Labor Market Fluctuations in Developing Countries [*]

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Abstract

This study documents the labor market properties of business cycle fluctuations for a group of 17 developing economies and the USA. We find that hours worked and employment volatility (relative to output volatility), on average, are lower while the volatility of productivity and wages are 2-3 times higher in these countries compared with the USA. We then present seven real business cycle models without nominal frictions driven by temporary and permanent productivity shocks following Aguiar and Gopinath (2007) to explain whether RBC models are consistent with the labor market features over the business cycle in these economies. We find that our models can reasonably well account for the relative volatility of hours worked to output while these models fail to generate the high volatility of wages. We further investigate the fluctuations of labor wedge in these economies. We discover that the labor wedge is more volatile than in the USA and the most of the fluctuations of labor wedge arises from the household component of the wedge rather than the firm component.

Key-words: Labor Market, Developing Economies, Real Business Cycle Model, Labor Wedge.

Jel-codes: E31,E32,E52,F41,O50.

1 Introduction

Quantitative analysis of business cycle fluctuations for developed markets has long been of interest to researchers since Kydland and Prescott (1982). This is also an old issue for developing countries but has only recently been revived within equilibrium business cycle models. The failure of frictionless real business cycle model to replicate second moments of labor market dynamics is well known in the literature, Christiano and Eichenbaum (1992), Hansen and Wright (1992). However, most of the analysis has focused on the USA and other developed countries. This paper explores the labor market dynamics of business cycle fluctuations in developing countries and reconcile these results within real business cycle models.

There are some reasons why we pay more attention to the documentation of the fluctuations of labor market dynamics of business cycle in developing countries rather than in developed countries: (1) It is recognized that business cycle volatility is significantly higher in developing countries than developed countries and these economies have experienced very large fluctuations in their output. Thus, the effect of the shocks in these countries is normally larger than developed countries. (2) Developing countries have different labor market institutions and their market behaviour is substantially different. For example; the flexibility of contract, employment protection, firing and hiring costs, unions, entry barriers. Also, they have less wage rigidity, large informal sectors, less social protection and unemployment benefits, different flexibility of market (not in all cases), such as, Brazil is a highly protected labor market, but in most of the cases, they have these type of institutions. Because of these differences between developing and developed countries, their reaction to changes in the macroeconomic fluctuations will be different and this makes these countries a good benchmark to compare the models of business cycle fluctuations. Thus, we are interested in the labor market fluctuations of business cycle in developing countries to know whether RBC models fit the features of these countries given that the institutions are potentially different. We are motivated from these characteristics of developing countries which make these countries unique in order to explain the labor market fluctuations over the business cycle.

In the first part of the paper, we systematically document some stylized facts of labor market properties of business cycle, which are essential to the characterization of the models, in developing countries for the period 1970-2013. Then, we compare the results with available features of business cycles in developing countries and the USA. For this analysis, we have a reasonable annual database of labor market dynamics for developing countries[1]. The results are based on relative standard deviations with output, autocorrelation of output, and correlation of labour market variables with output. We show the co-movements and relative volatilities in employment (extensive margin),

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[1]Typically, standard business cycle analysis uses quarterly data but we use an annual data since hours worked data is only available in annual frequency for developing countries. Using annual data in business cycle may not allow to capture the short term dynamics but it is still useful since it preserves the medium run dynamics

hours worked per employed (intensive margin), total hours worked[2], productivity, and wages with output for a large sample of developing countries. We find that the average volatility of wages (1.60) and productivity (0.90) relative to output volatility is higher in developing countries than in the USA (0.77), (0.42), respectively while the volatility of employment (0.61) and total hours worked (0.74) is lower in developing countries than USA (0.73), (0.89), respectively. We see that labor market in developing countries adjust more through prices and the fluctuations of employment are mostly responsible for the fluctuations of the total hours worked in these economies rather than the fluctuations of intensive margin (0.30). The other finding is that the average correlation for employment (0.88), total hours worked (0.90), and wages (0.54) with output in the USA is higher than in developing countries (0.48), (0.49), (0.42), respectively, while the average correlation between productivity and output is lower for these countries. The results show that the behaviour of labor market variables are very different between developing countries and USA over the business cycle.

Our second objective is to investigate whether a set of variants of the RBC model with no nominal rigidities are able to reproduce these labor market features observed in the data in developing countries. We first look at the performance of the most standard frictionless real business cycle model as a benchmark model driven solely by permanent and temporary shocks as in Aguiar and Gopinath (2007) using both separable and non-separable utility functions. The reason for looking at the standard RBC model is that it is the benchmark model with no nominal frictions and provides us an initial comparison for the data and model moments in terms of labor market variables. From the literature, we already know that the performance of frictionless real business cycle model is incapable of explaining business cycle fluctuations. Therefore, we build different RBC models, augmenting with real frictions to explain whether these frictions improve the performance of the model. We build RBC models augmented with capacity utilization and investment adjustment cost to explore how these models affect the model's ability to explain labor market moments. In these models, we can only see hours as employment where employment is perfectly divisible. However, the data shows that changes in total hours worked is mostly attributed to the fluctuations of the extensive margin. Therefore, we also build the RBC model with indivisible labor to point out the fluctuations of employment. This model allows us to separate employment from hours, that means all the variation in the labor comes from changes in the number of employed workers. The results show that our models do a fairly good job at matching the relative volatility of hours worked for both developing economies and USA. While these models do not do well at matching the relative volatility of wages and productivity for developing countries, they do a much better job for the USA. We conclude that RBC models fail to explain labor market fluctuations of business cycle in developing countries but the RBC model with investment adjustment cost does a fairly good job at explaining labor market facts for developing economies.

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[2]We separate total hours worked as intensive margin and extensive margin following Ohanian and Raffo (2012)

Lastly, marginal rate of substitution (MRS) and marginal product of labor (MPL) are equal to each other in the frictionless model set-up. However, this condition does not hold in the data so there is a wedge between these two. Following Karabarbounis (2014), we decompose the wedge into the household component and firm component to understand whether the fluctuations of labor wedge reflect fluctuations of the gap between the marginal product of labor and real wage or fluctuations of the gap between the marginal rate of substitution and the real wage in developing economies and in the USA. We find that there is a strong relationship between the household component of the labor wedge and the overall labor wedge. The figures show that most of the fluctuations are coming from the household component of labor wedge in both developing economies and the USA. We also present the cyclical properties of the firm component of the labor wedge, household component of labor wedge and total labor wedge with output between 1970 and 2013. We find that labor wedge on average is more volatile in developing countries than in the USA. It is 2-3 times higher. In particular, the household component of the labor wedge is more volatile than that of the firm component of labor wedge in both developing countries and USA. Also, the wedge in the USA moves countercyclical to output. For developing countries, we obtain heterogeneous results.

Standard literature has been tested for developed countries, mostly concentrated on the USA or a small set of developed countries business cycles due to the availability of quality data for these economies Kydland and Prescott (1982), Hodrick and Prescott (1997), Ravn and Simonelli (2008), Ohanian and Raffo (2012). These studies mostly focus on consumption, output and productivity. There are few studies focusing on labor market variables within real business cycle model. Christiano and Eichenbaum (1992) present the properties of productivity and hours worked using government spending shock and then explore the failure of RBC model to explain these data facts in USA. Hansen and Wright (1992) also present some labor market facts and show how standard RBC models do a poor job in matching labor market moments in USA. Again, we know from the literature that RBC model fail to explain labor market dynamics of business cycle in developed countries but in this study we are interested in exploring developing countries business cycle to figure out whether the RBC model (with real frictions) does a good or bad job compared to the USA.

There has been ongoing research to capture the stylized facts of business cycles in developing countries since Agenor et al. (2000) and reconcile these results in the real business cycle model Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010), Neumeyer and Perri (2004), Chang and Fernndez (2013).These studies have presented various characteristics of business cycles in developing countries focusing on mostly consumption, output, productivity, investment, interest rate, net export and trade balance to output ratio. However, these papers have largely remained silent to explore labor market dynamics over business cycles in developing countries. In this paper, we use the trend shock. Aguiar and Gopinath (2007) find that RBC model driven by permanent productivity shock does a good job at explaining business cycles features in developing countries. Garcia-Cicco

et al. (2010) show that RBC model driven by permanent and temporary shocks does a poor job in explaining business cycle in terms of trade balance and consumption. Neumeyer and Perri (2004) focus on the cyclical movement of interest rate and introduce the model with interest rate shocks or financial shocks. They find that the model can explain the facts well. Chang and Fernndez (2013) build an encompassing model that unify stochastic trends with interest rate shocks and financial frictions influenced by Aguiar and Gopinath (2007), Neumeyer and Perri (2004). There are very limited studies focusing on the labor market variables. Li (2011) presents the cyclical wage movements in emerging countries and find that the volatility of wages relative to output in developing countries is almost twice as high as those in developed economies. She also finds that real wages are positively correlated with output. Our results are roughly in line with her results. Also, she builds a small open economy model with productivity shock and countercyclical interest rate, then figure out that the model can explain the high volatility of wage. These studies ignore changes in the hours worked while changes in wages have been examined in the real business cycle model for a small set of developing countries. In this paper, we focus on labor market dynamics including wages and hours worked as well as output and productivity with a larger set of developing countries.

The remainder of this paper is organized as follows. In section 2, we describe the data. Section 3 lays out our models and then discusses the parameters values. Section 4 evaluates the performance of the models and then present impulse responses. Section 5 presents the labor wedge. Finally, section 6 concludes.

