Leading and Lagging Relationships in International Business Cycles

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Abstract

This paper documents that the US business cycle leads, statistically, business cycles in many other developed countries. I argue that this pattern is not largely explained by different timings of underlying shocks across countries but rather by differences in labor markets. In the US the labor market is flexible and the effects of shocks on economic activity are immediate. However, in the other countries hit by the same shock hitting the US, the effects of the shock manifest only through time since their labor markets are rigid. Therefore, statistically the US appears to be the leader. To verify this theory I introduce differential labor market frictions in a standard international business cycle model and show that the model can generate, with perfectly symmetric shocks, the same lead-lag pattern observed in the data. I bring two additional pieces of evidence in favor of the idea that labor markets are central in explaining the lead-lag patterns: i) for any given couple of countries the lead-lag pattern is much more pronounced for employment series than for output, investment and TFP. ii) countries which have more marked lead-lag patterns vis-a-vis the US are the ones with more rigid labor markets.

Keywords: Labor Protection, Asymmetric Correlations, Adjustment Cost, Leading-lagging Relation, International Business Cycles.

JEL Classification Numbers: F11, F16, F41, G15.

1 Introduction

This paper studies the leading and lagging relationships in international business cycles. I document that the US business cycle, statistically, leads the business cycles in many other developed countries. The main contribution of the paper is to argue that this pattern is not largely explained by different timings of shocks across countries but rather by differences in labor markets. Considering a standard open-economy model with differential labor market frictions, I find that the model can generate, with perfectly symmetric productivity shocks, the same lead-lag relation observed in the data.

In the first part of the paper I provide a detailed documentation of lead-lag relation between the business cycle in the US and business cycles in other eighteen developed countries. I summarize this relation using the cross-correlation functions for the main macroeconomic variables between the US and the other countries, focusing on output, employment and TFP. I find that in most (but not all) countries the cycle lags the US cycle, meaning that cycles in the those countries are more correlated with lagged US movements than with contemporaneous or future US movements.

In the second part of the paper I provide an interpretation of the observed lead-lag relation in a dynamic general equilibrium framework. I introduce differential labor market frictions in a standard international business cycle model with complete markets (see, for example, Bakus, Kehoe and Kydland, 1994). In the economy, two countries produce different goods using capital and labor with symmetric productivity shocks. The only difference between countries arises from the labor market frictions which are modeled as labor adjustment costs. I find that introducing differences in labor market frictions can explain the lead-lag relation: the business cycle in the country with the flexible labor market leads the one in the country with the rigid labor market.

The intuition is simple. In a country with a flexible labor market, a positive domestic productivity shock leads to increases in employment and output immediately. Later, employment and output start to decrease when the shock begins to decline. However, the response of employment in the country with the rigid labor market is smaller on impact and hump shaped. Driven by employment, output fluctuates in a similar way in response to the shock. Thus, if the two countries are hit by the same shock, the immediate effects of the shock are larger on the "flexible" country but more persistent in the "rigid" country. Therefore, employment and GDP in the "flexible" country, statistically, lead employment and GDP in the "rigid" country. Notice that the model predicts that the leading pattern is most pronounced in employment, is absent in TFP and is moderate in GDP. The data is qualitatively consistent with this as employment displays the strongest leading pattern, and TFP displays the weakest.

In the third part of the paper I exploit the heterogeneity in lead/lag patterns across countries and across decades to provide more evidence in favor of my theory. In particular I collect data on labor market rigidities for different countries/decades and show that, after controlling for a variety of factors, including size and population, countries/decades which have more rigid labor markets (relative to the US labor market) are also country/decades for which the lagging pattern of employment is more pronounced. Interestingly, and consistently with the model, labor market rigidities are not significantly associated with lead-lag pattern in TFP.

Many empirical papers on international business cycles have studied the lead-lag pattern between the US and other economies. Giannone and Reichlin (2004) find that the shock generating the common trend in the US and the European area has larger immediate effects on the US but more persistent effects on the European area. The empirical work by Elliot and Fatás (1996) emphasizes the role of asymmetric productivity shocks in explaining the different responses of economic activity across countries. So far, the existing interpretations of the lead-lag relation in the literature are about the effects of the asymmetric propagation of shocks (Gail, 2000).

The paper is also related to the literature that has documented some convergence of business cycles within the European area and the English-speaking countries (Canada, UK and US) and, at the same time, business cycle divergence between them (Artis and Zhang 1999, Helbling and Bayoumi 2003, Prasad 2008 and Stock and Willis 2003). The fact that these two groups are also characterized by very different labor market structures suggests that labor market might be a key explanation for these patterns too.

Finally this paper is obviously related to the very large literature that argues that labor market frictions are central to understanding business cycles.

A standard real business cycle model with labor market frictions predicts the positive autocorrelation of output in the short run and improves the its empirical performance in the volatilities of hours and wages (Cogley and Nason, 1995, Merz, Andolfatto, burnside Eichenmabum Christiano).

This paper is organized as follows. The next section presents the stylized facts. Section 3 presents the model. Section 4 reports the simulation results and the interpretation. In Section 5 I present the additional evidence. Concluding remarks are offered in Section 6.

2 Data

This section documents the facts of the leading and lagging relationships in international business cycles between the US and the other developed countries in the world. The countries in the sample are the EU15 members, Australia, Canada and Japan. The data sources are the OECD and the IFS databases, quarterly from 1985:1 to 2009:1, with details attached with each table reported. All statistics refer to HP-filtered logarithms.

In Table 1, I report the cross-correlations of output with the US for each country in the sample, with leads and lags up to four quarters. Numbers on the left side of the table indicate the correlations between current movements in each country, y_t^i, and past movements in the US, y_{t+s}^{US} with $s < 0$. Numbers on the right indicate the reverse. Although the data displays large heterogeneity in the magnitudes of the cross-correlations across countries, it exhibits the typical asymmetric patterns for the cross-correlation function. First, not surprisingly, the correlation function reaches its maximum at $s = 0$ for most countries. Only France, Portugal and Spain get the highest correlation with a lag of 1.

Second, the correlations with lagged US movements are generally higher than those with future US movements. Compare the values of correlations for $s = -4$ and 4. With the same distance in the time series of output, four quarters, the correlations with negative s are far away from zero, while the others are significantly below zero.

Third, the change in correlation is much slower for negative values of s than positive ones. For Canada, the correlation decreases only by 0.02 with s from 0 to -1, but decreases by 0.14 with s from 0 to 1. France shows constant correlations with past US movements within at least four lags, around 0.57. However, this pattern fades rapidly with future US movements.

I summarize these asymmetric patterns as the lead-lag relation with the US. Table 2 and 3 report the same statistics for employment and TFP. While TFP has the similar properties of cross-correlations to output, employment appears to have more asymmetric patterns. As shown in Table 2, the maximum values of correlations are no longer the contemporaneous ones. Instead, the correlation functions reach their maximum values typically for some negative values of s. Especially, France, Italy, and Netherlands exhibit little relation of employment with the US contemporaneously. However, fluctuations of employment in these three countries today are highly correlated with the US fluctuations one year ago.

In Figure 1, I graph the cross-correlation functions of the three variables within the same diagram for each country. Those functions are generally higher in the left than right. Among the three curves, the one of employment shows the steepest slope. It suggests that the lead-lag relation is most pronounced for employment. The figure displays significant discrepancies in the lead-lag patterns between output and TFP. For most countries, the curve of output is much steeper than that of TFP. It implies that the lead-lag relation is most pronounced in employment, moderate in output and weakest in TFP.

