HONG KONG INSTITUTE FOR MONETARY RESEARCH

REAL EXCHANGE RATE, PRODUCTIVITY AND LABOR MARKET RIGIDITIES

Yu Sheng and Xinpeng Xu

HKIMR Working Paper No.09/2009

February 2009

Hong Kong Institute for Monetary Research

(a company incorporated with limited liability)

Real Exchange Rate, Productivity and Labor Market Rigidities

Yu Sheng*

The Australian National University

and

Xinpeng Xu**

The Hong Kong Polytechnic University

Hong Kong Institute for Monetary Research

February 2009

Abstract

We extend the classic Balassa-Samuelson model to an environment with search unemployment. We show that the classic Balassa-Samuelson model with the assumption of full employment emerges as a special case of our more generalized model. In our generalized model, the degree of labor market rigidities affects the strength of the structural relationship between real exchange rate and sectoral productivity and in some circumstances, the standard Balassa-Samuelson effect may not hold. Empirical evidence supports our theory: controlling for the difference in labor market rigidities across countries provides a better fit in estimating the Balassa-Samuelson effect.

Keywords: The Balassa-Samuelson Model, Search Unemployment, Labor Market Rigidities

JEL Classification: F16, F31, J64

* Yu Sheng

Asia Pacific School of Economics and Government

The Australian National University

Canberra, Australia

E-mail: Yu.Sheng@anu.edu.au

** Xinpeng Xu (Corresponding author)

Faculty of Business (AF)

The Hong Kong Polytechnic University

Kowloon, Hong Kong

E-mail: afxxu@polyu.edu.hk Tel: (852) 2766 7139 Fax: (852) 2774 9364

Acknowledgement: We are grateful to Jean Imbs, Peter Drysdale, Martin Richardson, Guillaume Rocheteau, Rod Falvey, Ligang Song and one anonymous referee for helpful comments and suggestions. Part of the research in this paper was conducted while Xinpeng Xu was visting the Hong Kong Institute for Monetary Research and he is thankful for its hospitality and support. The views expressed in this paper are those of the authors, and do not necessarily reflect those of the Hong Kong Institute for Monetary Research, its Council of Advisors, or the Board of Directors.

1. Introduction

The relative price of a common basket of goods between two countries, the real exchange rate (RER), is one of the most important prices in an open economy. Balassa (1964) and Samuelson (1964), often referred to as the Balassa-Samuelson model, argue that productivity differentials between the tradable and non-tradable sectors, rather than Purchasing Power Parity (PPP), are the main driving force in the movement of the real exchange rate between two countries. Balassa and Samuelson posit that, as the law of one price (LOP) holds only for tradable goods, in a fast-growing economy, higher productivity growth in the tradable sector will increase real wages in all sectors since employed workers are mobile across sectors, which will lead in turn to an increase in the relative price of non-tradable goods, resulting in an overall rise in the national price level.[1]

One of the underlying assumptions of the Balassa-Samuelson model is that labor market is frictionless so that there is always full employment, as employed workers can move instantaneously and costlessly across sectors in response to changes in relative sectoral wages. Yet, it is well recognized that it takes time and other resources for an unemployed worker to find a job and for a firm to fill a vacancy so that there exist frictions in the labor market (see for example, McCall 1970; Diamond 1982; Mortensen 1982; Pissarides 1985; Mortensen and Pissarides 1999; Pissarides 2000 and Rogerson *et al*. 2005) and that there are significant differences in the degree of labor market rigidities across sectors and countries. How would differences in labor market institutions across sectors and countries affect the classic Balassa-Samuelson relationship between real exchange rate and productivity differentials?