2   The Data

This section documents the data sources, the construction of variables, key aspects of developing countries business cycles and the differences among these countries and USA. In appendix, Table 1A lists the countries, variables and sample lengths included in the analysis. We choose the countries according to the availability of data since it is difficult to find quality data for some variables, especially the hours worked and wages data have a lot of missing observations. Hence, we have to reduce the time period for some countries and variables. Table 1B contains some summary statistics for annual developing countries data and U.S data.

The data on GDP [3], hours worked[4], employment, and population are compiled from the Conference Board Total Economy Database (TED) [5] which is a comprehensive database with annual

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[3]Total GDP, in millions of 1990 US dollar.

[4]The Conference Board is the main source of estimates of hours worked per worker that are comparable across countries. These series are adjusted to reflect most sources of cross country variation in hours worked, including contracted length of the work week, statutory holidays, paid vacation, and sick days and days lost due to strikes and are consistent with output.

[5]Time series data for these variables are available from the file "Output, Labor and Labor Productivity" on the TED website for most countries. Statistics are collected and constructed by national agencies.

data. The data on wages and consumption [6] are collected from the United Nation Statistics Division which publishes data on national accounts. We have the data for 17 developing countries (Brazil, Bulgaria, Chile, Columbia, Costa Rica, Czech Republic, Ecuador, Estonia, Hungary, Jamaica, Mexico, Peru, Slovenia, South Korea, Sri Lanka, Thailand and Turkey) and USA for the period 1970-2013.

We use annual data and all variables are transformed in per capita terms. Employment per working age population (e) is defined as the ratio of level of employment (E) in the economy to the total working age population of the country (P), real GDP per capita (y) are constructed using real GDP(Y) and total working age population(P). Then, real wages per hour (w) are constructed using total compensation of employees(W) in real terms over total hours worked (H) in the dataset. Labour productivity (p) is the ratio between real GDP(Y) to the total hours worked(H) and lastly consumption per capita(c) are constructed using household consumption expenditure (C) over total working age population (P);

$$e = \frac{E}{P}, \ y = \frac{Y}{P}$$
$$w = \frac{W}{H}, \ p = \frac{Y}{H}, \ c = \frac{C}{P}$$
(1)

We use two measures of hours worked. First, we construct hours worked per employed person (he) using total hours worked (H) and employment (E). Second, we construct hours worked per working age population (hw) using total hours worked and working age population. It is important to separate them because hours per working age population (hw) can be split into two parts as intensive margin (hours worked per employed person) and extensive margin (employed people by working age population). The reason why we split out that is to know whether the most of the fluctuations in total hours comes from extensive margin or intensive margin in developing countries;

$$he = \frac{H}{E}$$
$$hw = he * \frac{E}{P}$$
(2)

The tables report the results for both hours worked per working age population and hours worked per employed person as well as employment but we only use hours worked per working age population (hw) when we compare the data and model moments in section 4 since we cannot separate employment from hours due to all population is employed in the model. However, this section presents business cycle facts of the developing countries about extensive margin, intensive margin and total hours as well as productivity and wages that are relevant for the analysis in this paper. We also compare these results with the USA.

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[6]We use household consumption expenditure data at constant (2005) prices in national currency including non-profit institutions serving households.

Any given data series are expressed in logs and de-trended using an Hodrick-Prescott filter with the standard smoothing parameter 100 for annual data to explain business cycle movements [7]. For each variable j, Table 1 reports the standard deviation relative to the standard deviation of output σ_j/σ_y. Table 2 documents autocorrelation of output $autocor(y)$ and the correlation with output $corr(j,y)$ at business cycle frequencies for each developing country considered and USA. [8] Presenting second moments of the data is important for the performance of theoretical models. We compare the second moments of the data and models in Section 4 to explain the performance of the our models.

In tables, we see that there is a substantial variation across countries but here is the main features of the data for developing countries and USA are:

- The volatility of wages (1.60) and productivity(0.90) are almost 2 times higher in developing countries than in the that of USA, 0.77 and 0.42, respectively. However, if we drop Brazil, Mexico, Peru, and Turkey, which show the highest wages volatility, from the sample, we obtain the lower volatility of wages as 1.25.

- In terms of quantities, the differences are not that big. The fluctuations of employment (0.61) and total hours (0.74) in developing economies are slightly less than in USA, 0.73 and 0.89, respectively but this is much driven by the Sri Lanka (1.18). If we take Sri Lanka away from here, we will certainly have lower relative standard deviations. In addition, if we drop Ecuador, Jamaica and Sri Lanka together, which show the highest total hours worked variation, from the sample, the differences between developing countries and USA based on the volatility of total hours worked are becoming lower.

- Output is somewhat more persistence with an autocorrelation of 0.62 in the developing countries than in the that of USA, 0.55.

- When we look at the correlation between productivity and wages with output, the differences are not that big but there are big differences the cyclicality of quantities between USA and developing countries. The correlation of employment (0.88) and total hours (0.90) with output in the USA are much higher than in the developing countries, 0.48 and 0.49, respectively.

- Sri Lanka exhibits the negative correlation with output in terms of quantities. Also, Turkey, Brazil and Thailand show weak countercyclical employment and total hours with correlation.

- Lastly, the most of the fluctuations in total hours comes from the fluctuations of extensive margin in both country group.

The tables show the notable features that distinguishes the business cycles in developing coun-

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[7]Backus et al. (1992) and Rogerson and Shimer (2011) detrend their series using HP filter with the smoothing parameter 100

[8]Our results might slightly be different than the literature. The reason why we get the different results is that we use annual data instead of using quarterly data since hours worked data is only available in annual frequency for developing countries. Business cycle volatility in annual data is lower than in the that of quarterly data, Ohanian and Raffo (2012)

Table 1: The Standard Deviations Relative to Standard Deviations with Output in Developing Countries and USA

Countries	$\frac{\sigma(e)}{\sigma(y)}$	$\frac{\sigma(he)}{\sigma(y)}$	$\frac{\sigma(hw)}{\sigma(y)}$	$\frac{\sigma(p)}{\sigma(y)}$	$\frac{\sigma(w)}{\sigma(y)}$
Brazil	0.76	0.04	0.76	1.07	3.10
Bulgaria	0.89	0.21	0.92	0.90	1.29
Chile	0.45	0.10	0.45	0.84	1.73
Colombia	0.77	0.43	0.91	0.71	1.24
Costa Rica	0.39	0.48	0.62	0.96	1.17
Czech Republic	0.36	0.33	0.51	0.83	0.94
Ecuador	0.72	0.36	1.35	1.06	-
Estonia	0.39	0.27	0.78	0.36	0.91
Hungary	0.75	0.39	0.86	0.73	1.28
Jamaica	0.74	0.38	1.01	0.63	1.19
Mexico	0.35	0.18	0.39	0.83	2.30
Peru	0.24	0.01	0.24	0.91	2.32
Slovenia	0.76	0.37	0.62	0.65	0.51
South Korea	0.59	0.37	0.67	0.71	1.76
Sri Lanka	1.18	0.94	1.50	2.02	1.77
Thailand	0.42	0.22	0.50	0.96	1.31
Turkey	0.51	0.21	0.50	1.09	2.68
Average	0.61	0.30	0.74	0.90	1.60
USA	0.73	0.27	0.89	0.42	0.77

This table presents the relative standard deviation of extensive margin (e), intensive margin (he), total hours worked (hw), productivity (p), and wages (w) with output (y) for the period 1970-2013. The series are logged first and then filtered using the Hodrick-Prescott filter with a smooting parameter of 100.

Table 2: Autocorrelation and Correlation with Output in Developing Countries and USA

Countries	$\rho(y)$	$\rho(e,y)$	$\rho(he,y)$	$\rho(hw,y)$	$\rho(p,y)$	$\rho(w,y)$
Brazil	0.57	0.27	0.14	0.28	0.73	0.68
Bulgaria	0.65	0.64	0.32	0.41	0.55	0.061
Chile	0.61	0.55	-0.01	0.54	0.89	0.67
Colombia	0.71	0.68	0.32	0.73	0.47	0.11
Costa Rica	0.62	0.65	-0.21	0.36	0.75	0.46
Czech Republic	0.58	0.38	-0.04	0.43	0.70	0.27
Ecuador	0.44	0.36	0.62	0.63	0.15	-
Estonia	0.73	0.66	0.83	0.92	0.65	0.30
Hungary	0.73	0.63	0.34	0.72	0.54	0.07
Jamaica	0.68	0.55	0.32	0.75	0.17	0.12
Mexico	0.58	0.76	-0.23	0.59	0.93	0.63
Peru	0.60	0.45	0.47	0.47	0.97	0.78
Slovenia	0.74	0.57	0.37	0.71	0.79	0.08
South Korea	0.47	0.75	0.06	0.70	0.74	0.54
Sri Lanka	0.62	-0.04	-0.39	-0.28	0.70	0.66
Thailand	0.76	0.25	0.23	0.30	0.90	0.81
Turkey	0.48	0.12	-0.14	0.059	0.89	0.41
Average	0.62	0.48	0.16	0.49	0.67	0.42
USA	0.55	0.88	0.61	0.90	0.47	0.54

This table presents the autocorrelation of output (y), correlation of extensive margin (e), intensive margin (he), total hours worked (hw), productivity (p), and wages (w) with output (y) for the period 1970-2013. The series are logged first and then filtered using the Hodrick-Prescott filter with a smooting parameter of 100.

tries and USA based on labor market variables. The fluctuations in prices are more pronounced than the fluctuations of quantities in developing economies. We find that business cycle volatility is significantly higher in developing countries than in the USA in terms of wages and productivity but the quantities are less slightly volatile in the developing countries than that of USA. That might be due to different characteristics of labor market institutions, or different shocks in these economies, such as labour market regulations, employment protection, firing and hiring cost. Also, developing countries have less wage rigidity, large informal sector and less social protection unemployment benefit. Not in all cases such as Brazil has a very rigid market and wages in Chile adjust through the inflation but in most of cases they have these common characteristics of labor market institutions. That's why we obtain discrepancies with relative volatility, persistence and co movements in country level although these countries share some common features in labor market institutions. Also, the flexibility of wages is matter because if there is a shock to the productivity, it increases employment as well as wages if wages are flexible. However, if wages are not adjust to the shock, that is fixed, only adjustment happens on employment. That might be explain the differences of labor market variability in developing countries and in the USA.