To summarize the data clearly, I also provide Figure 2 to show the cross-correlation functions for the rest of the world (ROW for short) which is the aggregate of all the countries in the sample. This figure preserves the common properties in Figure 1 well. First, for all three variables, the correlation functions are generally higher on the left side than on the right. Second, the slope of each curve is much flatter on the left, meaning that the correlation changes slowly with lags in US movements, but fast with leads. Third, the cross-correlation function of employment is likely to be decreasing with lag. In other words, employment displays the strongest lead-lag relation, and TFP the weakest. Last, the lead-lag patterns for consumption and investment are similar to output.

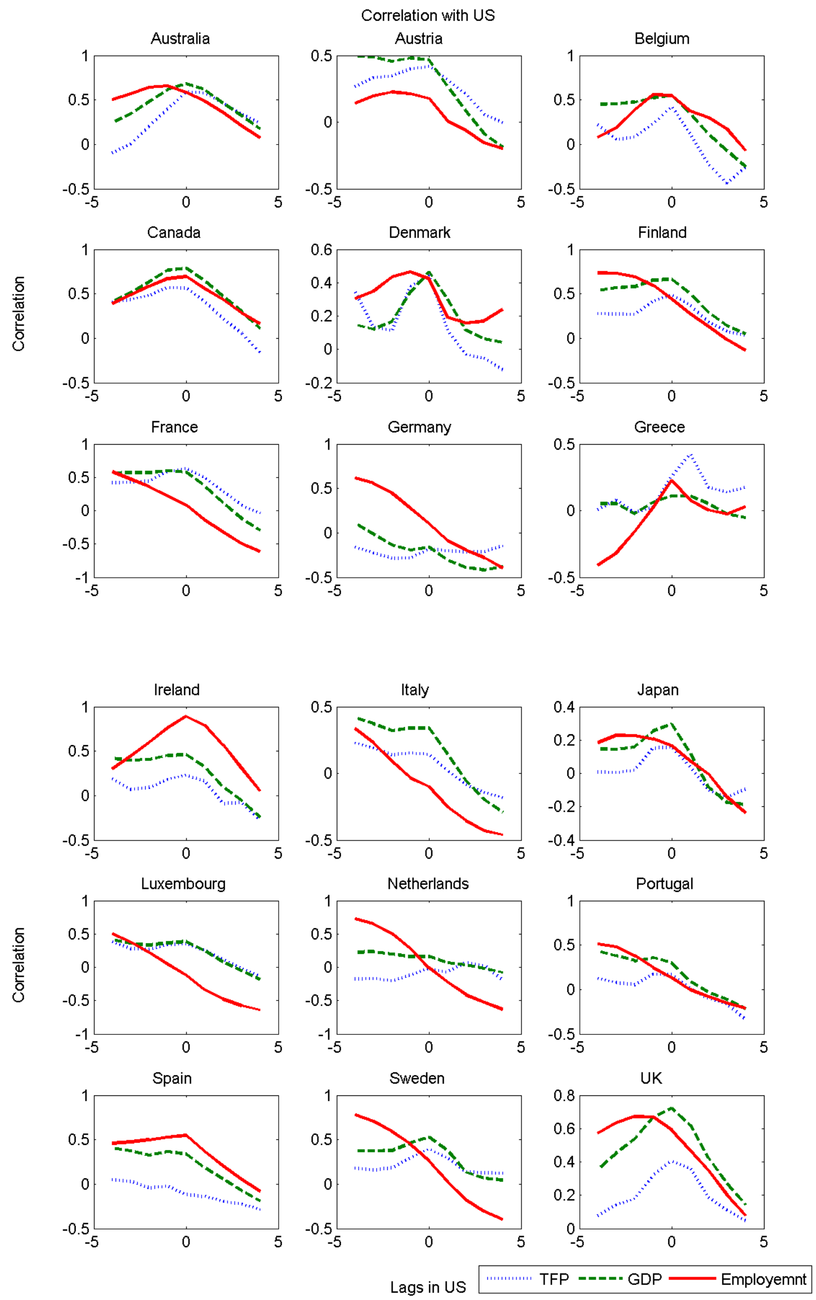

Figure 1: Cross Correlations for Each Country

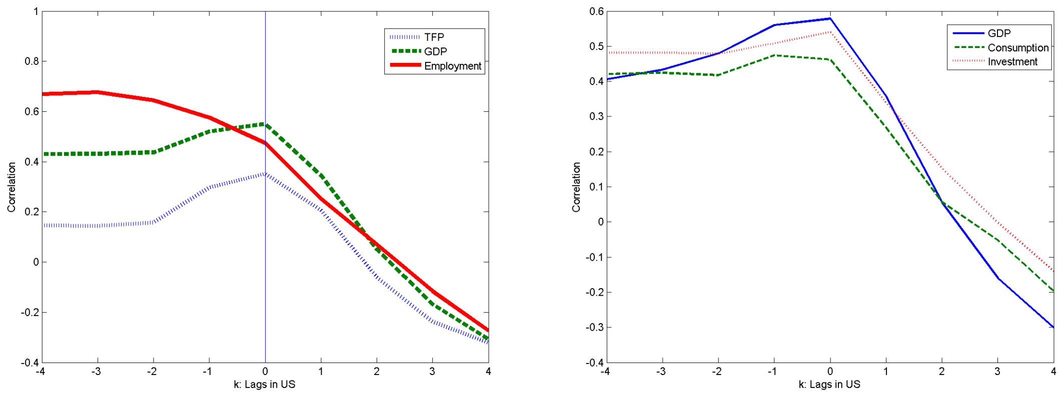

Figure 2: Cross Correlations: ROW vs US

3 Model

I apply a standard two-country two-good model by introducing labor adjustment costs to explain the leading and lagging relationships. In the theoretical world, each country specializes in the production of a different intermediate good with its own technology. In the beginning of each period t, an event $s_t \in S$ realizes, where S is the state pace. I denote by s^t the history path of events up to and including period t. In period 0, the probability of a history s^t is $\pi(s^t)$. The exogenous technology shocks are the only sources of uncertainty.

In country i, the total time endowment in each period is normalized to one. The representative household receives utility from consumption, $c_i(s^t)$, and from leisure, $1 - n_i(s^i)$, where $n_i(s^t)$ is the amount of labor supplied.

Period utility for a household after history s^t is given by

$$U\big(c_i(s^t), 1 - n_i(s^t)\big) = \frac{[c_i^{\mu}(s^t)(1 - n_i(s^t))^{1-\mu}]^{1-\gamma}}{1-\gamma} \tag{1}$$

The intermediate good produced in country 1 is labeled as a, and b for country 2. Both goods are tradable and produced using capital and labor with the same Cobb-Douglas function F:

$$F(z_i(s^t), k_i(s^{t-1}), n_i(s^t)) = e^{z_i(s^t)} k_i^{\alpha}(s^{t-1}) n_i^{1-\alpha}(s^t) \tag{2}$$

where $z_i(s^t)$ is an exogenous technology shock. $k_i(s^{t-1})$ is the capital stock in period t and is determined in the previous period. Neither labor nor capital is internationally mobile. For simplicity, I assume households make the production decisions for those intermediate goods in each country.

The law of motion for the vector shocks $z(s^t) = [z_1(s^t), z_2(s^t)]'$ is given by

$$z(s^t) = Az(s^{t-1}) + \varepsilon(s^t) \tag{3}$$

where A is a 2×2 matrix, and $\varepsilon(s^t)$ is a 2×1 vector of independently distributed random variables with variance-covariance matrix Σ.

The labor markets for intermediate goods are rigid, in the sense that for any changes in employment levels the intermediate sectors have to pay some costs using the aggregate goods which are specified in the next section. I use the quadratic function $\lambda_i \frac{(n_i(s^t) - n_i(s^{t-1}))^2}{n_i(s^t)}$ to account for the costs of adjusting labor in each period. λ_i represents the labor protection level in country i. High labor protection associates with large value of λ_i. The quadratic form of labor adjustment costs which is widely used in literature, implies that it is costly to change employment substantially within a single period.