We demonstrate in this paper that the degree of labor market rigidities across sectors and countries affects the strength of the structural relationship between real exchange rate and sectoral productivity differentials and in some circumstances, the standard Balassa-Samuelson effects may not hold. Specifically, in a world with labor market frictions and unemployment, the standard Balassa-Samuelson mechanism may have to be revised to incorporate the fact that workers cycle between employment and unemployment. In such an environment, employed workers no longer move instantaneously and costlessly across sectors in response to changes in relative sectoral wages. Instead, it is unemployed workers that move freely across sectors in response to changes in expected lifetime income arising from changes in relative sectoral wages and associated frictional costs such as the probability of finding a new job and of an existing job being destroyed. Thus, an increase in the relative productivity of the tradable sector may lead to an increase in the relative wage in that sector, but the extent of the increase would, in

1 Recent empirical investigations of the effect of productivity shocks (which are real shocks) on the real exchange rate, the so-called Balassa-Samuelson effect, include, inter alia, Asea and Mendoza (1994), De Gregorio *et al*. (1994), Froot and Rogoff (1995), Lothian and Taylor (2004) and Canzoneri *et al*. (1999). Although a survey of empirical findings by Froot and Rogoff (1995) finds weak support for the Balassa-Samuelson effect, recent work by Lothian and Taylor (2004) using data from 1820-2001 for the US, the UK and France in a nonlinear framework reports a statistically significant Balassa-Samuelson effect which explains 40% of the variation of sterling-dollar exchange rate. Asea and Mendoza (1994) and Canzoneri *et al*. (1999) also provide similar results to support the proposition that productivity differentials determine the relative price of non-tradables. See also recent work by Alessandra and Kaboski (2004).

general, be lower compared with what is predicted by the standard Balassa-Samuelson model, as part of the increase in the marginal product of labor will be used to cover frictional costs in the labor market. The increase in the wage of the tradable sector will lead to an increase in the expected lifetime income of unemployed workers searching in the tradable sector, attracting unemployed workers in the non-tradable sector to move to the tradable sector. This movement of unemployed workers across sectors will continue until the expected lifetime income of unemployed workers searching in each sector are equalized. The resulting increase in the expected lifetime income of unemployed workers in the non-tradable sector may bid up wages of employed workers in the non-tradable sector. However, the increase in the price of non-tradable good may be higher or lower than what is predicted by the standard Balassa-Samuelson model, depending on the relative market rigidities between the two sectors, as the effect of an increase in the non-tradable sector's wage on non-tradable price will be absorbed by the relative flexibility in its labor market, resulting in a higher or lower price of non-tradable goods and hence, the national price level. Furthermore, if the relative labor market rigidity in the tradable sector is too high, there is a potential that the relative increase in the tradable sector productivity may be more than offset by its relative high frictional costs, thus operating against the Balassa-Samuelson effect. The importance of labor market institutions highlighted in this paper offers an added dimension in explaining differences in price level for countries with different or similar income levels.

We view our work as complementary to the recent literature that emphasizes imperfections in the goods market in extending the Balassa-Samuelson model. Several recent papers have updated or extended the Balassa-Samuelson model by focusing on imperfection in goods market. For example, Fitzgerald (2003) revisits the classic Balassa-Samuelson model by dropping out the Balassa-Samuelson assumption that all countries produce the same tradable goods. Instead, Fitzgerald introduces production of differentiated goods across countries and increasing returns to scale in the production, which leads to endogenous specialization and intra-industry trade. Under such a different environment, the relationship between real exchange rate and sectoral productivity is shown to depend on the strength of terms-of-trade effects. Ghironi and Melitz (2005) propose a model highlighting the importance of endogenous firm entry and exit to both domestic and export markets in determining the movement of national price levels. Bergin *et al*. (2006) develop a model of endogenous tradability where instead of assuming productivity gains concentrating by coincidence in the production of existing tradable goods as in the Balassa-Samuelson model, productivity gains in the production of particular goods can lead to those goods becoming traded. They demonstrate that such a model can deliver endogenously time-varying correlations between incomes and prices. A recent paper by Helpman and Itskhoki (2007) extends Melitz's (2003) model by introducing search unemployment in one sector to examine the interaction of labor market rigidities and trade impediments in shaping the relationship between productivity and price levels across countries. They show that the country with more flexible labor market has both higher productivity and a lower price level, which operates against the standard Balassa-Samuelson effect.