These differences make these countries an interesting contexts to test certain macro theory of fluctuations. That's why there has been an interest in the literature in emerging market business cycle to know whether RBC model fits the features of these countries given that the institutions are potentially different. This section described labor market facts that are the same endogenous variables that come out of a simple real business cycle model, about developing countries and USA. In the next section, we examine how well the standard real business cycle model can fit those facts. Then, we also look at the performance of RBC model augmented with some real frictions.

3   The Model

The model we present here is a canonical real business cycles model to assess the fluctuations of hours worked, wages, productivity and output of business cycles in developing countries motivated by the findings in the previous section. We first present the standard real business cycle model as a benchmark model including transitory TFP shock and a permanent labour-augmenting productivity shock following Aguiar and Gopinath (2007). These shocks are largely studied in the literature since Aguiar and Gopinath (2007)[9]. They find that the business cycle in developing countries is mainly driven by shocks to trend growth.

The model is annual as opposed to quarterly which is commonly used in the literature since we are interested in obtaining the fluctuations of labor market dynamics of business cycles over a longer term as in the data. The RBC model is a good benchmark to compare the data and model moments in terms of labor market variables since the construction of the same variables for the

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[9]Chang and Fernndez (2013), Garcia-Cicco et al. (2010)

model and for the data. In section 4, we explain whether a standard real business cycle model can successfully account for labor market features of the business cycles in these economies.

Then, we build RBC model augmented capacity utilization, investment adjustment cost and indivisible labor using the same shocks to explore whether RBC models with real frictions do a much better job at explaining developing countries business cycles than a canonical business cycle model. The model consists of households and firms. The households consume, invest in capital and provide labor and capital for the firms. The firms rent labor and capital from households in a market.

3.1 The Standard Real Business Cycle Model

3.1.1 Households Problem

The model economy is populated by a continuum of identical consumers. The household's preferences are defined by consumption, C_t and hours worked, H_t and are described by the utility function;

$$E_0 \sum_{i=0}^{\infty} \beta^t \ u(C_t, H_t) \tag{3}$$

where Cobb-Douglas preferences are non-separable;

$$U(C_t, H_t) = \frac{\left(C_t^{\psi}(1 - H_t)^{1-\psi}\right)^{1-\sigma}}{1 - \sigma} \tag{4}$$

$E(.)$ denotes the expectation operator conditional on information available at time t, β represents a discount factor between zero and one. $U(.)$ represents a period utility function. The parameter σ is the inverse of the inter-temporal elasticity of substitution for consumption and in particular, the intertemporal elasticity of substitution for consumption is given by $\frac{1}{\sigma}$. ψ determines the inverse of the Frisch elasticity of labour supply. As a baseline, we use non-separable utility function which implies preferences are non-separable in consumption and hours. This utility function eliminates the wealth effect on leisure, so labor supply depends on wages. Also, this function is compatible with balanced growth and stationary hours, irrespective of choice for σ.

We also consider the separable utility function which means no interaction between consumption and hours worked. In contrast to nonseparable utility function, this function implies a wealth effect on leisure. Thus, labor supply is not independent of consumption as in the non-separable case so that household substitutes consumption to leisure. Notice that there is also a requirement for balanced growth path in this model that utility function has to be logarithmic that is σ equals to 1 for balanced growth to hold in the long run as there is a permanent shock. Thus, in balanced growth, hours has been stationary even though the other variables have grown. The household maximizes the following lifetime utility function;

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$$U(C_t, H_t) = \frac{C_t^{1-\sigma}}{1 - \sigma} - \chi \frac{H_t^{1+\psi}}{1 + \psi} \tag{5}$$

where χ specifies the preference weight of hours in utility. The Frisch elasticity for labor supply is simply $\frac{1}{\psi}$. The reason we consider both these preferences is to show that whether our results are sensitive to the choice of preferences in our analysis. In section 4, we report results for both preference specifications.

The household is assumed to own capital ,K_t, which accumulates according to the following law of motion;

$$K_{t+1} = (1 - \delta) K_t + I_t \tag{6}$$

where I_t denotes investment and δ is the depreciation rate of capital.

The household is subject to the following inter temporal budget constraint;

$$C_t + I_t = W_t H_t + R_t K_t \tag{7}$$

where W_t denotes the wage rate and R_t denotes the rental rate of capital.

Then, consumers choose to maximize the utility subject to capital accumulation and their budget constraint;

$$C_t + K_{t+1} = W_t H_t + R_t K_t + (1 - \delta) K_t \tag{8}$$

3.1.2 Firms Problem

The firm has access to the following Cobb Douglas production function that uses capital K_t, and labor H_t from households. The production technology takes the form;

$$Y_t = e^{z_t} K_t^{1-\alpha} (H_t \Gamma_t)^\alpha \tag{9}$$

where Y_t denotes output and α represents the share of labor. The parameters z_t and Γ_t are stochastic productivity processes. These two productivity processes are characterized by different stochastic properties. Specifically, the temporary shock z_t to total factor productivity is stationary and follows $AR(1)$ process;

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \tag{10}$$

with $|\rho_z| < 1$ is the persistence of the transitory productivity shock and ε_t^z represents independent and identical distribution draws from a normal distribution with zero mean and standard deviation σ_z.

The permanent labour-augmenting productivity shock Γ_t is non stationary and represents the cumulative product of "growth shocks" and is given by;

$$\Gamma_t = g_t \Gamma_{t-1} = \prod_{s=0}^{t} g_s$$

$$\ln(g_t) = (1 - \rho_g)log(\mu_g) + \rho_g In(g_{t-1}) + \varepsilon_t^g$$

where the parameter g_t represents the rate of growth of the permanent technology shock and $|\rho_g| < 1$ represents the persistence parameter of the process g_t and ε_t^g represents iid drawn from a normal distribution with zero mean and standard deviation σ_g. μ_g represents productivity's long run average growth rate. Notice that shocks to g_t permanently affect labour productivity Γ_t.

3.1.3 Labor and Capital Demand

If we assume that factor market is characterized by perfect competition, the real depreciation rental rate on capital, R_t^K and real wage W_t are given by;

$$R_t = e^{z_t} (1 - \alpha) (\frac{K_t}{H_t})^{-\alpha} \Gamma_t^{\alpha} \tag{11}$$

$$W_t = e^{z_t} \alpha (\frac{K_t}{H_t})^{1-\alpha} \Gamma_t^{\alpha}$$

3.1.4 Equilibrium Conditions in Stationary Form

In this paper, we are building a nonstationary model to be consistent with the data. Since the data series are nonstationary, we first express the data in logs and then detrended using HP filter to make it stationary. In the model, g permanently influences Γ_t, so we need to normalize all the variables except H_t with this trend shock Γ_t to induce stationarity. Let $\hat{C}_t \equiv \frac{C_t}{\Gamma_t}$, $\hat{Y}_t \equiv \frac{Y_t}{\Gamma_t}$, $\hat{I}_t \equiv \frac{I_t}{\Gamma_t}$, $\hat{K}_{t+1} \equiv \frac{K_{t+1}}{\Gamma_t}$, $\hat{W}_t \equiv \frac{W_t}{\Gamma_t}$. However, the stationary model cannot explain HP filtered data. To properly compare the data and model moments, the model needs to be transformed to the level of nonstationary variables of adding back the stochastic trends to the stationarized variables. Then, we apply HP filter to get the non-stationary variables to make the simulated model comparable with the actual data. We introduce a hat to denote its de-trended counterpart for any variable x ;

$$\hat{x}_t \equiv \frac{x_t}{\Gamma_t}$$

Thus, we have the following equilibrium conditions that characterize this economy [10]:
Cobb Douglas production function:

$$\hat{Y}_t = e^{z_t} \hat{K}_{t-1}^{1-\alpha} H_t^{\alpha} g_t^{-1} \tag{12}$$

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[10]First order conditions are presented in Appendix

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Labor demand:

$$\hat{W}_t = \alpha \hat{Y}_t / H_t$$

Demand for capital:

$$R_t = (1 - \alpha)\hat{Y}_t / \hat{K}_{t-1} g_t^{-1}$$

Labor supply :

$$(1 - \psi)\hat{C}_t = \psi(1 - H_t)\hat{W}_t$$

Euler for capital:

$$\hat{C}_t^{\psi(1-\sigma)-1}(1 - H_t)^{(1-\psi)(1-\sigma)} = \beta g_{t+1}^{\psi(1-\sigma)-1}$$
$$\hat{C}_{t+1}^{\psi(1-\sigma)-1}(1 - H_{t+1})^{(1-\psi)(1-\sigma)}(1 + R_{t+1} - \delta)$$