In each country, there is a representative firm to produce the aggregate good using intermediate goods a and b. The representative household purchases the domestic aggregate good to consume, to invest, and to pay labor adjustment costs. The technology in the aggregate sector is given by

$$\begin{aligned} G_1(a_1(s^t), b_1(s^t)) &= \left[\omega a_1(s^t)^{\frac{\sigma-1}{\sigma}} + (1-\omega) b_1(s^t)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \\ G_2(a_2(s^t), b_2(s^t)) &= \left[(1-\omega) a_2(s^t)^{\frac{\sigma-1}{\sigma}} + \omega b_2(s^t)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \end{aligned}$$

where σ is the elasticity of substitution between good a and b. The weight ω allows us to match the home bias in consumption on domestic and foreign goods. Good a is the numeraire, $p(s^t)$ is the terms of trade in country 1. Let P_i be the price of the aggregate good in units of good a in country i. The firm's problem in aggregate sector given history s^t in period t is:

$$\max_{a_i(s^t), b_i(s^t) \geq 0} P_i(s^t) G_i(a_i(s^t), b_i(s^t)) - a_i(s^t) - p(s^t) b_i(s^t) \tag{4}$$

Furthermore, the market clearing conditions on the final good markets in each country are

$$c_i(s^t) + x_i(s^t) = G_i(a_i(s^t), b_i(s^t)) - \lambda_i \frac{(n_i(s^t) - n_i(s^{t-1}))^2}{n_i(s^t)} \tag{5}$$

for any period t and any history s^t, where $x_i(s^t)$ is the investment. That is, the aggregate good serves as the final good and intermediate good at the same time.

Last, the capital accumulates in a standard way with a depreciation rate δ:

$$k_i(s^t) = x_i(s^t) + (1-\delta)k_i(s^{t-1}) \tag{6}$$

The financial markets are complete. There is a complete set of Arrow-Debreu securities denominated in units of good a. $B_i(s^t, s_{t+1})$ is the amount of bonds purchased by the representative household of country i in period t given history s^t. Each share pays one unit of good a in period $t+1$ if the state of the economy is s_{t+1} in period $t+1$. The price of these bonds is $q(s^t, s_{t+1})$ in terms of good a.

Equilibrium

An equilibrium is a set of prices $(P_1(s^t), P_2(s^t), p(s^t), q(s^t, s_{t+1}))$ and allocations for all s^t and t such that

- Given the prices, the allocation in each country maximizes the representative household's expected utility $\sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t)\beta^t U(c_i(s^t), 1 - n_i(s^t))$

such that equation (6) and the following budget constraints are satisfied:

$$P_i(s^t)[c_i(s^t) + x_i(s^t)] + \sum_{s_{t+1}} q(s^t, s_{t+1}) B_i(s^t, s_{t+1}) =$$

$$B_i(s^t) - P_i(s^t)\lambda_i \tfrac{(n_i(s^t) - n_i(s^{t-1}))^2}{n_i(s^{t-1})} + \begin{cases} F_1(z_1(s^t), k_1(s^{t-1}), n_1(s^t)) & \text{if } i = 1 \\ p(s^t) F_2(z_2(s^t), k_2(s^{t-1}), n_2(s^t)) & \text{if } i = 2 \end{cases}$$

for any s^t and t,

- Given prices, the allocation in each country solves the aggregate good firm's problem (4).
- Markets are clear:
  - For intermediate goods,

$$\begin{aligned} a_1(s^t) + a_2(s^t) &= F_1(z_1(s^t), k_1(s^{t-1}), n_1(s^t)) \\ b_1(s^t) + b_2(s^t) &= F_2(z_2(s^t), k_2(s^{t-1}), n_2(s^t)) \end{aligned}$$

  - For final goods, equation (5) holds for each country.
  - For financial markets,

$$B_1(s^t, s_{t+1}) + B_2(s^t, s_{t+1}) = 0$$

for any s^t and s_{t+1}.

GDP Accounting

To be consistent with the calculation method of real output in constant prices in the data, I need to verify the amount of intermediate goods used in the production of final goods. Since the model assumes that the labor adjustment costs have to be paid by the aggregate goods, the real output is no longer the amount of the intermediate good produced in each period. Therefore both good a and b serve as the final goods in consumption and investment and as the intermediate goods to pay the labor adjustment costs when we calculate the real output by expenditure approach as in the data. Note that the production functions in the aggregate sectors are homogeneous of degree one, hence the real output $y_i(s^t)$ in country i using the constant prices of good a and b in the initial period is measured by

$$y_i(s^t) = \frac{c_i(s^t) + x_i(s^t)}{G_i(s^t)}(a_i(s^t) + p(s^0)b_i(s^t)) + \begin{cases} a_2(s^t) - p(s^0)b_1(s^t) & \text{if } j = 1 \\ p(s^0)b_1(s^t) - a_2(s^t) & \text{if } j = 2 \end{cases}$$

where the last item is the real export.

4 Calibration

4.1 Parameter values and Computation

The parameter values are reported in Table 4. I identify country 1 as the ROW and country 2 as the US. Parameters concerning the preferences and production functions are set to have the properties of the steady state in the model consistent with the data. Details on how to select the parameters are the same as those in BKK(1994). The elasticity of substitution between good a and b, σ, is taken from Heathcote and Perri(2002).

The productivity is calculated by

$$z_i(s^t) = \log y_i(s^t) - (1-\alpha)\log n_i(s^t), \quad i = 1, 2 \tag{7}$$

where $y_i(s^t)$ and $n_i(s^t)$ are the real output and employment in each economy. The estimates of the transition matrix A with and without symmetry assumption are both reported in Table 4.

Here, I estimate the transition matrix using the HP-filtered data of productivity. Comparing the estimates of A using HP-filtered data and unfiltered data, I find that the lead-lag relation for TFP preserves much better by using HP-filtered data, with little change in the contemporaneous correlation. I show the cross-correlation functions generated by these two estimates of A in Figure 12. We can see that the estimate of transition matrix by unfiltered TFP data can not generate the similar timing patterns of TFP as the data.[1] Hence the estimates of A used in this paper are not similar to those in the literature.

[1] I find the same problem for the estimate of A in BKK(1992) which uses data of US and EU from 1970:1 to 1986:4. The cross-correlation function of TFP generated shows the opposite lead-lag relation compared with the data).

The estimation of A uses the following equation:

$$z_t = z_0 + Az_{t-1} + \varepsilon_t$$

where z_0 is a constant 2×1 vector. The symmetric transition matrix is estimated by imposing symmetry assumption in the regression.

The selection of λ_i is the following. First, I choose the value of λ_2 to match the contemporaneous correlation of employment in the US data. Then let λ_1 to match the ratio of the relative volatility of employment to output between the two economies, $\frac{\sigma(n^{Agg})}{\sigma(y^{Agg})} / \frac{\sigma(n^{US})}{\sigma(y^{US})}$. The underlying reason for choosing λ_i by this way is that, with a rigid labor market, employment in the country does not change substantially in response to productivity shocks. Hence the volatility of employment is low. Different values of λ_i are selected for different transition matrices.

Finally, to solve the model, I log-linearize the equations that characterize the equilibrium around the steady state. See the appendix for the equations describing the equilibrium.

4.2 Results

This section lays out the simulation results for different productivity processes and parameter values of λs provided in Table 4. Statistics about volatilities and contemporaneous correlations with domestic output in each country are reported in Table 5 and 6.

