | | (0.13) |
| | 1985-2010 | - | -0.22 |
| | | | (0.19) |
| | 1955-2010 | - | 0.23* |
| | | | (0.13) |
| Chile | 1955-1984 | - | -0.16 |
| | | | (0.18) |
| | 1985-2010 | - | -0.13 |
| | | | (0.20) |
| | 1955-2010 | - | -0.21 |
| | | | (0.13) |
| Mexico | 1955-1984 | - | 0.09 |
| | | | (0.18) |
| | 1985-2010 | - | -0.74** |
| | | | (0.09) |
| | 1955-2010 | - | -0.41** |
| | | | (0.11) |
| Peru | 1955-1984 | - | -0.69** |
| | | | (0.10) |
| | 1985-2010 | - | -0.64** |
| | | | (0.12) |
| | 1955-2010 | - | -0.66** |
| | | | (0.08) |

Note: data is detrended using a HP filter with smoothing parameter 6250. S.e. are in parenthesis and significance is indicated by one asterisk (10-percent level) or two asterisks (5-percent level)

Table A6: Summary Statistics of employment for countries and model data 1973-2007

| | U.S. | | U.K. | | Germany | | Spain | | Sweden | | Norway | | Japan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Data | Model | Data | Model | Data | Model | Data | Model | Data | Model | Data | Model | Data | Model |
| Standard deviation | 0.006 | 0.007 | 0.005 | 0.001 | 0.005 | 0.004 | 0.008 | 0.002 | 0.006 | 0.001 | 0.006 | 0.001 | 0.003 | 0.005 |
| Autocorrelation | 0.70 | 0.75 | 0.76 | 0.71 | 0.76 | 0.77 | 0.79 | 0.72 | 0.75 | 0.75 | 0.68 | 0.77 | 0.58 | 0.71 |

# Appendix B: Figures

Figure B1: Cyclical Components of Productivity, Employment and Unemployment in U.S. and U.K.

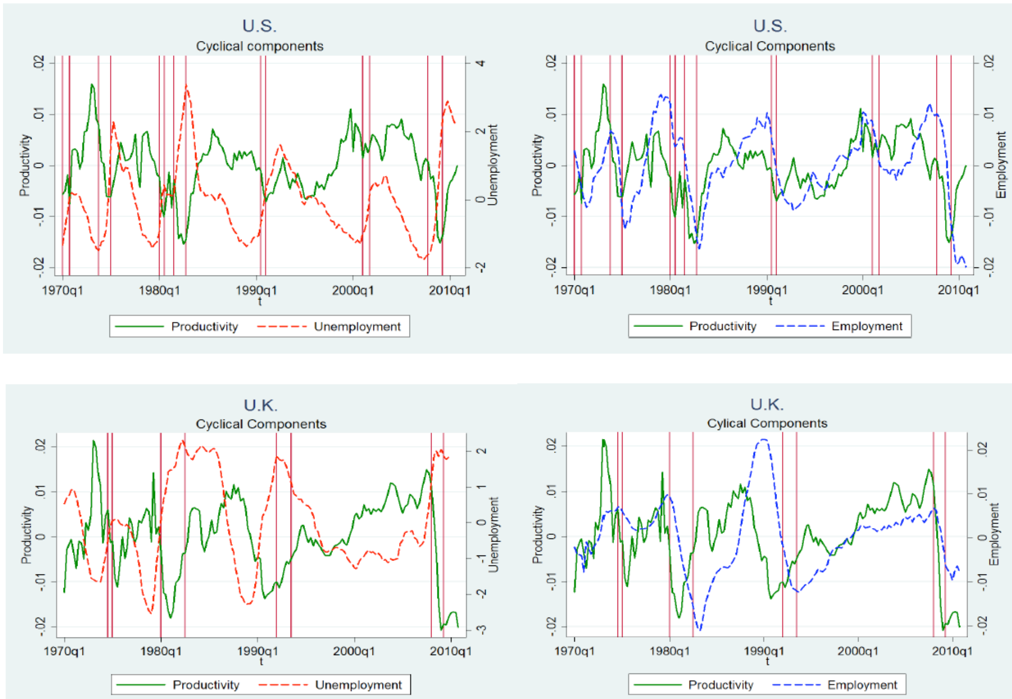



Figure B2: Cyclical Components of Productivity, Employment and Unemployment in Spain and Italy