Law of motion for capital:

$$\hat{K}_t = (1 - \delta)\hat{K}_{t-1} g_t^{-1} + \hat{I}_t$$

Aggregate resource contraint:

$$\hat{C}_t + \hat{K}_t = \hat{Y}_t + (1 - \delta)\hat{K}_{t-1} \ g_t^{-1}$$

$$\hat{Y}_t = \hat{C}_t + \hat{I}_t$$

3.2 Extensions

3.2.1 The Real Business Cycle Model with Capacity Utilization

We also analyze the role of capacity utilization in business cycle model. Thereby, we incorporate the capacity utilization into the standard RBC model as an amplification mechanism following Greenwood et al. (1988). In the standard RBC model, there is a weak amplification since the output substantially reacts more than the productivity shock. That means there is instantly a positive output effect due to the capital is predetermined. The basic idea of using capacity utilization is that it allows capital to vary in response to productivity shocks in the business cycle fluctuations by intensifying the capital while the capital enters the period which is predetermined. Thus, the law of motion capital becomes;

$$K_{t+1} = (1 - \delta \ X_t^{\Omega})K_t + I_t \tag{13}$$

X_t represents the capacity utilization rate and the parameter Ω determines the intensity of capacity utilization. The term $\delta \ X_t^{\Omega}$ shows the capital depreciation rate which depends on capital utilization where δ is increasing and convex in X_t and $\Omega > 1$[11].

Now, the production function depends on hours, the amount of capital and utilization as follows:

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[11]The first order condition is presented in Appendix.

$$Y_t = e^{z_t}(K_t X_t)^{1-\alpha}(H_t \Gamma_t)^{\alpha} \tag{14}$$

The term $K_t X_t$ is capital services which depend on the production of utilization and the amount of physical capital. An additional optimality condition in this model is the first order condition for the capacity utilization is given by:

$$X_t = (\frac{1-\alpha}{\Omega \delta} \frac{Y_t}{K_t})^{1/\Omega} \tag{15}$$

3.2.2 The Real Business Cycle Model with Investment Adjustment Costs

We also introduce the model with investment adjustment cost to explore the role of investment adjustment cost in a frictionless RBC model. The reason why we are interested in investment adjustment cost is that the standard RBC model causes the high volatility of investment. However, the incorporation of investment adjustment cost with RBC model reduces the volatility of investment in response to shock since these costs causing investment to adjust slowly to the shock. Also, recent studies consider the cost of changing in investment to improve the performance of the model[12].

We have the following properties as in Christiano et al. (2005) for the functional form of the investment adjustment cost. Households face investment adjustment cost depends on current and lagged investment. Thus, the law of motion for capital with adjustment costs on investment is given by[13]:

$$K_{t+1} = (1 - \frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2)I_t + (1 - \delta)K_t \tag{16}$$

The term $\frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2$ with $\phi > 0$ captures adjustment costs on investment, I_t. It implies that the cost increases when there is a change in the level of investment.

Thus, the Lagrangian multiplier for the model with investment adjustment cost is as follow;

$$q_t = \frac{\theta_t}{\lambda_t} \tag{17}$$

We define Tobin' q as shadow value of having an extra unit of capital θ_t and marginal utility of consumption λ_t. If there is no adjustment cost which means $\phi = 0$, Tobin's q equals to 1.

In here, we do not present all the stationarized equations since some of them are the same as in the basic RBC model. Thus, we have the following the equilibrium conditions that characterize this economy:

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[12]See Khan and Groth (2007), Albonico et al. (2012). To our knowledge, Albonico et al. (2012) is only study to look at the role of investment adjustment cost in frictionless RBC model

[13]The model set-up and the first order conditions are presented in Appendix

Euler for capital:

$$\hat{q}_t = \beta \frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t} g_{t+1}^{-1}((1-\delta)q_{t+1} + R_{t+1}) \tag{18}$$

Euler for investment:

$$1 = \hat{q}_t(1 - \frac{\phi}{2}(\frac{\hat{I}_t}{\hat{I}_{t-1}}g_t - 1)^2 - \phi(\frac{\hat{I}_t}{\hat{I}_{t-1}}g_t - 1)\frac{\hat{I}_t}{\hat{I}_{t-1}}g_t) + \beta \hat{q}_{t+1} \tag{19}$$

$$\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t} g_{t+1}^{-1} \phi(\frac{\hat{I}_{t+1}}{\hat{I}_t}g_t - 1)(\frac{\hat{I}_{t+1}}{\hat{I}_t}g_{t+1})^2$$

Law of motion for capital:

$$\hat{K}_t = (1 - \frac{\phi}{2}(\frac{\hat{I}_t}{\hat{I}_{t-1}}g_t - 1)^2)\hat{I}_t + (1-\delta)\hat{K}_{t-1}g_t^{-1} \tag{20}$$

where q_t is the shadow price of capital in terms of consumption. Equation (18) is the present discounted value of having an additional unit of capital measured in terms of future value and the rental rate.

3.2.3 RBC Model with Indivisible Labor

We now add to the indivisible labor into RBC model. The models we work so far assume that employment equals to hours. However, Hansen (1985) emphasises that fluctuations in hours worked in the economy comes from the changes in both extensive and intensive margins. His finding about USA, which is the most of the fluctuations in hours is due to variation in extensive margin, supports modelling of RBC model with indivisible labor. Thereby, Hansen (1985) modifies the standard RBC model by introducing labor indivisibility in which individuals are restricted to work either full time, denoted by h_0, or not at all. In this model, all the variations in labor comes from the changes in the number of employed workers. However, in the standard RBC model, all variation in labor comes from the changes in hours per worker. Utility function is given by:

$$U(c_t, h_t) = ln(c_t) + Aln(1 - h_t) \tag{21}$$

'A' describes the weight on leisure in the utility function.

Households choose the same probability of working since they are the identical. With probability of π_t, they work h_0. With probability (1-π), they do not work. Thus:

$$= ln(c_t) + A[\pi_t ln(1 - h_0) + (1 - \pi_t)ln(1)]$$

$$= ln(c_t) + A\pi_t ln(1 - h_0)$$

h_t represents hours worked per capita and households work h_0 with probability of π_t, and the rest work zero. This is given by:

$$h_t = \pi_t h_0 \tag{22}$$

Thus, preferences can be written as,

$$U = ln(c_t) + A\frac{ln(1-h_0)}{h_0}h_t \tag{23}$$

In this economy, utility is linear in h_t and the intertemporal elasticity of substitution is infinite for households. With this formula, labor supply varies a lot more intertemporally.

$$B = -A\frac{ln(1-h_0)}{h_0} \tag{24}$$

'B' represents composite labor disutility parameter. Then, we can write it within period utility function as[14]:

$$U(c_t, h_t) = ln(c_t) - Bh_t \tag{25}$$

3.3 Calibration

In this section, we discuss the baseline calibration of the RBC models and the implied parameters values are reported in Table 3. We follow the existing literature in choosing the parameters values governing stochastic productivity processes, preferences, production, utilization and adjustment cost. More specifically, the model is calibrated to match annual frequency following the literature.

We set the annual discount rate to 0.95 so that steady state real interest rate is around 5% per year. Following Aguiar and Gopinath (2007), we set the labour share in production to 0.68 so that the value of capital share is set to 1/3. The value of depreciation rate δ set to 0.05 per year which corresponds to a quarterly depreciation rate of 0.0125. The value of inverse of the Frisch elasticity of labour supply ψ set to 0.33 as in Lind (2004). These values are commonly used in the related literature. Since we have a permanent shock, we set the coefficient of relative risk aversion σ to 1 in the case of separable utility function in order to have balance growth path in the model. However, we set the inverse of the inter temporal elasticity of substitution to 2 in non separable utility function case as in Aguiar and Gopinath (2007).

Regarding the stochastic processes, we have the five parameters defining the stochastic process of the productivity shocks, g , ρ_z, ρ_g , ϵ_g, ϵ_z . The persistence value of temporary shocks ρ_z set to 0.6 as in Lind (2004) and the persistence of permanent shock ρ_g set to 0.1. Then, we set the productivity of growth rate μ_g to log (1.0066) as in Aguiar and Gopinath (2007). The standard deviation of the temporary shock ϵ_z and permanent shock ϵ_g are normalized to 1%. We allow the

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[14]The model solution is in Appendix.

Table 3: Parameters Values in Models

Parameters	Definition	Value
β	Discount factor	0.95
ψ	Inverse of the Frisch elas. of labour supply	0.33
α	Labour share of output	0.68
σ	Intertemporal elasticity of subs. for consumption	2
δ	Depreciation rate of capital	0.05
μ_g	The productivity's mean growth rate	$\log(1.0066)$
ρ_z	The persistence of transitory shocks	0.6
ρ_g	The persistence of growth shock	0.1
χ	The preference weight of hours in utility	0.69
Ω	elas. of depreciation in utilization	2.26
ϕ	adjustment cost on investment	4

investment adjustment cost parameter ϕ is set to 4 following Albonico et al. (2012). They use the values between 0 and 20 for the investment adjustment cost.

Based on these parameters values of the model, the hours worked h from steady state solution is calibrated as a 0.28 in non-separable preference, but we set the hours worked to 1 in separable preference in order to find the value of the preference weight of hours in utility χ which is calculated as a 0.69 from the solution of steady state. Later, we normalize capacity utilization to 1 and then we calculate the value of elasticity of depreciation to changes in utilization Ω as a 2.26. Lastly, we set Tobin q to 1 since there is no investment adjustment cost in steady state.