It is useful to start with an experiment varying the value of λ_1 with a symmetric productivity process. This experiment provides an assessment of the importance of labor market frictions in explaining the lead-lag relation in international business cycles. The productivity process applied in this experiment is the symmetric process specified in Table 4 with

$$A = \begin{bmatrix} 0.818 & 0.113 \\ 0.113 & 0.818 \end{bmatrix}.$$

I set the labor market rigidity parameter $\lambda_2 = 0$, and vary the value of λ_1 from 3.8 to 10. Thus country 1 is identified as the "rigid" country. The cross-correlation functions of employment, output and TFP of country 1 are reported graphically in Figure 3.

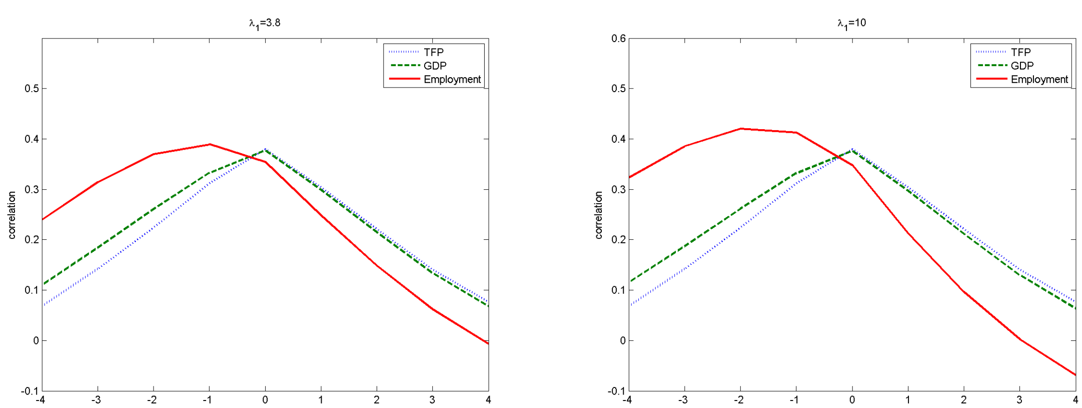

Figure 3: Experiment: Symmetry TFP Process

I have the following observations. First, the differential labor market frictions do give rise to the lead-lag relation of employment in absence of an asymmetric productivity process. In Figure 3, the two cross-correlation functions of employment have the similar asymmetric patterns observed in the data, with slow increase on the left and fast decrease on the right. It indicates that the effects of shocks are more persistent in the "rigid" country. Second, the lead-lag relation of employment is more pronounced in the more rigid labor market. The cross-correlation function of employment reaches its maximum at lag $k = -1$ when $\lambda_1 = 3.8$, but at lag $k = -2$ when $\lambda_1 = 10$. An increase in the labor market rigidity (λ_1) leads to an increase in the correlation with lagged movements in the "flexible" country ($corr(d_t^1, d_{t-k}^2)$), a decrease in the correlation with future movements ($corr(d_t^1, d_{t+k}^2)$) and little change in the contemporaneous correlation. This implies that introducing differential labor frictions can improve the model in explaining the lead-lag relation without losing the contemporaneous properties of the standard model. Third, the cross-correlation function of output has the more asymmetric shape than TFP. Thus the theory predicts that the lead-lag pattern is most pronounced in employment, is modest in output and is absent in TFP.

Now I turn to the calibrated results. Obviously, with a symmetric productivity process and zero labor adjustment costs, every variable has the same symmetric tent-shaped correlation function as TFP. The statistics for this case are listed in Table 5 and 6 as the benchmark case. Note that with the estimate of the transition matrix using HP-filtered TFP data, the contemporaneous correlation of employment is now positive in the benchmark case. In the end of this section, I will discuss the role of this positive correlation in success of my theory. However, using HP-filtered data gives me the volatilities of the innovations (0.002) much lower than those in the literature (for example, Heathcote and Perri, 2002), and hence low volatilities of outputs in my results. In a business cycle model, the volatility of output mainly results from productivity shocks, while in the data productivity shocks can only account for part of it. As shown in Table 5, the relative standard deviation of TFP to output is only 0.28 in the US, whereas it is 0.69 in the model without labor adjustment costs.

For the case of symmetric productivity process and differential labor adjustment costs, the calibrated results on cross-correlations are shown in Figure 4 with $\lambda_1 = 4.40$ and $\lambda_2 = 0.65$. Since I set λ_2 to match the contemporaneous correlation of employment, the middle point of the curve for employment is higher than the other two. The properties of cross-correlation functions are similar to those discussed in the experiment part. Note that the calibrated correlation of employment at lag $k = -4$, $Corr(d_t^1, d_{t-4}^2)$ (0.27), is much lower than that in the data (0.67).

The next productivity process I apply is the asymmetric one which is estimated without imposing symmetry assumption.

$$A = \begin{bmatrix} 0.880 & 0.183 \\ 0.029 & 0.759 \end{bmatrix}$$

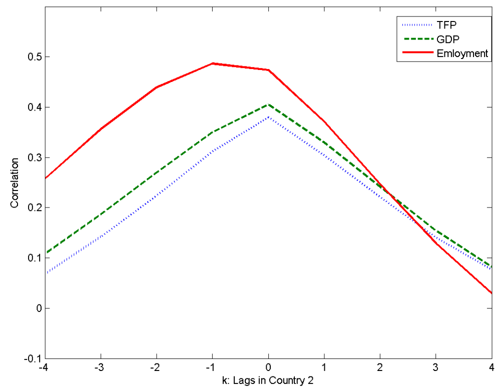

Figure 4: Cross Correlations: Symmetry TFP Process
$\lambda_1 = 4.40$, $\lambda_2 = 0.65$.

I report two cases, with and without differences in labor market rigidities. Figure 5 shows that the asymmetric TFP process can not fully explain the lead-lag relations. Not surprisingly, it generates the asymmetric timing patterns for output and employment as TFP. However, the differences in the lead-lag relations among the three variables disappear. In the data, employment displays the most marked lead-lag relation, and TFP the most weakest. In literature, TFP process is viewed as the only source of lead-lag relation for the economy. Figure 5 gives the shortcomings of this explanation.

Figure 6 lays out the results fot the case with the asymmetric TFP process and differential labor adjustment costs. Now the model predicts the same lead-lag relations of employment, output and TFP as those in the data. Note that in this case, the correlation of employment at lag $k = -4$ (0.51) is improved significantly using the new values of λs. This suggests that both TFP and labor rigidity are the most important factors in the lead-lag relations.

The results for consumption and investment can be found in Figure 7. Both of them exhibit asymmetric patterns but not as much as in the data. The inconsistency is due to the disadvantages of the standard two-country business cycle model itself. By perfect risk sharing in complete markets, households are fully insured. Hence it is not surprising to have the quite symmetric correlation function of consumption.

Now I compare the statistics about contemporaneous correlations and volatilities among different cases in Table 5 and 6. Since the volatilities of output are much lower than the data, the volatilities in country 1 (ROW) listed in Table 6 are calculated as $\frac{\sigma(d^{Agg})}{\sigma(y^{Agg})}/\frac{\sigma(d^{US})}{\sigma(y^{US})}$, where d is the relevant variable. we can see that introducing labor adjustment costs has no impact on the relative volatilities and correlations.