To the best of our knowledge, our paper is the first to develop a model that integrates the standard Balassa-Samuelson model with search theory so that the classic Balassa-Samuelson model can be examined in an environment without the assumption of full employment.[2] In contrast to the latest literature that focuses on imperfection in the goods market, we centre our analysis on imperfection in the factor market – labor market. Unlike other theoretical models, the standard Balassa-Samuelson channel, i.e., sectoral productivity differentials affecting real exchange rate movements, is still operative in our generalized model. A focus on the frictional labor market reflects, practically, the rising importance of the issue of unemployment in the age of globalization, whereby the real exchange rate movements may have interacted with domestic labor market institutions when countries integrate more and more with each other.

To anticipate our results, we show that: (1) the classic Balassa-Samuelson model emerges as a special case of our more generalized model with unemployment; (2) the effects of sectoral productivity differentials on the real exchange rate have to be adjusted quantitatively for differences in labor market flexibility across sectors and between countries, which highlights a new and potentially important channel for the transmission of various shocks to labor market institutions to the real exchange rate, i.e., labor market institutions matter; (3) in fact, there is the potential to reverse the classic positive relationship between sectoral productivity and the real exchange rate, if certain conditions are met. Most importantly, our empirical evidence confirms that controlling for labor market flexibility provides a better fit in estimating the Balassa-Samuelson effect.

The rest of our paper proceeds as follows. In the next section we develop a two-sector model that distinguishes between the tradable and non-tradable sectors and endogenizes unemployment in a simple framework of search theory. This provides us with a setup that is useful in discussing the relationship between real exchange rate, sectoral productivity and labor market flexibility across sectors and between countries. We summarize the main results in a proposition and several lemmas and corollaries. In section 3, we discuss our empirical results. The final section concludes.

2. The Model

Consider a small open economy that produces two composite goods, tradable goods (T) priced in international markets and non-tradable goods (N) priced in the domestic market. The production technology of tradables and non-tradables is characterized by constant returns to scale (CRS) production functions of the capital K_i ($i = T, N$) and labor L_i employed, $Y_i = A_i F(K_i, L_i) = A_i L_i f(k_i)$, where Y_i is output in the tradable and non-tradable sectors respectively, and the *A*'s are productivity shifters while tradable goods are taken as numeraire.

[2] For an introduction to search theory, see Ljungqvist and Sargent (2000).

Output per unit of labor, $y_i \equiv Y_i/L_i$, can then be written as, $y_i = A_i f(k_i)$, which makes use of the condition of CRS where $k_i \equiv K_i/L_i$ is the capital-labor ratio in sector *i*. The production function $F(\bullet)$ exhibits positive and diminishing marginal products with respect to each input. Capital is perfectly mobile across sectors domestically and internationally.

We now depart from the standard full employment assumption as in the Balassa-Samuelson model. In a frictional economy, it takes time and other resources for a worker to land a job and for a firm to fill a vacancy. Since there are workers searching for a job and vacancies waiting to be filled, there is always unemployment in the labor market. With labor market frictions and unemployment, it is now unemployed workers that move freely across sectors and, therefore, it is the expected income of unemployed workers that will be equalized across sectors. In contrast, employed workers' income w_i may be different as it has to take into account compensation differentials arising from labor market frictions. We now specify job matching, job creation, job destruction, and wage determination in general equilibrium.

2.1 Matching

Suppose the number of matches between firms and workers depends on the number of unemployed workers (*U*) chasing the number of vacancies (*V*). Let *Z* be the labor force, *u* the unemployment rate (*U*/*Z*) and *v* be the number of vacant jobs as a fraction of the labor force (*V*/*Z*). We have the number of matches, $mZ = m(Zu, Zv)$. A typical assumption of the functional form for the matching function is constant returns to scale (Blanchard and Diamond 1989). Thus, we can express all variables as a function of the tightness of the labor market, $\theta \equiv v/u$. The rate at which a vacant job is filled is therefore $q(\theta)$, which is equal to m/v. The rate at which an unemployed worker finds a match is $\theta q(\theta)$, which is equal to m/u.