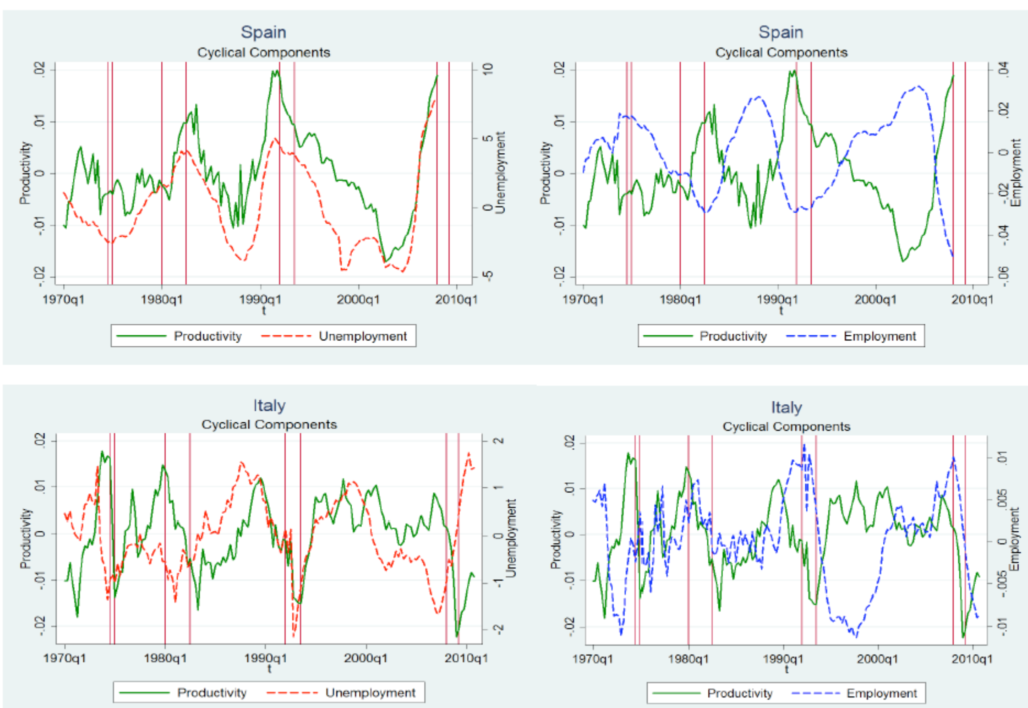


Figure B3: Cyclical Components of Productivity, Employment and Unemployment in Norway and Sweden

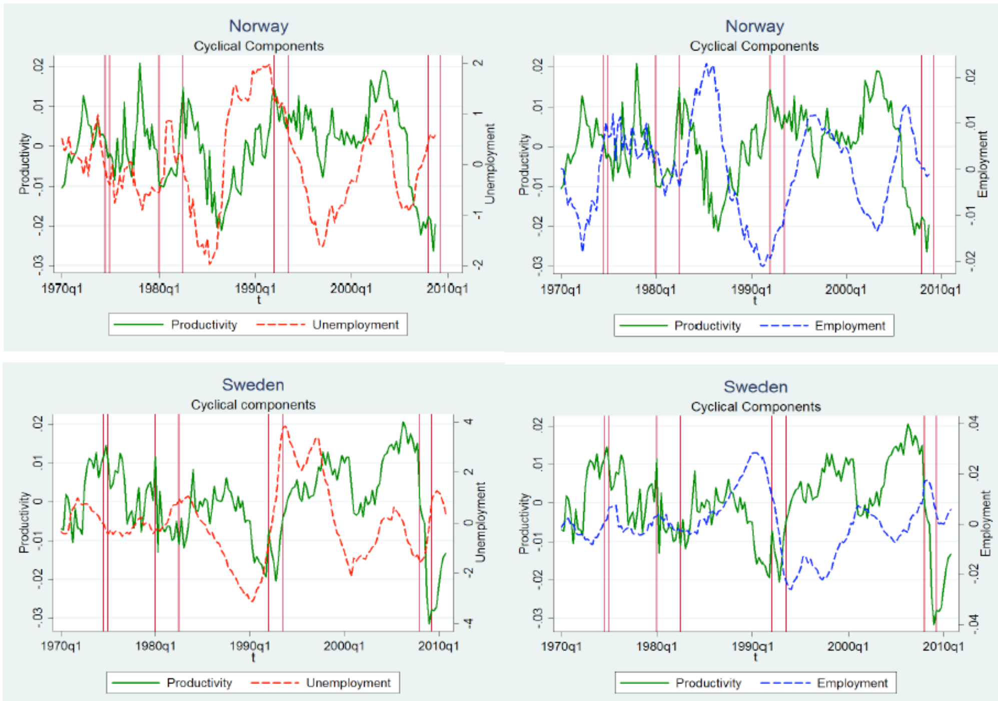



Figure B4: Cyclical Components of Productivity, Employment and Unemployment in Germany