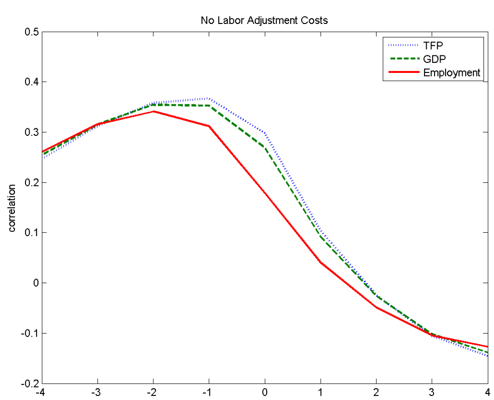

Figure 5: Asymmetric TFP Process
No Labor Adjustment Costs

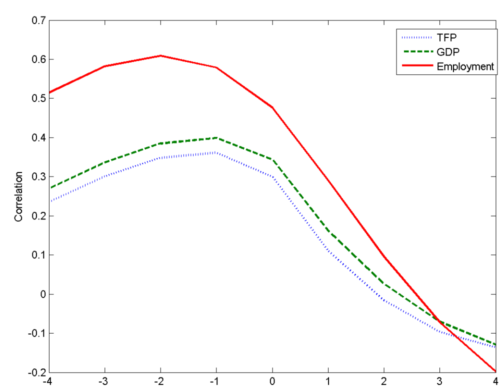

Figure 6: Asymmetric TFP Process
With Labor Adjustment Costs

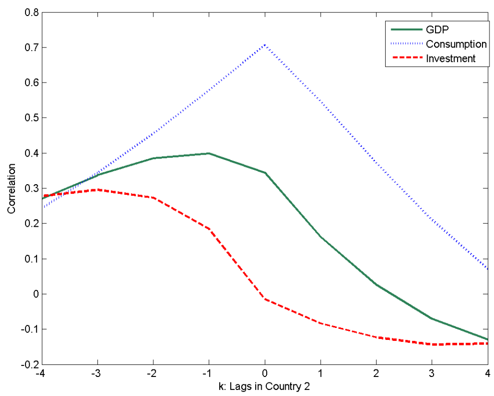

Figure 7: Consumption and Investment with Asymmetric TFP Process
$\lambda_1 = 19.0$ and $\lambda_2 = 4.3$

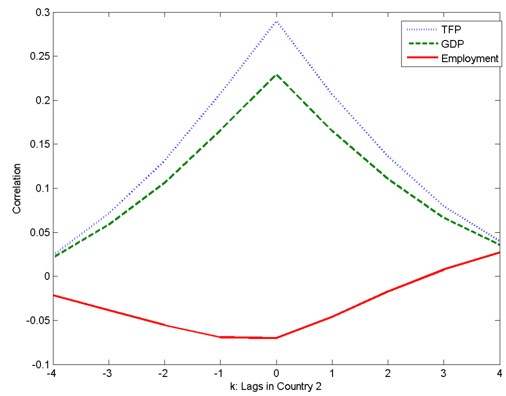

Figure 8: Cross-Correlations with TFP Process in Heathcote and Perri(2002)
$\lambda_1 = 4.4$ and $\lambda_2 = 0.65$

Varying the productivity process

The success of differential labor market frictions in explaining the lead-lag relation across countries relies on the positive contemporaneous correlation of employment. The estimates of transition matrix used in the literature generate negative cross-country correlation of employment. In those cases, the effects of labor markets are ambiguous. Otherwise we need very high values of λs to generate a positive contemporaneous correlation of employment first. To illustrate it, I use the transition matrix in Heathcote and Perri(2002),

$$A = \begin{bmatrix} 0.970 & 0.025 \\ 0.025 & 0.970 \end{bmatrix}$$

with $\sigma(\varepsilon_i) = 0.0073$ and $corr(\varepsilon_1, \varepsilon_2) = 0.290$. The values for λs are 4.4 and

0.65 respectively. As shown in Figure 8, the asymmetric timing pattern of employment disappears with the transition matrix estimated by the unfiltered TFP data.

Interpretation

I now discuss the intuition for the behavior underlying the lead-lag relation using impulse response functions. To emphasize the role of labor markets, I use the case when $\lambda_1 = 3.8$ and $\lambda_2 = 0$, so country 2 has the perfectly flexible labor market.

In Figure 10, we see that a positive productivity shock in country 2 leads to an increase in employment in the same country immediately and a small increase in employment in country 1. We do not observe a decrease in employment in country 1 due to the rigid labor market and the spill-over effects of shocks. As the shock declines, the employment in country 2 decreases at the same time.

More interesting are the responses if the shock hits country 1 first. With frictions in the labor market, it is costly to adjust employment substantially within a single period. Therefore, a shock hitting country 1 leads to a mild increase in employment in country 1 only and a decrease in employment in country 2. However, as time passes, employment in country 1 keeps increasing for a while before going back to the steady state. So country 1 reacts to the productivity shocks much more slowly, and in a hump shaped fashion, than country 2.

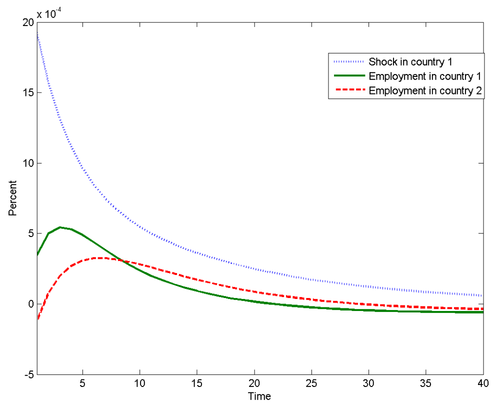

Figure 9: Impulse Response Functions
Temporary Shock in Country 1

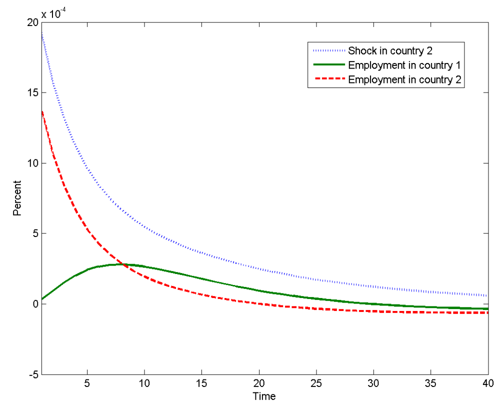

Figure 10: Impulse Response Functions
Temporary Shock in Country 2

Consider a common shock hitting both countries. Due to different labor market rigidities, the shock has larger immediate effects on the country with the flexible labor market but more persistent effects on the other country. Statistically country 2 appears to be the leader. Thus the differences in labor markets play a central role in international business cycles.

In Figure 11 I check the response of employment to a domestic shock for different levels of rigidity in the labor market. The value of λ_1 varies from 0 to 10 and λ_2 is zero. We can see that, as labor market rigidity increases, the increase in employment is smaller on impact but more persistent. This implies the more rigid the labor market, the stronger the lead-lag relation.

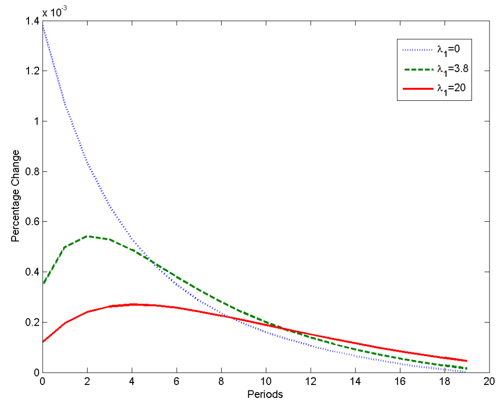

Figure 11: Impulse Response Functions of Employment: Temporary Shock in Country 1

5 Regression

I now provide some additional empirical evidence in favor of the idea that labor markets are central in explaining the lead-lag patterns. First, I discuss the measures of labor market rigidity and the level of lead-lag relation.