2.2 Firms

Following Pissarides (2000), a typical firm has jobs that are vacant and has to pay cost γ as an advertising and recruiting cost in order to fill a vacancy. During hiring, a vacant job is filled at the rate $q(\theta)$ while an unemployed worker finds a job at the rate $\theta q(\theta)$. When a firm and a worker meet and agree to an employment contract, a job is occupied. The firm then goes on to rent capital k for each worker and produces output, which is sold in competitive markets.

We consider the optimal decision of a typical firm in the tradable sector first. Let V_T be the present-discounted value of expected profit to the firm from a vacant job and J_T the present-discounted value of expected profit to the firm from an occupied job in the tradable sector. V_T satisfies the Bellman equation

$$rV_T = -\gamma + q(\theta_T)(J_T - V_T) \tag{1}$$

A job is an asset owned by the firm and is valued in a perfect capital market characterized by a risk-free interest rate *r*. The asset value of a vacant job, rV_T , is exactly equal to the rate of return on the asset: the vacant job costs γ but has the probability of $q(\theta)$ for the vacancy to turn into a filled job which will yield the net return $J_T - V_T$. At equilibrium, perfect competition and profit maximization requires that the gains from job creation are always exhausted, so that jobs are created up to the point where V_T =0, implying that $J_T = \gamma / q(\theta)$. The implicit assumption here is that firms decide to create jobs whenever the value of a vacancy is positive and thus potential profits will be eroded quickly by free entry.

As the capital stock owned (or rented) by the firm becomes part of the value of the job, the asset value of an occupied job is given by $J_T + k_T$. The job yields net return $A_T f(k_T) - w$. Similar to the valuation of a vacant job, the asset value of an occupied job, $r(J_T + k_T)$, satisfies the following Bellman equation

$$r(J_T + k_T) = A_T f(k_T) - w - \lambda(J_T - V_T) \tag{2}$$

where λ is the job destruction rate which leads to the loss of J_T but not k_T.[3] Intuitively, the annuity of the return to the asset of an occupied job is equal to the output $A_T f(k_T)$, net of its cost (which is wage here if we assume no capital depreciation for simplicity), with a probability of λ that the relationship may come to an end so that the firm will lose J_T.

Given the interest rate and wage rate, the firm rents capital k_T to maximize the value of the job J_T . We can write the firm's first-order condition with respect to capital as

$$A_T f'(k_T) = r \tag{3}$$

which has the standard interpretation where firms rent capital k_T up to the point where the marginal product of capital is equal to the market rental rate, *r*, as we assume that there is no friction in the capital market.

Substituting the firm's first order condition with respect to capital and the equilibrium job creation condition $J_T = \gamma / q(\theta_T)$ into the asset value equation of an occupied job yields the familiar equilibrium condition for the firm's employment of labor. The firm hires workers up to the point where marginal benefit of an

[3] For simplicity, we assume that job destruction rates are exogenous and the same across sectors but it can be relaxed easily without affecting our main results.

additional worker, the marginal product of labor, is equal to marginal cost, i.e., the market wage, after adjusting for the frictional cost,

$$A_T\,(f(k_T) - k_T f'(k_T)) = w + \frac{(r+\lambda)\gamma}{q(\theta_T)} \tag{4}$$

If there is no recruitment cost so that γ=0, the last term on the right hand side of equation (4) becomes zero and (4) is the familiar Euler equation for labor in a full-information, frictionless labor market.

2.3 Workers

Workers search for jobs and, once offered, have to make a decision to accept or reject the offer. Therefore workers' decisions will impact on the equilibrium market wages. Similar to a firm described in the above section, a typical worker makes an optimal decision to accept a job offer and receive wage *w* or to remain unemployed and receive unemployed benefits during the search. Again we illustrate a typical worker's decision making in the tradable sector. Let U_T and E_T be the present-discounted value of expected income streams of an unemployed worker and an employed worker in the tradable sector respectively. U_T satisfies the Bellman equation

$$rU_T = b + \theta_T q(\theta_T)(E_T - U_T) \tag{5}$$

Equation (5) says that the asset value of the unemployed worker's human capital is made up of two components: the unemployment benefits *b* and the expected capital gain from change of state $q(\theta_T)(E_T - U_T)$.[4] rU_T can be interpreted as the annuity (permanent income) that an unemployed worker expects to receive during the search.