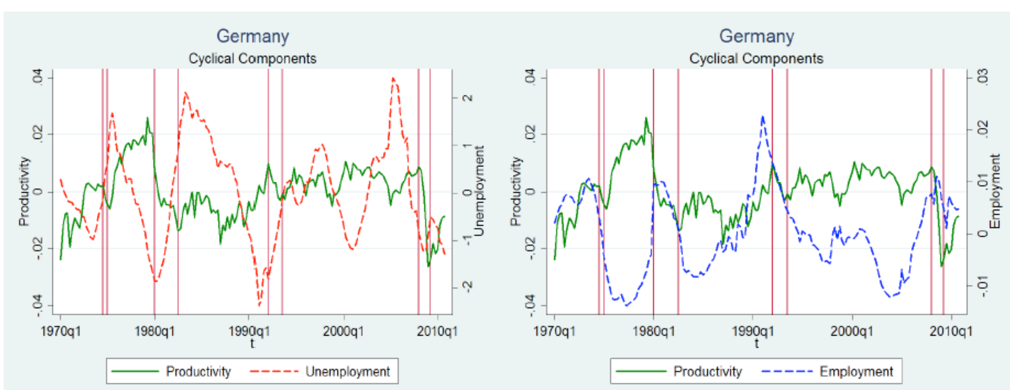


Figure B5: Cyclical Components of Productivity, Employment in Latin Countries

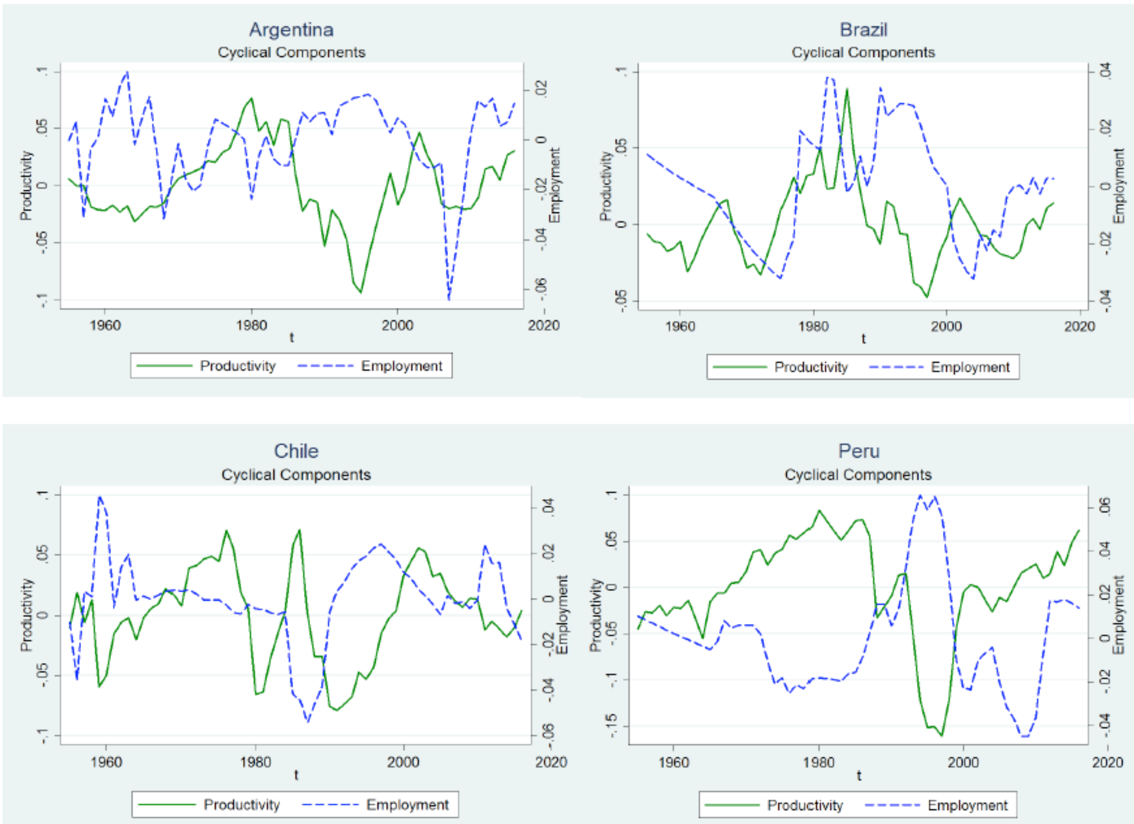


Figure B6: Empirical impulse Response functions for U.K.