The measure of labor market rigidity I choose is the Employment Protection Legislation (EPL) index (version 1) from the OECD database, which is an overall annual indicator of the unweighted average of sub-indicators for regular employment and temporary employment. Although version 1 of the index does not incorporate all the data items as other versions, there is little change in the rank of countries in terms of the index among different versions. And only version 1 covers the complete sample period, from 1985 to 2008. To measure the overall strictness of the labor market in each country, I take the average of EPL indices over the same period as the cross-correlations.[2]

The lead-lag relation for a variable is measured by the level of asymmetry of the corresponding cross-correlation function. The idea is that if the lead-lag relation is more pronounced, the correlation with lagged US movements tends to be higher. Thus the cross-correlation function is more asymmetric with respect to the line $k = 0$. Here, the asymmetry of a cross-correlation function is measured as the difference between sum of the correlations with lagged US movements and the sum of those with future US movements:

$$Asy_d = \sum_{k=1}^{4}(corr(d_t^i, d_{t-k}^{US}) - corr(d_t^i, d_{t+k}^{US})) \tag{8}$$

Where d^i is a HP-filtered logged variable of country i. If a cross-correlation function is symmetric, the number calculated by the formula above is close to zero. The more asymmetric the function, the larger the number. Meanwhile, a negative value of Asy_d means that the current movements of variable d in the country are followed by US movements.

I construct a small panel data to analyze the effects of labor market rigidity on the lead-lag patterns. Specifically, I split the period: 1985:1-2009:1 into two sub-periods, 19851-1996:4 and 1997:1-2009:1. After dropping some samples with missing data on employment in the early sub-period, I get thirty

[2]The data for Luxembourg are missing except for 2008. Since the EPL index changes little over periods, I simply use the index in 2008 to measure the labor protection in Luxembourg over the sample periods.

observations. Including other factors, such as population and output, the regression model is specified as:

$$
\begin{aligned}
Asy_{d_{ij}} &= \beta_0 + \beta_1 Asy_{TFP_{ij}} + \beta_2 EPL_{ij} + \\
&\quad \beta_3 \log(Populatioon_{ij}) + \beta_4 \log(GDP_{ij}) + \nu + \varepsilon
\end{aligned}
$$

where $d \in \{\text{GDP, Employment, TFP}\}$, $\beta_1 = 0$ if $d = TFP$, $j = 1, 2$.

The dependent variable is the asymmetry index of output, employment or TFP calculated by equation (8) for country i. The regression is applied for each of them separately. The data is for the early subperiod if $j = 1$, and for the late subperiod if $j = 2$. The ν is the dummy variable indicating whether the subperiod is the early one or not, and ε the noise. The independent variable Asy_{TFP_i} is dropped when it is the dependent variable. The variables EPL_i, $Population_i$ and GDP_i are the averages of the annual time series over the same subperiod as the dependent variable for country i. The data for the independent variable GDP are in units of US dollars with fixed PPPs in the same reference year 2000 across countries. They are used to measure the effects of country size on the lead-lag relations.

Regression Results

Table 9 presents the results of the three regressions. For the asymmetry of employment, the results indicate that the differential labor market frictions play the central role in explaining the leading and lagging relations between countries. The coefficient associated with the EPL index in the regression of employment asymmetry is significantly positive (0.764) which is about two times as large as that in the regression of output. It implies that if the EPL index increases by 1, the asymmetry index of employment will increase by around 0.76. Thus, on average, the correlation with past US movements will be higher than that with future US movements by 0.19. Note that the cross-correlation function of employment tends to be decreasing with lag, meaning that difference $corr(d_t^i, d_{t-k}^{US}) - corr(d_t^i, d_{t+k}^{US})$ is increasing with lag k. Thus an average increase by 0.19 implies a substantial increase on the difference when $k = 4$.

In Table 8, I provide the rank of labor market rigidities using the average of the EPL indices over the whole period 1985-2008, which indicate the UK and Canada have the most flexible labor markets among the eighteen countries. The regression results suggest that the lead-lag relations of these two countries are not as strong as the others. This implication is consistent with the literature which has documented some convergence of business cycles within the European area and the English-speaking groups but divergence between them. The fact that these two groups are also characterized by very different labor market structures suggests that labor market might be the key to explain these patterns.

The results also indicate that the propagation of productivity shocks between countries can not explain the lead-lag relation in labor markets. The sign of the coefficient of TFP is negative and insignificant in the regression of employment. The negative coefficient means that if a country has the same flexible labor market as the US, the current employment movements in the country lead the movements in US labor market, which is the reverse of what the data shows.

As for the asymmetry of output, TFP process now contributes substantially. Both productivity and labor market frictions account for the asymmetry in output significantly. This is consistent with the observation that the lead-lag relation of output is stronger than TFP but weaker than employment.

Other implications of the regression results are the following. The regression of TFP asymmetry shows that labor market rigidities have positive but insignificant effects on the TFP process, which may be due to country specific reasons.[3] Second, the coefficients associated with population and GDP are not significant in the regressions of output and TFP, and the sum of them in each regression is close to zero. This suggests that the effects of demography on the international business cycles are not significant. [4]

To summarize, I find the following implications of the regression results. First, countries which have more marked lead-lag patterns with the US are the ones with more rigid labor markets. Second, the different timings of underlying shocks can not explain the lead-lag pattern of employment. Third,

[3]Theoretically, the TFP processes can generate asymmetric cross-correlations if the autocorrelations are different across countries even without spill-over effects.

[4]I also use alternative measures on asymmetry, which take the contemporaneous correlation into account: $Asy = \frac{\sum_{s=1}^{4}(corr(d_t^i, d_{t-s}^{US}) - corr(d_t^i, d_{t+s}^{US}))}{e^{corr(d_t^i, d_t^{US})}}$. The regression results are similar to those using equation 8. The coefficients associated with EPL are more significant by using this measure.

both productivity and employment contribute to the lead-lag relation of output. Last, the role of country size is ambiguous in international business cycles.

Discussion

The theory I propose in the paper suggests the way on how to explain the lead-lag relations in international business cycles with the pattern of TFP unexplained. Note that the TFP data in empirical analysis are obtained by calculation. Further research could focus on looking for the reasons which can explain the asymmetry in calculated TFP process while the underlying productivity process is symmetric. The regressions reported in this paper imply that the impacts of labor market frictions on calculated TFP are not significant. The following extensions on the model confirm this implication.

I have tried two modifications to check if the differences in labor markets can explain the lead-lag relation of the calculated TFP. The first is to assume each country has more than one sector, so that labor is not perfect mobile across sectors in a "rigid" country. Consider a productivity shock in one sector in the country with the strict labor market, we can infer that the fluctuations of the calculated TFP in this country may follow those in the country with lower frictions. However, I can not find asymmetry in the calculated TFP in the model.

The second attempt is to incorporate capital utilization. The more intensive the capital is utilized in the production, the higher the rate of depreciation is. One can show that the capital utilization rate has the lead-lag relation with differential labor market frictions, but the resulting calculated TFP is still symmetric.

Both modifications can not generate the lead-lag relation of the calculated TFP. We need to find other factors which have impacts on calculated TFP process.

6 Conclusion

This paper studies the leading and lagging relationships in international business cycles by using a standard open-economy model with differential labor market frictions. I document the stylized facts of the lead-lag relations with the US for a group of developed countries. Instead of emphasizing the role of productivity shocks in explaining the patterns, I argue that differences in labor markets play the central role in explaining the lead-lag relations, especially for employment. Additional empirical evidence is provided. First, the lead-lag relation is more significant for employment than for output and TFP. Second, countries which have more marked lead-lag relations with the US are those with rigid labor market. Third, the impacts of differential labor market frictions on the TFP relation are insignificant, which is also supported by the model.

Due to the different levels of rigidity in labor markets, the impacts of shocks on countries are not the same. The immediate effects are larger if a country has lower labor protection, otherwise the effects are more persistent instead. Hence, statistically the countries with the flexible labor markets appear to be the leaders in international business cycles.

Further research on this area could focus on looking for the factors which have significant effects on the lead-lag relation of TFP.