Similarly, the asset value of an employed worker's human capital satisfies the following Bellman equation

$$rE_T = w + \lambda(U_T - E_T) \tag{6}$$

Equation (6) has a similar interpretation to (5). The permanent income of an employed worker is made up of two components: the constant wage *w* and the expected capital loss from change of state $\lambda(U_T - E_T)$.

[4] The unemployment benefits *b* can be interpreted more broadly to include the value of leisure and home production, net of any cost of search. See Rogerson *et al.* (2005).

Combining (5) and (6), we can solve for permanent income of an unemployed and an employed worker as follows

$$rU_T = \frac{(r+\gamma)b + \theta_T q(\theta_T)w_T}{r+\lambda+\theta_T q(\theta_T)} \tag{7}$$

$$rE_T = \frac{\lambda b + [r+\theta_T q(\theta_T)]w_T}{r+\lambda+\theta_T q(\theta_T)} \tag{8}$$

In contrast to the standard Balassa-Samuelson model with full employment where employed workers move instantaneously and costlessly across sectors in response to changes in relative sectoral wages, in a model with labor market frictions, it is the searching unemployed workers that move freely across sectors. In equilibrium, free mobility of unemployed workers across sectors ensures that the asset value of the unemployed workers in the tradable sector should be equal to that of the unemployed workers in the non-tradable sector. However, employed workers' income may be different across sectors as sectoral employment income may have to reflect wage differentials in compensating for the risks associated with each sector, for example, the probabilities of finding a new job and of being fired.

2.4 Wage Determination

As an occupied job yields returns that go beyond the sum of the expected returns of a searching firm and a searching worker, the pure economic rent needs to be shared between the firm and the worker. A simple approach is to assume that w is determined by the generalized Nash bargaining solution with threat points U_T and V_T for each job-worker pair, $w_j \in \arg\max[(E_T^j - U_T)^\beta (J_T^j - V_T)^{1-\beta},]$, where $\beta \in (0,1)$ is the worker's bargaining power.

The solution to the above first-order maximization problem satisfies

$$E_T^j - U_T = \beta(J_T^j + E_T^j - V_T - U_T) \tag{9}$$

which says that the worker receives his threat point U_T, plus a share of the pure economic rent created by the job match. Equation (9) can be solved for the representative worker's wage in the tradable sector w_T. By substituting (2) and (6) in (9), and making use of the equilibrium condition V_T =0, we have

$$w_T = (1-\beta)rU_T + \beta(A_T(f(k_T) - rk_T) \tag{10}$$

Substituting (9) in (5) and making use of $J_T = \gamma / q(\theta_T)$, we can derive another equation

$$rU_T = b + \frac{\beta}{1-\beta}\gamma\theta_T \tag{11}$$

Substituting (11) in (10), we have

$$w_T = (1-\beta)b + \beta\gamma\theta_T + \beta(A_T f(k_T) - rk_T) \tag{12}$$

where $\gamma\theta_T$ is the average frictional cost for each unemployed worker. Note that with search frictions in the labor market, the wage for employed workers is no longer pinned down by the sectoral capital-labor ratio and productivity. It also depends on the value of the employed workers' outside options (unemployment benefits *b*), frictional costs and the probabilities of the existing job being destroyed and of finding a new job in the future. As such, employed workers' wage w_i may be different across sectors as it has to take into account compensation differentials arising from labor market frictions. This is in contrast to the standard Balassa-Samuelson model where wages are equalized across sectors due to free mobility of workers without frictions.