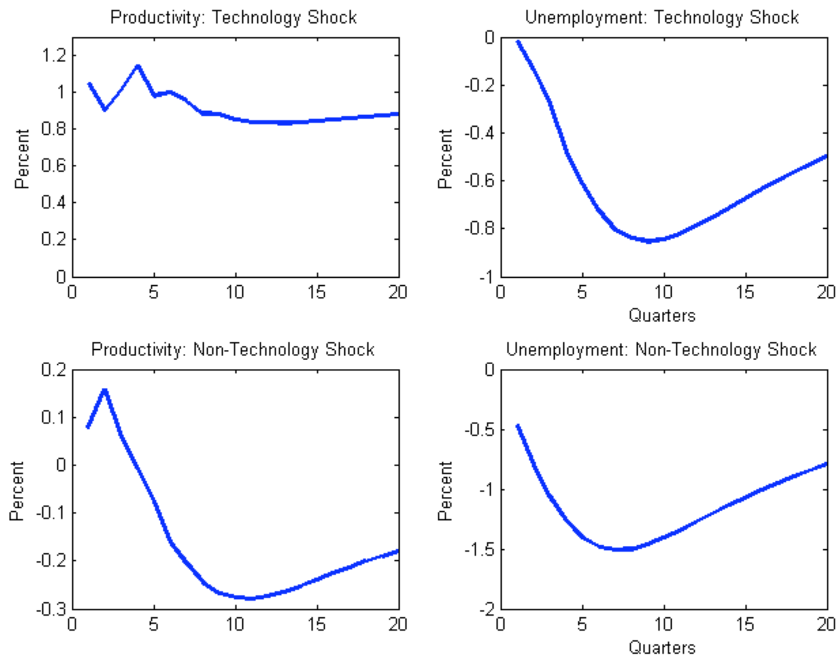



Figure B7: Empirical impulse Response functions for Sweden

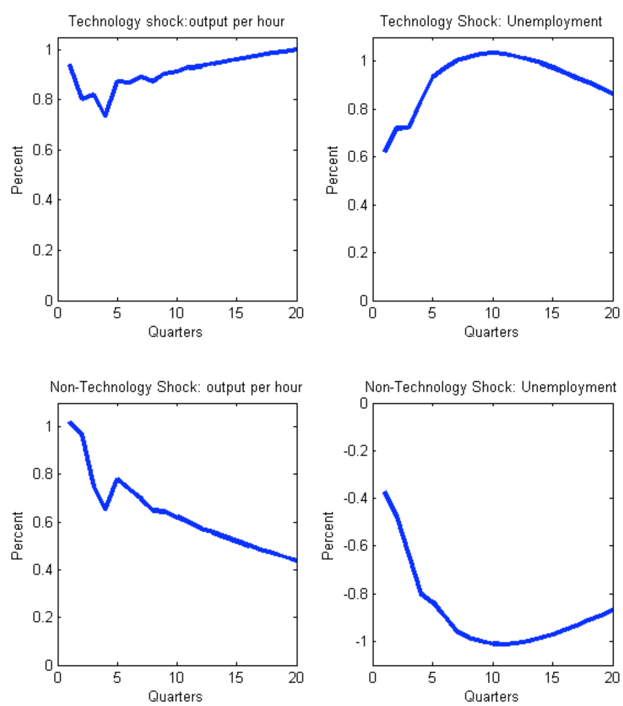


Figure B8: Empirical impulse Response functions for Norway

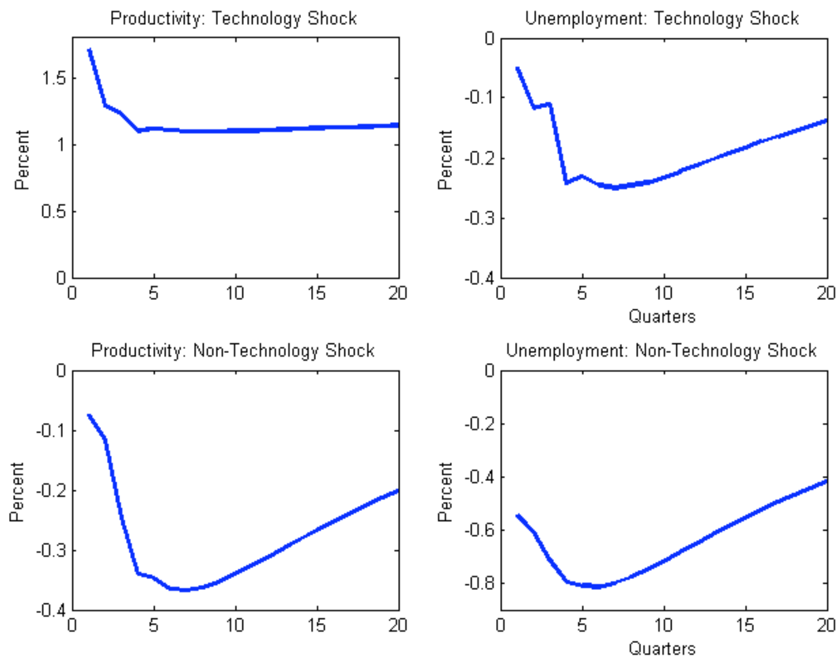