Table 1: Cross Correlation with US: GDP*

	Correlation of y_t and y_{t+s}^{US}								
Country	$s = -4$	-3	-2	-1	0	1	2	3	4
Australia	0.24	0.34	0.48	0.61	0.68	0.61	0.46	0.33	0.18
Austria	0.49	0.49	0.46	0.48	0.47	0.27	0.08	-0.09	-0.19
Belgium	0.45	0.46	0.48	0.53	0.55	0.35	0.16	-0.07	-0.25
Canada	0.41	0.51	0.63	0.77	0.79	0.65	0.47	0.30	0.11
Denmark	0.15	0.12	0.17	0.34	0.47	0.30	0.11	0.06	0.04
Finland	0.54	0.57	0.58	0.65	0.66	0.50	0.29	0.14	0.05
France	0.57	0.57	0.57	0.59	0.57	0.37	0.12	-0.12	-0.30
Germany	0.11	-0.01	-0.14	-0.19	-0.16	-0.31	-0.39	-0.42	-0.38
Greece	0.05	0.05	-0.02	0.06	0.11	0.11	0.05	-0.03	-0.05
Ireland	0.42	0.40	0.40	0.45	0.46	0.33	0.10	-0.05	-0.24
Italy	0.42	0.37	0.32	0.34	0.34	0.14	-0.05	-0.20	-0.29
Japan	0.15	0.14	0.16	0.25	0.29	0.12	-0.08	-0.18	-0.19
Luxembourg	0.42	0.36	0.33	0.37	0.38	0.25	0.08	-0.05	-0.18
Netherlands	0.22	0.24	0.20	0.16	0.16	0.07	0.03	-0.02	-0.08
Portugal	0.43	0.38	0.32	0.36	0.30	0.09	-0.03	-0.11	-0.21
Spain	0.41	0.37	0.32	0.37	0.34	0.18	0.06	-0.07	-0.19
Sweden	0.38	0.37	0.38	0.46	0.53	0.38	0.13	0.07	0.04
UK	0.35	0.45	0.54	0.67	0.72	0.62	0.42	0.27	0.14
EU15	0.50	0.49	0.47	0.51	0.53	0.31	0.03	-0.18	-0.34
ROW	0.43	0.43	0.44	0.52	0.55	0.36	0.05	-0.17	-0.31

*Data are quarterly, from the OECD's QNA and the IFS, seasonally adjusted. All statistics refer to HP-filtered variables. Sample period is 1985:1-2009:1. I sum up the real GDPs (US dollars, fixed PPP) of all countries above to get the GDP of the ROW.

Table 2: Cross Correlation with US: Civilian Employment*

	Correlation of n_t and n_{t+s}^{US}								
Country	$s=-4$	-3	-2	-1	0	1	2	3	4
Australia	0.50	0.57	0.64	0.66	0.59	0.49	0.36	0.21	0.07
Austria	0.14	0.19	0.22	0.21	0.18	0.01	-0.06	-0.16	-0.20
Belgium	0.08	0.19	0.39	0.56	0.55	0.38	0.30	0.17	-0.07
Canada	0.39	0.49	0.58	0.67	0.69	0.56	0.43	0.29	0.17
Denmark	0.31	0.35	0.43	0.47	0.42	0.19	0.16	0.17	0.24
Finland	0.74	0.73	0.69	0.60	0.44	0.28	0.13	-0.02	-0.13
France	0.58	0.47	0.36	0.22	0.08	-0.14	-0.32	-0.49	-0.61
Germany	0.62	0.56	0.45	0.28	0.10	-0.08	-0.19	-0.28	-0.39
Greece	-0.41	-0.32	-0.16	0.02	0.23	0.08	0.00	-0.03	0.03
Ireland	0.30	0.44	0.60	0.76	0.89	0.79	0.57	0.31	0.05
Italy	0.34	0.23	0.09	-0.03	-0.10	-0.25	-0.35	-0.43	-0.46
Japan	0.19	0.23	0.23	0.21	0.17	0.07	-0.01	-0.14	-0.24
Luxembourg	0.50	0.38	0.22	0.05	-0.12	-0.34	-0.48	-0.58	-0.64
Netherlands	0.73	0.65	0.50	0.28	-0.01	-0.22	-0.41	-0.53	-0.63
Portugal	0.52	0.48	0.38	0.25	0.13	-0.00	-0.08	-0.16	-0.22
Spain	0.46	0.48	0.50	0.53	0.55	0.37	0.20	0.06	-0.08
Sweden	0.78	0.70	0.59	0.45	0.26	0.03	-0.18	-0.31	-0.40
UK	0.57	0.64	0.67	0.67	0.59	0.47	0.35	0.20	0.08
EU15	0.70	0.68	0.61	0.52	0.40	0.18	0.00	-0.15	-0.29
ROW	0.67	0.68	0.64	0.58	0.47	0.25	0.07	-0.12	-0.27

*Data are quarterly, from OECD's Labor Force Statistics(MEI). All the sample periods are 1985:1-2009:1, except for Belgium 1999:1-2009:1, Denmark 1995:1-2009:1, France 1995:1-2009:1, Greece 1998:1-2009:1, Ireland 1997:4-2009:1, and Netherlands 2001:1-2009:1. The employment for the ROW is the total employment of all countries above which have complete time series in 1985:1-2009:1.

Table 3: Cross Correlation with US: TFP*

	Correlation of z_t and z_{t+s}^{US}								
Country	$s = -4$	-3	-2	-1	0	1	2	3	4
Australia	-0.10	0.00	0.20	0.40	0.59	0.57	0.47	0.34	0.24
Austria	0.27	0.33	0.35	0.40	0.42	0.32	0.21	0.06	-0.00
Belgium	0.22	0.05	0.08	0.23	0.43	0.11	-0.23	-0.44	-0.26
Canada	0.41	0.43	0.48	0.57	0.56	0.42	0.22	0.06	-0.16
Denmark	0.34	0.13	0.11	0.38	0.44	0.11	-0.03	-0.05	-0.12
Finland	0.28	0.27	0.27	0.41	0.49	0.38	0.18	0.07	0.03
France	0.42	0.42	0.44	0.59	0.64	0.50	0.29	0.08	-0.04
Germany	-0.16	-0.22	-0.29	-0.28	-0.18	-0.20	-0.22	-0.21	-0.15
Greece	0.01	0.08	-0.02	0.03	0.26	0.42	0.17	0.14	0.17
Ireland	0.19	0.07	0.09	0.18	0.23	0.16	-0.09	-0.08	-0.28
Italy	0.22	0.19	0.14	0.15	0.14	0.02	-0.08	-0.14	-0.18
Japan	0.01	0.01	0.02	0.15	0.16	0.04	-0.10	-0.14	-0.10
Luxembourg	0.38	0.28	0.27	0.34	0.35	0.25	0.11	-0.02	-0.13
Netherlands	-0.18	-0.17	-0.20	-0.12	-0.02	-0.07	0.07	0.02	-0.19
Portugal	0.12	0.08	0.05	0.17	0.17	0.01	-0.10	-0.16	-0.34
Spain	0.05	0.03	-0.04	-0.02	-0.12	-0.14	-0.19	-0.23	-0.29
Sweden	0.18	0.16	0.18	0.30	0.39	0.30	0.14	0.12	0.12
UK	0.08	0.14	0.18	0.32	0.41	0.36	0.18	0.11	0.05
EU15	0.17	0.18	0.19	0.29	0.36	0.21	-0.04	-0.22	-0.33
ROW	0.15	0.14	0.16	0.30	0.35	0.21	-0.06	-0.24	-0.32

*The TFP is calculated as $\log z_t = \log y_t - (1 - \alpha) \log n_t$. The sample periods are the same as the Civilian Employment.