Finally, since job creation, $u_T\theta_T q(\theta_T)Z$, should be equal to job destruction, $\lambda(1-u_T)Z$ in equilibrium, the steady-state unemployment rate in the tradable sector can be written as:

$$u_T = \frac{\lambda}{\lambda + \theta_T q(\theta_T)} \tag{13}$$

Equation (13) shows that the search generated unemployment rate in the tradable sector is positively related to the job destruction rate (λ) but negatively associated with the probability of an unemployed worker encountering a job opportunity ($\theta_T q(\theta_T)$). It describes a fundamental equilibrium relationship between unemployment and vacancy, which is often referred to as the Beveridge Curve. This relationship can be illustrated as a downward sloping locus of unemployment and vacancy combinations in the U-V space that are consistent with the steady state at which total workers' flow into unemployment being equal to total workers' flow out of unemployment (Pissarides 2000, p 32).

2.5 Equilibrium

We are now able to characterize the steady-state equilibrium. The equilibrium conditions in the tradable sector consist of firms' profit maximization conditions with respect to capital and labor, (3) and (4) respectively, the equilibrium in wage bargaining (12), and the labor market equilibrium condition (13), which are rewritten as

$$A_T f'(k_T) = r \tag{3}$$

$$A_T(f(k_T) - k_T f'(k_T)) = w + \frac{(r+\lambda)\gamma}{q(\theta_T)} \tag{4}$$

$$w = (1-\beta)b + \beta\gamma\theta_T + \beta(A_T(f(k_T) - rk_T) \tag{12}$$

$$u_T = \frac{\lambda}{\lambda + \theta_T q(\theta_T)} \tag{13}$$

Similarly, the equilibrium conditions for the non-tradable sector can be written as follows.

$$pA_N g'(k_N) = r \tag{3'}$$

$$pA_N(g(k_N) - k_N g'(k_N)) = w + \frac{(r+\lambda)\gamma}{q(\theta_N)} \tag{4'}$$

$$w = (1-\beta)b + \beta\gamma\theta_N + \beta(A_N(g(k_N) - rk_N) \tag{12'}$$

$$u_N = \frac{\lambda}{\lambda + \theta_N q(\theta_N)} \tag{13'}$$

where *p* denotes the relative price of non-tradable to tradable goods. Both sets of four equations for the tradable and non-tradable sectors consist of a recursive system that can be solved easily for four unknowns, i.e., k, θ, w and u.[5]

2.6 The Generalized Balassa-Samuelson Effect

To examine the price effect of anticipated productivity shifts, as in the Balassa-Samuelson model, we take natural logs of both sides of equations (4) and differentiate them, which yields

$$\frac{dA_T}{A_T} + \frac{A_T f'(k_T)k_T}{A_T f(k_T)}\frac{dk_T}{k_T} = \frac{rk_T}{A_T f(k_T)}\frac{dk_T}{k_T} + \frac{w}{A_T f(k_T)}\frac{dw}{w} + \frac{\frac{(r+\lambda)\bar{\gamma}}{q(\theta_T)}dA_T}{f(k_T)A_T} \tag{14}$$

where the recruitment cost is assumed to be proportional to the worker's productivity $\gamma = A_T\bar{\gamma}$.[6] We adopt the convention that a "hat" above a variable denotes a logarithmic derivative: $\hat{X} \equiv d\log X = d\,X/X$ for any variable *X* restricted to some positive values.

[5] For example, (5) can be used to solve for *k* and then (6) and (14) can jointly be used to solve for *θ* and *w*. Finally, *θ* and (15) are to solve for *u*.

Let $\mu_{LT} \equiv w_T / A_T \, f(k_T)$ and $\mu_{CT} \equiv \dfrac{[r+\lambda)\bar{\gamma}]/q(\theta_T)}{f(k_T)A_T}$ be the labor's share and the share of frictional cost out of the income generated in the tradable sector respectively. Then (14) reduces to

$$(1-\mu_{CT})\hat{A}_T = \mu_{LT}\hat{w}_T \tag{15}$$

Increased productivity in the tradable sector will increase real wage, as in the Ballassa-Samuelson model, but the extent of the increase in real wage has to be adjusted by the sector's labor market efficiency, $(1-\mu_{Ci}) \equiv 1-\dfrac{[r+\lambda)\bar{\gamma}]/q(\theta_i)}{f(k_i)A_i}$ as defined below.