Figure B9: Empirical impulse Response functions for Japan

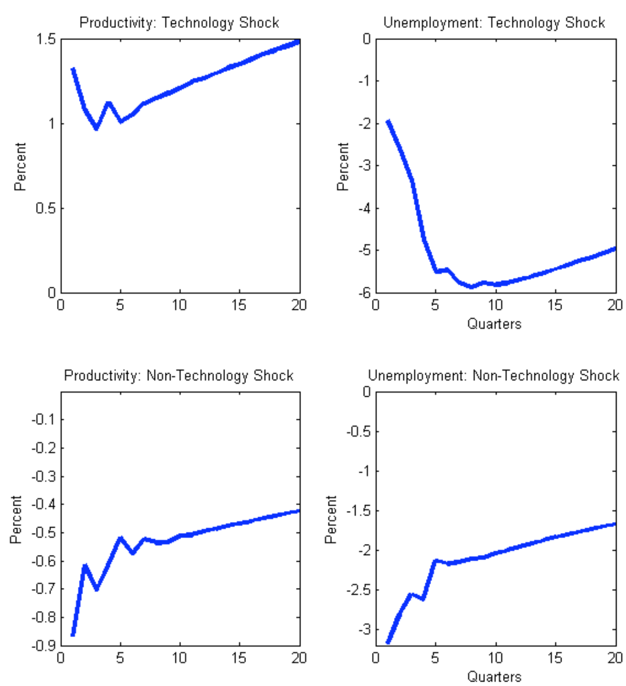


Figure B10: Impulse Response Functions Sweden: Data and Model

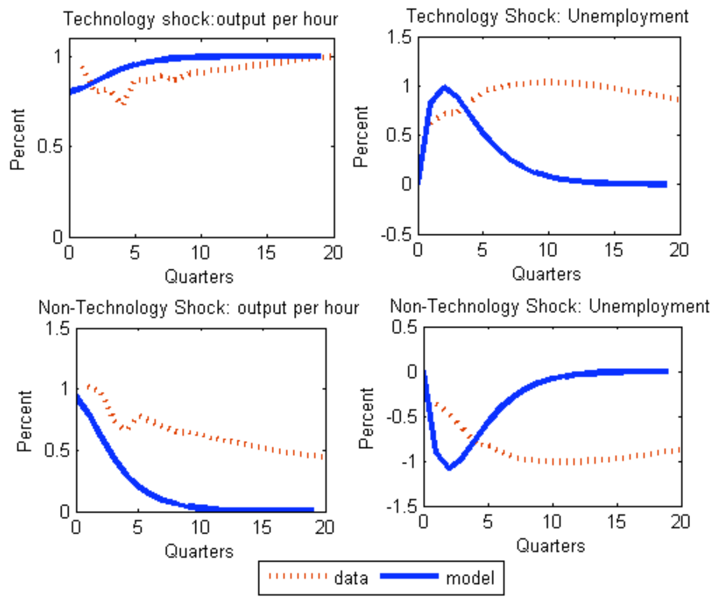
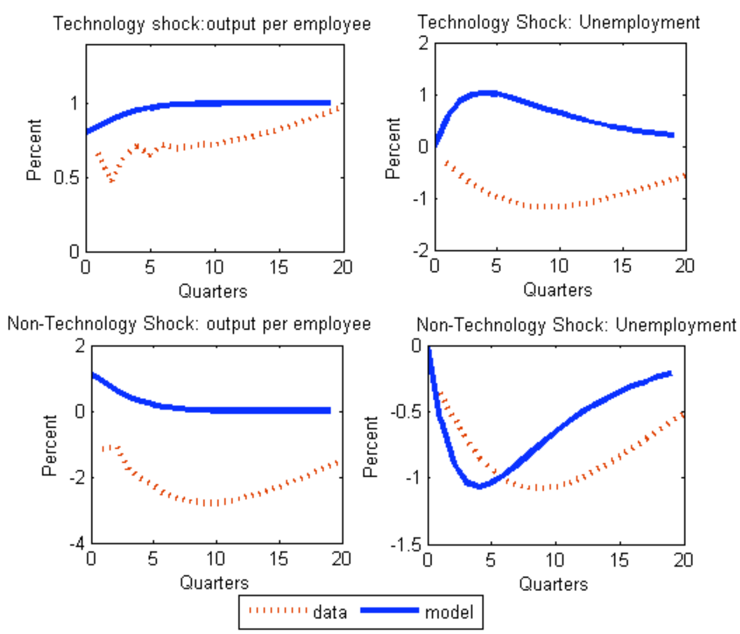