Table 4: Parameter Values

Preferences	Discount factor	$\beta = 0.99$
	Consumption share	$\mu = 0.34$
	Risk aversion	$\gamma = 2$
Technology	Depreciation rate	$\delta = 0.025$
	Capital share	$\alpha = 0.36$
	Home bias	$\omega = 0.8915$
	Elasticity of substitution	$\sigma = 0.9$
TFP process		
	Symmetric A	$\begin{bmatrix} 0.818 & 0.113 \\ (0.053) & (0.053) \\ 0.113 & 0.818 \\ (0.053) & (0.053) \end{bmatrix}$
	Asymmetric A	$\begin{bmatrix} 0.880 & 0.183 \\ (0.079) & (0.075) \\ 0.029 & 0.759 \\ (0.081) & (0.077) \end{bmatrix}$
	Innovations	$\sigma(\varepsilon_1) = 0.0019$
		$\sigma(\varepsilon_2) = 0.0020$
		$corr(\varepsilon_1, \varepsilon_2) = 0.271$
Labor protection		
Symmetric A	ROW	$\lambda_1 = 4.4$
	US	$\lambda_2 = 0.65$
Aymmetric A	ROW	$\lambda_1 = 19$
	US	$\lambda_2 = 4.3$

Table 5: Simulation Results: US economy

Volatility

	%std.dev.	$\frac{std.dev}{std.dev.of y}$							
Economy	y	c	x	n	z	ex**	im	nx	p
Data	1.02	0.69	3.05	0.78	0.28	3.53	3.42	0.40	1.57
No protection*	0.35	0.31	3.47	0.49	0.69	1.01	1.02	0.20	0.29
Symmetric	0.33	0.32	3.44	0.41	0.75	0.89	1.00	0.17	0.28
Asymmetric	0.27	0.25	3.82	0.28	0.85	0.94	1.15	0.19	0.38

Correlations with Output

Economy	c	x	n	z	ex	im	nx	p
Data	0.82	0.93	0.84	0.91	0.68	0.84	-0.54	0.31
No protection	0.93	0.97	0.99	1.00	0.33	0.98	-0.55	0.38
Symmetric	0.92	0.98	0.98	0.99	0.42	0.98	-0.58	0.43
Asymmetric	0.83	0.98	0.89	0.98	0.27	0.97	-0.63	-0.01

Cross-country Correlations

Economy	y	c	x	n	z
Data	0.55	0.46	0.54	0.47	0.35
No protection	0.34	0.66	-0.04	0.23	0.38
Symmetric	0.40	0.74	0.03	0.47	0.38
Asymmetric	0.34	0.71	-0.02	0.46	0.30

* This is for the model with symmetric TFP and no labor adjustment cost.
**ex=real export, im=real import, nx=net export ratio, p= terms of trade.

Table 6: Simulation Results: ROW

Volatility					
	$\frac{\%std.dev.}{\%std.dev.US}$	$\frac{std.dev}{std.dev.of y}$ relative to US			
Economy	y	c	x	n	z
Data	0.96	0.67	0.82	0.73	1.14
No labor protection	0.35	0.31	3.47	0.49	0.69
Symmetric	0.88	1.00	1.00	0.72	1.12
Asymmetric	1.07	1.29	0.88	0.72	1.06

Correlations with Output				
Economy	c	x	n	z
Data	0.83	0.94	0.82	0.96
No labor protection	0.93	0.97	0.99	1.00
Symmetric	0.89	0.97	0.90	0.98
Asymmetric	0.90	0.96	0.82	0.98

Table 7: Statistics of ROW and US

	$\%std.dev.$	$\frac{std.dev}{std.dev.of y}$				Correlation with y			
Country	y	c	x	n	z	c	x	n	z
ROW	0.98	0.46	2.49	0.58	0.32	0.83	0.94	0.82	0.96
US	1.02	0.69	3.05	0.78	0.28	0.82	0.93	0.84	0.91

y = GDP, c = consumption, x = investment, n = employment, z = TFP.

Table 8: EPL Index

Country	EPL index	Country	EPL index
US	0.21	Belgium	2.66
UK	0.65	Sweden	2.68
Canada	0.75	Germany	2.68
Ireland	0.98	Italy	2.88
Australia	1.07	France	2.95
Japan	1.64	Luxembourg	3.25
Denmark	1.88	Spain	3.3
Finland	2.14	Greece	3.32
Austria	2.14	Portugal	3.77
Netherlands	2.47		

Note: The EPL index (version 1) is from OECD Labor Statistics. Numbers here is the average values of the indices from 1985 to 2008. The only exception here is Luxembourg of which number is only for 2008. The regression on subperiods uses the average values of the indices from 1985-1996 and the averages of 1997-2008 for each country in the sample.

Table 9: Regression Results

Dependent	TFP	EPL	log(Population)	log(GDP)	R-squared
Asy_y	0.636***	0.328***	-0.182	0.300	0.678
	(0.101)	(0.007)	(0.477)	(0.521)	
Asy_n	-0.171	0.764***	-2.608**	2.803**	0.40
	(0.231)	(0.253)	(1.087)	(1.187)	
Asy_z		0.061	-0.298	0.302	0.154
		(0.219)	(0.939)	(1.03)	

†Number of observations: 30.

‡y is real GDP, n is employment, z is TFP. The symbols *,** and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent.

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A Appendix

A.1 Data Description

Table 10 lists the data sources for quarterly GDP in detail.

Notes:

- The GDP data from OECD's QNA are the GDP by expenditure approach.
- LNBQRSA: Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted.
- VOBARSA: Millions of national currency, volume estimates, OECD reference year, annual levels, seasonally adjusted.
- VPVOBARSA: Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted.

A.2 Estimation of TFP Transition Matrix

The estimate of transition matrix A by using unfiltered TFP data is

$$A = \begin{bmatrix} 0.976 & 0.007 \\ 0.036 & 0.967 \end{bmatrix}$$

The Figure 12 shows that using unfiltered TFP data cannot generate the time pattern of cross-correlations.

Table 10: GDP Data

Country	*Source*	Series	Measure
Australia	OECD		LNBQRSA
Austria	OECD		VOBARSA
Belgium	OECD		VOBARSA
Canada	OECD		LNBQRSA
Denmark	IFS	12899BVPZF... *	Index 2005=100
Finland	IFS	17299B.PVF... *	at 2000 prices
France	OECD		LNBQRSA
Germany	IFS	13499BVRZF...	Index 2005=100
Greece	OECD		VOBARSA
Ireland	OECD		VOBARSA
Italy	IFS	13699B.RYF...	at 1995 prices
Japan	IFS	15899B.RXF...	ref 1995, chained
Luxembourg	OECD		VOBARSA
Netherlands	IFS	13899B.RXF...	ref 1995, chained
Portugal	IFS	18299BVPZF... *	Index 2005=100
Spain	IFS	18499BVRZF...	Index 2005=100
Sweden	IFS	14499B.PUF...	ref 2000, chained
UK	IFS	11299B.RXF...	ref 2003, chained
EU15	OECD		VPVOBARSA
US	IFS	11199B.RZF...	ref 2000, chained

*Data are seasonal adjusted by the author

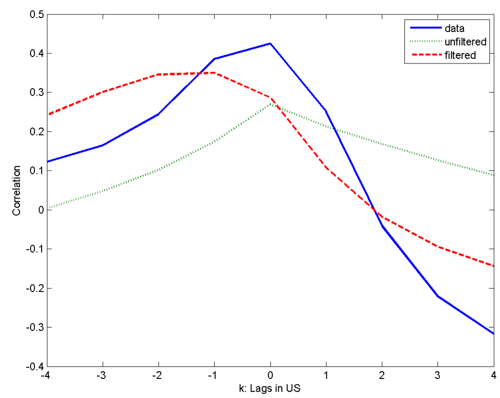

Figure 12: Cross Correlations of TFP: Different Estimates of Transition Matrix