We later discuss the sensitivity of the results to give different parameter values following other studies in the literature for the inverse of the Frisch elasticity of labor supply, intertemporal elasticity of substitution for consumption, investment adjustment cost and the persistence of the temporary and permanent shocks. The persistence of the shock matters how labor supply react and interact with the intertemporal elasticity of substitution for consumption. In the next section, we first present the results based on the our baseline parameter values in Table 4, then discuss the sensitivity of the results and lastly present the dynamic responses of the labor market variables.

4 Results

4.1 Second Moments

The aim of this section is to compare the second moments of the models with those of the data. Table 4 reports the moments of the labor market variables in the data and in the models to examine how well the RBC models fit the data in developing countries and in USA. We first take log of the data then de-trend it using HP-filter with the standard smoothing parameter 100 as we use annual data. For comparison of properly the data and model moments, we first simulate the stationary model and then add the trend back to the non-stationary variables by applying the HP-filter to these variables. We select the following moments to be calculated: the relative standard deviation to output with hours worked, wages and productivity and also autocorrelation of output and then the correlation of these variables with output.

In table 4, the first column shows the results for the data moments on average for developing countries and the second column presents the moments of USA data for the business cycle frequencies between 1970-2013. The data shows that the fluctuations of wages and productivity are very high in developing countries when we compare the results with the USA but the cyclicality of wages in these economies is slightly less than the that of in USA. Also, hours worked is quite pro-cyclical in the USA while productivity and hours worked are somewhat more weakly correlated with output in developing countries. Afterwards, Model 1 shows the performance of our benchmark model which is the frictionless RBC model by solely driven temporary and permanent shock at matching the stylized facts presenting in data section and Model 3 presents the results for the RBC model augmented capacity utilization, then model 5 presents RBC model's results with investment adjustment cost, lastly Model 7 shows the performance of the RBC model with indivisible labor. We also present the results of separable utility function in Model 2 (benchmark RBC), Model 4 (RBC with capacity utilization), Model 6 (RBC with investment adjustment cost) to explore the sensitivity of our results. In addition, we are not able to present the results both employment and hours worked in this section since we cannot separate employment from hours due to all population are employed in first 6 RBC models. Thus, hours worked represents hours worked per working age population (total hours) in Table 4. However, the model with indivisible labor (Model 7) gives us a chance to explore whether this model where all variation in labor input comes from the fluctuations of employment can confront the facts of employment.

We see that the models do a fairly good job in matching the relative volatility of hours for both developing economies and USA while the models do not generate enough volatilities of wages for developing countries since the volatility of wages relative to output is much higher in data than in the models for developing countries but fairly a good job for the USA in the our benchmark model with separable utility function. Also, these results show that the model with investment adjustment cost does slightly better job than the other models, especially for the relative volatility

Table 4: Business Cycle Moments

	Data	USA	Model1	Model2	Model3	Model4	Model5	Model6	Model7
$\sigma(h)/\ \sigma(y)$	0.74	0.89	0.82	0.80	0.79	0.76	0.80	0.80	0.91
$\sigma(w)/\ \sigma(y)$	1.60	0.77	0.57	0.61	0.45	0.50	1.02	1.02	0.47
$\sigma(p)/\ \sigma(y)$	0.90	0.42	0.57	0.61	0.45	0.50	1.02	1.02	0.47
$\rho(y)$	0.62	0.55	0.36	0.37	0.35	0.36	0.32	0.32	0.36
$\rho(y,h)$	0.48	0.90	0.93	0.88	0.97	0.96	0.62	0.61	0.95
$\rho(y,w)$	0.42	0.54	0.86	0.90	0.86	0.89	1.00	1.00	0.70
$\rho(y,p)$	0.68	0.47	0.86	0.90	0.86	0.89	1.00	1.00	0.70

This table reports the second moments implied by the models in comparison with the developing countries (on average) and the USA data. σ represents relative volatility with output and ρ represents the correlation with output.

of productivity for developing country since the model with investment adjustment cost brings the moments closer to the data but still not good in term of the volatility of wages. In addition, the model with capacity utilization can account for pretty well the volatility of productivity in USA while it fails to explain the volatility of productivity for developing countries.

In particular, in these models, the volatility of hours worked is higher than the volatility of wages. The reason might be that labor supply is very elastic in our models so there are large changes in labor supply. However, in the model with investment adjustment cost, hours worked fluctuates less than wages. That is, the adjustment cost changes this margin, the reason might be that Tobin s q is affecting consumption and then, the reaction of consumption has effect on labor supply so an increase in labor demand. In addition, with investment adjustment cost, capital stock cannot adjust instantly hence neither hours so with adjustment cost the volatility of hours decline as well as investment. Also, output is persistent with autocorrelation of around 0.35 in the models. The benchmark RBC model and the model capacity utilization capture well the high correlation between hours and output for the USA while they fail to capture this data fact for developing countries but the model with investment adjustment cost is a slightly better job. In model 7, labor supply is infinitely elastic so it raises the hour worked volatility and decreases the cyclicality of wages and then productivity. The volatility of hours in this model almost perfectly matches for the USA fact while cyclicality of productivity in the model matches well for the developing countries data fact.

In the benchmark model, the model with capacity utilization and the model with investment adjustment cost, hours worked, wages and productivity are quite pro-cyclical. Thus, these models do not capture data facts since these correlations are less pro-cyclical for developing countries but these models do a pretty good job at matching the correlation of hours worked with output for USA. However, the model with investment adjustment cost does fairly a good job in terms of hours for developing countries since this model brings those fact close to the data. In addition, we have noticed that the volatility of variables to output is slightly higher in the case of separable Cobb Douglas utility function than that of non separable ones. We have obtained nearly the same results for the basic RBC model and the model with capacity utilization.

These models do not do great at explaining the variability of wages in these countries but these models do a fairly good job at matching the variability of hours. Also, the model with investment adjustment cost brings the correlation between hours worked and output closer the data so hours worked is less responsive to the changes in output. In addition, the correlation between wages-output and productivity-output in the models is more pro cyclical than in the developing country's data. Overall, as we see in Table 4, we can conclude that RBC models fail to explain the key labour market variables in developing economies but the model with investment adjustment cost does a better job in volatilities of hours and wages as well as the correlation between hours and output.

We check also the results for the sensitivity by giving different values of σ, ϕ, ψ, and the

persistence of the shocks. In non-separable utility function, the value of ψ is important because the steady state of hours has to be 1/3 but we can give the different value of σ. Thus, we set the value of σ to 0.99. Also, in the separable utility function case, the value of σ has to be 1 for balance growth but we can play with ψ. We set the adjustment cost to 2 as in Albonico et al. (2012) [15]. We figure out that our results are almost insensitive to the changes in those parameters. Then, we set the value of persistence of the ρ_z and ρ_g as in Aguiar and Gopinath (2007) as 0.95 and 0.01, respectively. The results show that the volatility of hours decreases but the volatility of wages increases so the persistence of shocks matters how labor supply and demand react. It increases the performance of the models in terms of volatilities but decreases in terms of the correlations. Later, we shut down the interaction between temporary shock and permanent shock in the our baseline model, it means that ϵ_z or ϵ_g is equal to 0. When we shut down the temporary shock, there is a large rise in the volatility of hours worked (1.18). It reduces the performance of the model in terms of the matching hours worked volatility but improves the performance of the model in terms of productivity volatility (0.91) and wages volatility (0.91). It also rises the persistent of the output to 0.43. When we shut down the permanent shock, the model significantly underpredicts the volatility of wages (0.40) and there are not much significant changes in terms of the correlation of the variables.

As seen in Table 4, the model moments for productivity and wages are the same since average and marginal product of labor with the Cobb Douglas are the same. However, they are not the same in the data so it shows that there is wedge between these two. In section 5, we evaluate the fluctuation of labor wedge by decomposing it marginal rate of substitution and marginal product of labor.

4.2 Impulse Responses

We analyse the dynamic responses of the labor market variables to a shock to the level of technology ($\varepsilon^z = 0.01$) and to trend growth ($\varepsilon^g = 0.01$). In Appendix, Figure 1 and Figure 2 show impulse responses for transitory productivity shock and shock to the trend growth in non-separable utility function case, respectively. Then, Figure 3 and Figure 4 show impulse responses in separable utility function case. We later present the dynamic responses of variables for the model with indivisible labor and the baseline RBC model for comparison. We have obtained quite similar results in the separable and non-separable utility functions case.

We see that output, hours worked, labour productivity and wages all increase in response to a temporary shock. The impulse responses for the standard RBC model and the model with capacity utilization are quite similar, but the model with investment adjustment cost is slightly different. When there is a temporary shock to the economy in the case of adjustment cost, we have seen that productivity and wages give react more than in the case of standard RBC model and the

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[15]They give the values to the adjustment cost between 0 and 20.

model with capacity utilization at the initial jump. We also notice that hours worked does not react significantly to an temporary shock in the model with investment adjustment cost while it responds more noticeably to a temporary shock on impact in the capacity utilization model relative to the basic RBC and adjustment cost models. The reason might be that capacity utilization increases after a temporary shock and it increases output more noticeably in this model than it does in the other models and then it increases wages and labor supply.