Figure B11: Impulse Response Functions Spain: Data and Model



## MASTER'S THESIS CEMFI

0801 *Paula Inés Papp*: "Bank lending in developing countries: The effects of foreign banks".

0802 *Liliana Bara*: "Money demand and adoption of financial technologies: An analysis with household data".

0803 *J. David Fernández* Fernández: "Elección de cartera de los hogares españoles: El papel de la vivienda y los costes de participación".

0804 *Máximo Ferrando Ortí*: "Expropriation risk and corporate debt pricing: the case of leveraged buyouts".

0805 *Roberto Ramos*: "Do IMF Programmes stabilize the Economy?".

0806 *Francisco Javier Montenegro*: "Distorsiones de Basilea II en un contexto multifactorial".

0807 *Clara Ruiz Prada*: "Do we really want to know? Private incentives and the social value of information".

0808 *Jose Antonio Espin*: "The "bird in the hand" is not a fallacy: A model of dividends based on hidden savings".

0901 *Víctor Capdevila Cascante*: "On the relationship between risk and expected return in the Spanish stock market".

0902 *Lola Morales*: "Mean-variance efficiency tests with conditioning information: A comparison".

0903 *Cristina Soria Ruiz-Ogarrio*: "La elasticidad micro y macro de la oferta laboral familiar: Evidencia para España".

0904 *Carla Zambrano Barbery*: "Determinants for out-migration of foreign-born in Spain".

0905 *Álvaro de Santos Moreno*: "Stock lending, short selling and market returns: The Spanish market".

0906 *Olivia Peraita*: "Assessing the impact of macroeconomic cycles on losses of CDO tranches".

0907 *Iván A. Kataryniuk Di Costanzo:* "A behavioral explanation for the IPO puzzles".

1001 *Oriol Carreras:* "Banks in a dynamic general equilibrium model".

1002 *Santiago Pereda-Fernández:* "Quantile regression discontinuity: Estimating the effect of class size on scholastic achievement".

1003 *Ruxandra Ciupagea:* "Competition and "blinders": A duopoly model of information provision".

1004 *Rebeca Anguren:* "Credit cycles: Evidence based on a non-linear model for developed countries".

1005 *Alba Diz:* "The dynamics of body fat and wages".

1101 *Daniela Scidá:* "The dynamics of trust: Adjustment in individual trust levels to changes in social environment".

1102 *Catalina Campillo:* "Female labor force participation and mortgage debt".

1103 *Florina Raluca Silaghi:* "Immigration and peer effects: Evidence from primary education in Spain".

1104 *Jan-Christoph Bietenbeck:* "Teaching practices and student achievement: Evidence from TIMSS".

1105 *Andrés Gago:* "Reciprocity: Is it outcomes or intentions? A laboratory experiment".

1201 *Rocío Madera Holgado:* "Dual labor markets and productivity".

1202 *Lucas Gortazar:* "Broadcasting rights in football leagues and TV competition".

1203 *Mª. Elena Álvarez Corral:* "Gender differences in labor market performance: Evidence from Spanish notaries".

1204 *José Alonso Olmedo:* "A political economy approach to banking regulation".

1301 *Joaquín García-Cabo Herrero:* "Unemployment and productivity over the business cycle: Evidence from OECD countries".