If there is a permanent shock, we will end up in a new steady state. That means impulse responses of the labor market variables are relative to the new steady state. Hours worked increases relative to new steady state after the permanent shock in the models. However, hours worked inherits hump-shape to the permanent shock in the model with investment adjustment cost. We can also see that labour productivity and real wages decrease relative to new steady state despite the increase in hours worked inducing a negative correlation between hours worked and productivity. In addition, wages and hours have negative correlation as well in the model 1 and model 3. The reason might be that when there is a permanent shock to the economy, output falls the relative to the new steady state but it does not really fall, de-trend output falls. Normally, when there is permanent shock, people supply less labor because their income and wages are going to be higher in the future but relative to the new steady state hours increases and wages decrease. Lastly, labor supply gives a higher reaction in the model with indivisible labor than the our baseline model at the initial jump.

5   The Labor Wedge

From the model set-up, we know that the household's first order condition that measured marginal rate of substitution (MRS) equals to the wages (w) and the firm's first order condition that measured marginal product of labor (MPL) equals to the wages (w). Thus, MRS and MPL are equal to each other in the equilibrium. However, this condition does not hold in data. Hereby, there is a wedge between these two. In this section, we are interested in exploring whether the fluctuation of labor wedge is mostly coming from the household component of labor wedge or the firm component of labor wedge in developing countries and USA. Therefore, we decompose the labor wedge into a gap between the MPL and the real wage (the firm component of the labor wedge) and a gap between the real wage and the MRS (the household component of labor wedge) as in Karabarbounis (2014)[16]. It is important to understand whether frictions in firm level or household level are relatively more important in these countries for building a model of the business cycle. For this analysis, we use both the non-separable and separable preferences for the sensitivity of our results.

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[16]We also follow this paper to set discretionary time available work and leisure equal to 92 hours per week per person

$$exp(-\tau_t^f)MPL_t = w_t \tag{26}$$

$$exp(\tau_t^h)MRS_t = w_t$$

where τ_t^f denotes the firm component of labor wedge, τ_t^h denotes the household component of labor wedge. The total labor wedge τ_t defined as the gap between the MPL and the MRS;

$$\tau_t = log(MPL_t) - log(MRS_t) = \tau_t^f + \tau_t^h \tag{27}$$

Table 5 shows the cyclical properties of each component of labor wedge in both non-separable and separable preferences between 1970 and 2013. We find that labor wedge is more volatile in developing countries than in the USA. In particular, the household component of the labor wedge is more volatile than that of the firm component of labor wedge in both developing countries and USA. Also, the wedge in the USA moves countercyclical to output. In developing countries, we obtain very heterogeneous results on average that is, when we look at the results in country level, the wedge moves pro-cyclical or countercyclical to output. That's why we are obtaining this small number on average. When we compare our result with Karabarbounis (2014) for the USA, we find slightly different results, especially for the correlation between the firm component of labor wedge and output. We obtain a negative value while he finds positive value for the correlation between the firm component of labor wedge and output . The reason might be that he uses quarterly data and adjust wages with taxes but we use annual data and do not use tax adjustment real wages. That might be the reason why we obtain these different results. In addition, Table 5 shows that our results are insensitive the choice of preferences.
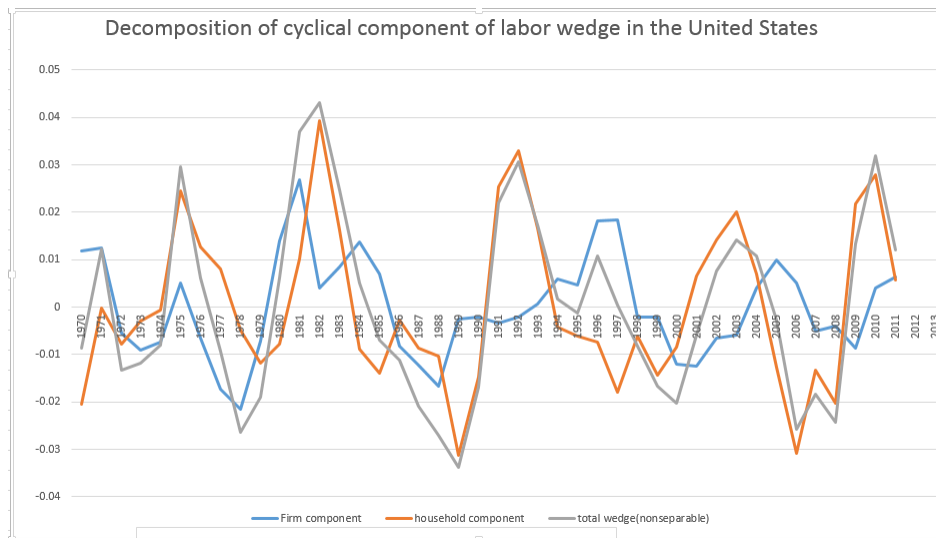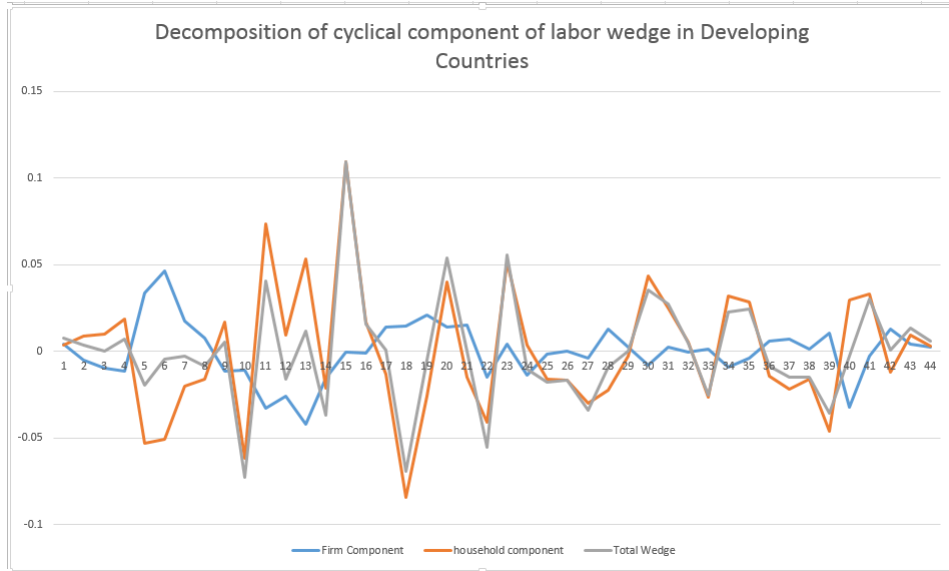
Figure 'A' shows that the fluctuations of the labor wedge predominantly reflect fluctuations of the gap between the real wage and the marginal rate of substitution for developing countries and for the United States. As we see from the figure, there is a strong relationship between the household component of the labor wedge and the overall labor wedge in both countries since the household component of the wedge co-moves very closely to the total wedge in these countries.

Table 5: The Cyclical Properties of Firm and Household Component of Labor Wedge in Developing Countries and USA

Countries	$\frac{\sigma(\tau^f)}{\sigma(y)}$	$\frac{\sigma(\tau^h_n)}{\sigma(y)}$	$\frac{\sigma(\tau^T_n)}{\sigma(y)}$	$\frac{\sigma(\tau^h_s)}{\sigma(y)}$	$\frac{\sigma(\tau^T_s)}{\sigma(y)}$	$\rho(y,\tau^f)$	$\rho(y,\tau^h_n)$	$\rho(y,\tau^T_n)$	$\rho(y,\tau^h_s)$	$\rho(y,\tau^T_s)$
Brazil	2.10	2.21	0.93	2.18	0.91	-0.50	0.45	-0.05	0.45	-0.06
Bulgaria	1.17	2.22	1.84	2.23	1.86	0.10	-0.31	-0.31	-0.31	-0.31
Chile	1.14	1.72	1.17	1.73	1.17	-0.37	0.21	-0.05	0.20	-0.05
Colombia	1.06	2.13	1.72	2.12	1.71	0.19	-0.48	-0.48	-0.48	-0.47
Costa Rica	1.10	1.73	1.89	1.73	1.89	0.17	0.19	0.28	0.18	0.27
Czech Republic	0.55	1.72	0.50	1.71	1.49	-0.002	-0.20	-0.23	-0.19	-0.21
Estonia	0.75	1.77	1.88	1.77	1.87	-0.05	-0.16	-0.17	-0.14	-0.15
Hungary	1.02	1.32	1.51	1.23	1.4	-0.29	-0.06	-0.25	-0.02	-0.23
Jamaica	0.98	2.60	2.64	2.57	2.61	-0.45	-0.55	-0.71	-0.54	-0.71
Mexico	1.86	2.13	1.00	2.12	0.99	-0.48	0.34	-0.17	0.34	-0.16
Peru	1.81	2.13	1.14	2.12	1.14	-0.51	0.62	0.33	0.61	0.32
Slovenia	0.67	1.43	1.26	1.43	1.26	0.58	-0.46	-0.22	-0.46	-0.21
South Korea	1.47	2.72	2.55	2.69	2.5	-0.30	0.10	-0.07	0.13	-0.03
Sri Lanka	1.03	3.54	3.88	2.55	3.9	0.12	0.18	0.20	0.19	0.20
Thailand	0.65	1.53	1.50	1.49	1.45	-0.30	0.15	0.02	0.16	0.03
Turkey	2.40	2.41	0.98	2.42	1.009	-0.07	0.04	-0.06	0.04	-0.06
Average	1.24	2.09	1.72	2.00	1.69	-0.14	0.004	-0.12	0.01	-0.11
USA	0.52	0.82	0.95	1.14	-1.34	-0.38	-0.74	-0.85	-0.87	-0.88

$\sigma(\tau^f)$, $\sigma(\tau^h)$, $\sigma(\tau^T)$ show the standard deviation of firm component, household component and total labor wedge, respectively relative to the standard deviation of output. $\rho(\tau^f)$, $\rho(\tau^h)$, $\rho(\tau^T)$ show the correlations of these component with output. 'n' shows the results for the non-separable preference and 's' represents the results for the separable preference.

A : The Decomposition of Labor Wedge - Nonseparable preference

Decomposition of cyclical component of labor wedge in Developing Countries

Decomposition of cyclical component of labor wedge in the United States

6   Conclusion

We present labor market fluctuations of business cycles for developing countries, and compare these results with the findings from USA. We then check the performance of a set of variants of the RBC models by comparing the second moments of the data and models. Compared to the USA, real wages and productivity are very volatile but less volatile in terms of quantities in developing countries. The result shows that the fluctuations in prices are more pronounced in developing countries. Overall, our models do reasonably well in matching the relative volatility of hours worked data for both USA and developing countries. They fail to account for the relative volatility of the wages for developing countries but they generate fairly enough wage volatility for the USA. Also, the model with investment adjustment cost can satisfactorily account for productivity volatility for developing countries but it does not generate sufficient volatility for the USA.

We conclude that the RBC models driven by productivity shocks fail to explain labour market fluctuations of business cycle in these economies but RBC model with investment adjustment cost brings the moments close to the data and so it improves the performance of model. Lastly, labor wedge is more volatile in developing countries than in the that USA and the fluctuations of the labor wedge is mostly driven by the fluctuations of the gap between the real wage and the MRS in both developing countries and USA.

For future research, we could improve our results using an augmented version of the RBC model then see whether this augmented model bring the moments closer to data. We could augment in the business cycles model with a financial frictions or different shocks influencing labor market variables. We could also develop a model with labour market frictions, such as wage rigidities or a model with informal sector. In order to improve the model's abitility to match the data further research is needed.

7 Appendix

7.1 The Standard RBC Model

The first order conditions of consumption, hours and capital respectively are given by:

For non-separable utility function;

$$\lambda_t = \psi C_t^{\psi(1-\sigma)-1}(1 - H_t)^{(1-\psi)(1-\sigma)} \tag{28}$$

$$(1 - \psi)C_t = \psi(1 - H_t)W_t$$

$$\lambda_t = \beta\lambda_{t+1}(1 + R_{t+1} - \delta)$$

Since all variables in (12) are stationary, we can compute a steady state dropping time subscripts:

$$\hat{Y} = \hat{K}^{1-\alpha}H^\alpha\mu_g^{\alpha-1} \tag{29}$$

$$\hat{W} = \alpha\hat{Y}/H$$

$$\hat{R} = (1 - \alpha)\hat{Y}/\hat{K}\mu_g^{-1}$$

$$(1 - \psi)\hat{C} = \psi(1 - H)\hat{W}$$

$$1 = \beta\mu_g{}^{\psi(1-\sigma)-1}(1 + R - \delta)$$

$$\hat{C} + \hat{K} = \hat{Y} + (1 - \delta)\hat{K}\mu_g^{-1}$$

$$\hat{K} = (1 - \delta)\hat{K}\mu_g^{-1} + \hat{I}$$

$$\hat{Y} = \hat{C} + \hat{I}$$

Then, here is solving steady state of the model:

$$R = \frac{1}{\beta\mu_g^{\psi(1-\sigma)-1}} - (1 - \delta) \tag{30}$$

$$\frac{Y}{K} = \frac{R}{(1 - \alpha)\mu_g}$$

$$\frac{I}{Y} = \frac{K}{Y}(1 - (1 - \delta))\mu_g^{-1})$$

$$\frac{C}{Y} = 1 - \frac{I}{Y}$$

$$H = (\frac{1 - \psi}{\psi\alpha}\frac{C}{Y} + 1)^{-1}$$

$$K = (\frac{H^\alpha\mu_g^{\alpha-1}}{\frac{Y}{K}})^{\frac{1}{\alpha}}$$

$$Y = K^{1-\alpha}H^\alpha\mu_g^{\alpha-1}$$

$$C = \frac{C}{Y} Y$$

$$I = \frac{I}{Y} Y$$

$$W = \alpha \, \frac{Y}{H}$$

For separable utility function, σ equals to 1 to hold balance growth in the long run. For households, the first order conditions of consumption, hours and capital, respectively are given by:

$$\lambda_t = C_t^{-1} \tag{31}$$

$$\chi H_t^{\psi} = C_t^{-1} W_t$$

$$\lambda_t = \beta \lambda_{t+1}(1 + R_{t+1} - \delta)$$

We set the steady state of hours to 1 in order to find the value of χ in steady state. Then, here is solving steady state of the model for separable utility function:

$$R = \frac{1}{\beta \mu_g^{-1}} - (1 - \delta) \tag{32}$$

$$H = 1$$

$$\chi = C^{-1} W$$

The rest of steady state solutions for variables are the same with RBC model with nonseparable utility function.

7.2 The Standard RBC Model with Capacity Utilization

The first order conditions of consumption, hours, capital and utilization, respectively are given by;
For non-separable utility function;

$$\lambda_t = \psi C_t^{\psi(1-\sigma)-1}(1 - H_t)^{(1-\psi)(1-\sigma)} \tag{33}$$

$$(1 - \psi)C_t = \psi(1 - H_t)W_t$$

$$\lambda_t = \beta \lambda_{t+1}(1 + R_{t+1} - \delta X_t^{\Omega})$$

$$X_t = (\frac{1 - \alpha}{\Omega \delta} \frac{Y_t}{K_t})^{1/\Omega}$$

We set the steady state of utilization to 1 in order to find the value of Ω. Then, here is solving steady state of the model:

$$X = 1 \tag{34}$$

$$R = \frac{1}{\beta \mu_g^{\psi(1-\sigma)-1}} - (1 - \delta X^\Omega)$$

$$\Omega = \frac{R}{\delta}$$

$$\frac{I}{Y} = \frac{K}{Y}(1 - (1 - \delta X^\Omega))\mu_g^{-1})$$

$$K = (\frac{H^\alpha \mu_g^{\alpha-1} X^{1-\alpha}}{\frac{Y}{K}})^{\frac{1}{\alpha}}$$

$$Y = K^{1-\alpha} H^\alpha \mu_g^{\alpha-1} X^{1-\alpha}$$

The rest of the steady state values are the same with standard RBC model.

7.3 The Standard RBC Model with Investment Adjustment Cost

The households maximize the Lagrangian, with two separate constraints:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t U(C_t, H_t) + \lambda_t(W_t H_t + R_t K_t - C_t - I_t)+$$

$$\theta_t((1 - \frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2)I_t + (1 - \delta)K_t - K_{t+1}) \tag{35}$$

So, first order conditions of consumption, hours, capital and investment, respectively are given by;

$$\lambda_t = \psi C_t^{\psi(1-\sigma)-1}(1 - H_t)^{(1-\psi)(1-\sigma)} \tag{36}$$

$$(1 - \psi)C_t = \psi(1 - H_t)W_t$$

$$\theta_t = \beta \lambda_{t+1} R_{t+1} + \beta \theta_{t+1}(1 - \delta)$$

$$\lambda_t = \theta_t(1 - \frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2 - \phi(\frac{I_t}{I_{t-1}} - 1)\frac{I_t}{I_{t-1}})$$

$$+ \beta \theta_{t+1}\phi(\frac{I_{t+1}}{I_t} - 1)(\frac{I_{t+1}}{I_t})^2$$

Then, we define Tobin' q as shadow value of having an extra unit of capital θ_t and marginal utility of consumption λ_t. If there is no adjustment cost which means adjustment cost ϕ equals to 0, and then Tobin's q equals to 1.

$$q_t = \frac{\theta_t}{\lambda_t} \tag{37}$$

From the Tobin q equation, we already know that $q_t \lambda_t$ equals to θ_t. If we substitute this equation into the FOC of capital and then dividing both sides by λ_t, we get:

$$q_t = \beta \frac{\lambda_{t+1}}{\lambda_t}((1-\delta)q_{t+1} + R_{t+1})$$ (38)

Also, if we do the same process for the FOC of investment, and then dividing both sides by λ_t, we get:

$$1 = q_t(1 - \frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2 - \phi(\frac{I_t}{I_{t-1}} - 1)\frac{I_t}{I_{t-1}})$$

$$+\beta q_{t+1}\frac{\lambda_{t+1}}{\lambda_t}\phi(\frac{I_{t+1}}{I_t} - 1)(\frac{I_{t+1}}{I_t})^2$$

There is no adjustment cost in steady state, so q equals to 1. Here is the solving steady state of the model with investment adjustment cost:

$$q_t = 1$$ (39)

$$R = \frac{1}{\beta \mu_g^{-1}} - (1 - \delta)$$

$$\frac{I}{Y} = \frac{K}{Y}\frac{(1 - (1 - \delta))\mu_g^{-1})}{(1 - \frac{\phi}{2}(\mu_g - 1)^2)}$$

The rest of steady state solution is the same with the steady state solution of basic RBC model.

7.4   The Standard RBC Model with Indivisible Labor

For household, the first order condition of consumption, hours and capital are given by:

$$\lambda_t = \beta C_t^{-1}$$ (40)

$$Bc_t = w_t$$

$$\frac{1}{c_t} = \beta \frac{1}{c_{t+1}}(1 + r_{t+1} - \delta)$$

Lastly, the steady state of hours is:

$$H = \alpha(\frac{C}{Y})^{-1}\frac{1}{B}$$ (41)

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Table 1A : Time Covered By Country

Country	Employment	Hrs. Wrk.,Prod.	Wages	Output
Brazil	1970-2013	1970-2013	1992-2009	1970-2013
Bulgaria	1970-2013	1995-2013	1996-2011	1970-2013
Chile	1970-2013	1970-2013	1974-2013	1970-2013
Colombia	1970-2013	1970-2013	1970-2012	1970-2013
Costa Rica	1970-2013	1987-2013	1987-2012	1970-2013
Czech Republic	1970-2013	1993-2013	1994-2008	1985-2013
Ecuador	1970-2013	1995-2013	-	1970-2013
Estonia	1970-2013	2000-2013	2000-2013	1980-2013
Hungary	1970-2013	1980-2013	1995-2008	1970-2013
Jamaica	1970-2013	1986-2013	1998-2013	1970-2013
Mexico	1970-2013	1970-2013	1980-2011	1970-2013
Peru	1970-2013	1970-2013	1970-2011	1970-2013
Slovenia	1970-2013	1996-2013	1996-2009	1980-2013
South Korea	1970-2013	1970-2013	1970-2008	1970-2013
Sri Lanka	1970-2013	1970-2013	1983-2012	1970-2013
Thailand	1970-2013	1970-2013	1970-2012	1970-2013
Turkey	1970-2013	1970-2013	1987-2006	1970-2013

Table 1B : Descriptive Statistics for Developing Countries on Average and USA.

Variables	Mean	Std. Dev.	Var.	Median
Employment	4.14(4.24)	0.08(0.05)	0.007(0.002)	4.15(4.26)
Hours worked(he)	7.59(7.46)	0.48(0.02)	0.003(2.70E-04)	7.14(7.46)
Hours worked(hw)	7.12(7.09)	0.06(0.04)	0.005(0.001)	7.12(7.12)
Productivity	2.08(3.37)	0.22(0.21)	0.80(40.51)	2.53(28.57)
Wages	10.52(3.06)	0.28(0.08)	0.13(0.006)	10.51(3.02)
Output	9.16(10.47)	0.23(0.23)	0.07(0.05)	9.14(10.47)

Parenthesis show the descriptive statistics for USA

Figure 1 : Impulse Responses for Temporary Shock-Nonseparable Case
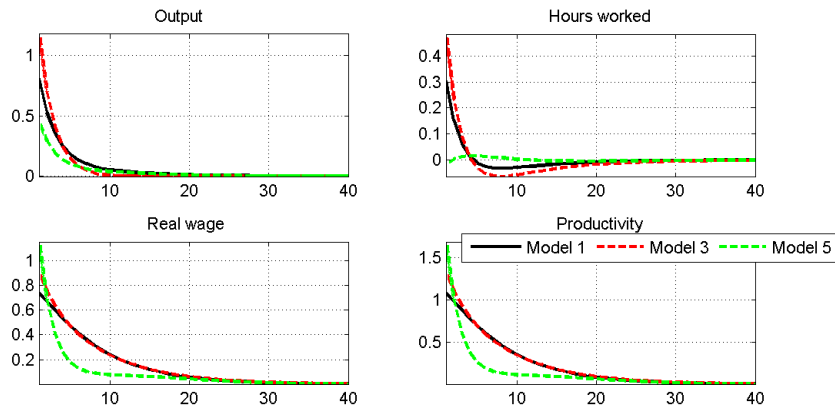
Figure 1: Impulse Responses for Trend Shock-Nonseparable Case
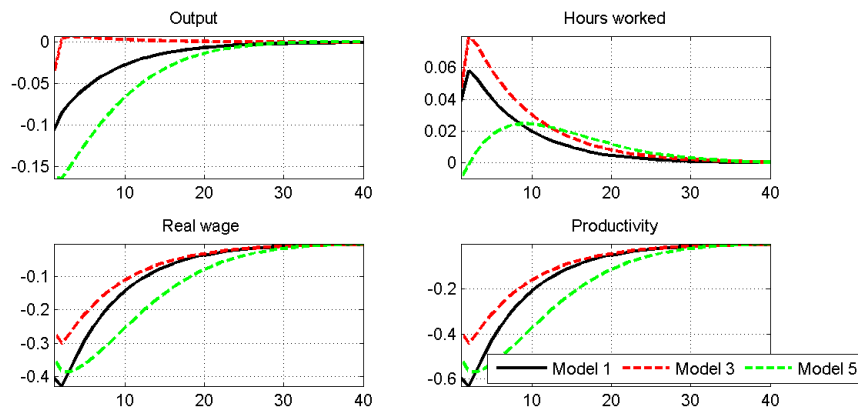
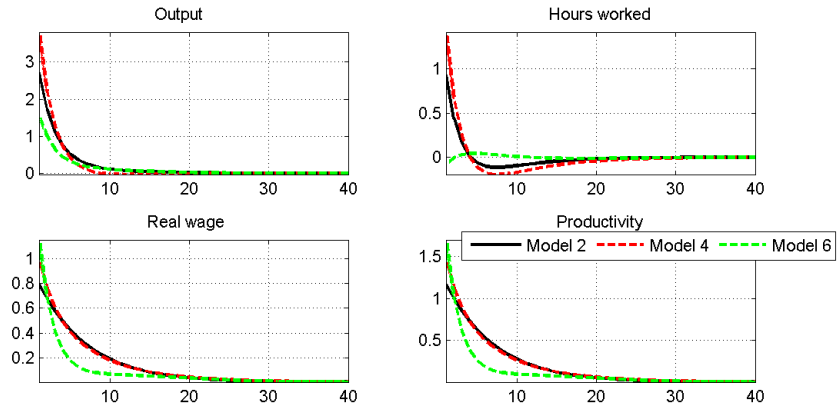Figure 3 : Impulse Responses for Temporary Shock-Separable Case

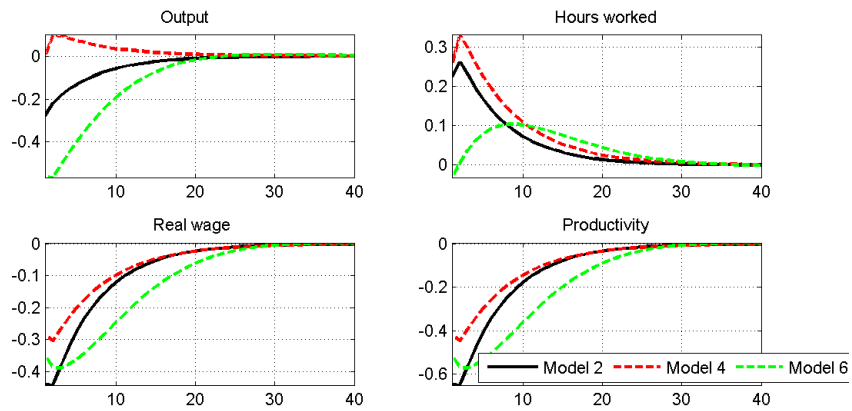
Figure 4 :Impulse Responses for Trend Shock-Separable Case
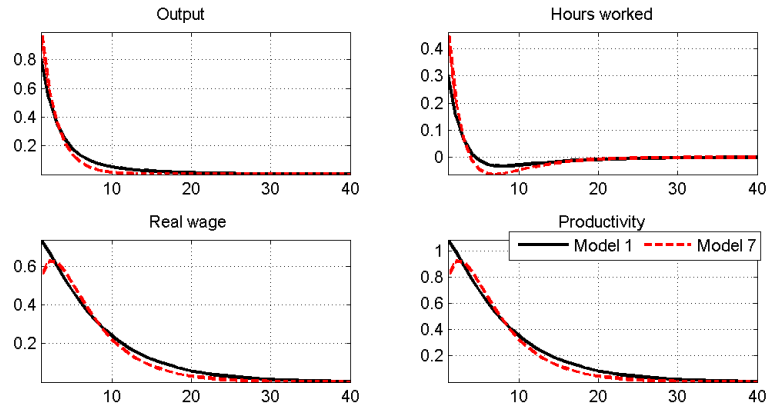
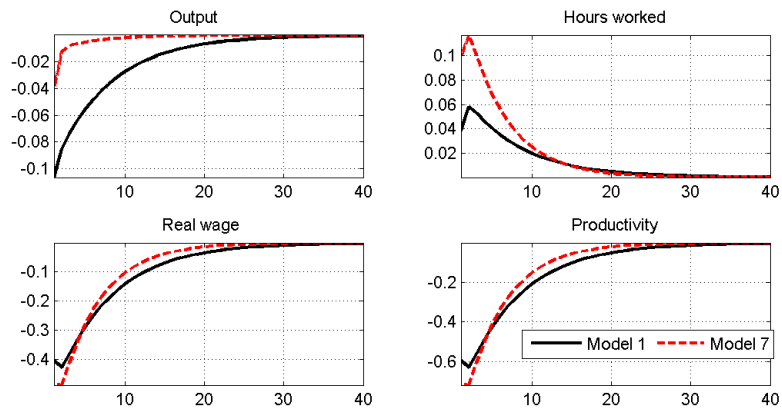Figure 5 : Impulse Responses for Temporary Shock

Figure 6 : Impulse Responses for Trend Shock

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