Definition 1. We define $(1-\mu_{Ci}) \equiv 1-\dfrac{[r+\lambda)\bar{\gamma}]/q(\theta_i)}{f(k_i)A_i}$ (where *i* = *T*, *N*) as an indicator of labor market efficiency for sector *i*. The higher this index, the better a sector (country)'s labor market efficiency.

There are three labor market variables that are important in determining the degree of labor market flexibility. The first is the frictional cost (advertising and recruitment costs) $\bar{\gamma}$. The higher the frictional cost $\bar{\gamma}$, the less flexible is the labor market institution in facilitating workers' searching for jobs and firms' hiring of workers. The second and third factors are the job destruction rate and the job creation rate. A higher job destruction rate, together with a lower job creation rate imply a less flexible labor market institution. We summarize the relationship between these three labor market variables and a country's labor market flexibility as follows.

Lemma 1. *If the productivity-adjusted recruitment cost of a new vacancy is not equal to zero ($\bar{\gamma} \neq 0$), the labor market inefficiency increases with respect to the job destruction rate (λ) and decreases with respect to the job creation rate ($\theta_i q(\theta_i)$)*.

Proof: From definition 1, we have $\partial\mu_{Ci}/\partial\lambda_i \succ 0$ and $\partial\mu_{Ci}/\partial\theta_i q(\theta_i) \prec 0$ (since $\partial\theta_i q(\theta_i)/\partial\theta_i \succ 0$).

Similarly, the equilibrium condition of (4) for the non-tradable sector, after log-differentiation, can be written as follows

[6] The recruitment cost is made proportional to the productivity on the grounds that it is more costly to hire more productive workers. See Pissarides (2000, Ch.1). We offer an alternative rationalization to this assumption. Although most search economists believe that it is the search and matching process that is causing labor market friction, we think that such a friction may also be affected by some exogenous institutional factors, which is the rationale behind our assumption that recruiting cost is a function of exogenous factor, productivity in this context. For example, two countries with the same size and the same labor flow characteristics such as market tightness and search efforts may experience different recruiting cost for each vacancy due to different labor market institutional arrangements.

$$\hat{p} + (1 - \mu_{CN})\hat{A}_N = \mu_{LN}\hat{w} \tag{16}$$

Substituting $\hat{w} = (1 - \mu_{CT})\hat{A}_T / \mu_{LT}$ from (15) in (16) yields

$$\hat{p} = \frac{\mu_{LN}}{\mu_{LT}}(1 - \mu_{CT})\hat{A}_T - (1 - \mu_{CN})\hat{A}_N \tag{17}$$

Equation (17) implies that the relative price of non-tradable goods depends on labor market efficiency-adjusted productivity differential in the tradable and non-tradable sectors. As a country's price index is an average of the prices of tradable and non-tradable goods, we thus have the following:

Lemma 2. *The national price levels are positively related to the labor market efficiency-adjusted productivity in the tradable sector and negatively related to the labor market efficiency-adjusted productivity in the non-tradable sector*.

Proof: From equation (17), we have $\partial p / \partial \mu_{CT} \prec 0$ and $\partial p / \partial \mu_{CN} \succ 0$. As the Home price level is a weighted average of the prices of tradable and non-tradable goods, the change in the Home price level will be proportional to the change of non-tradable prices, i.e., $\partial \hat{P} / \partial \hat{p} \succ 0$. Using the rule of chain, we thus have $\partial \hat{P} / \partial \mu_{CT} \prec 0$ and $\partial \hat{P} / \partial \mu_{CN} \succ 0$.

A few notes are in order here. Lemma 1 and 2 demonstrate that the degree of labour market rigidity matters for the relationship between productivity and wage in both the tradable and non-tradable sectors. When workers have to cycle between employment and unemployment and it is unemployed workers who move across sectors to equalize their expected income, the increase in employed workers' wages due to productivity shocks may be less than what the standard Balassa-Samuelson model predicts as employed workers only share part of the benefit from the increase of productivity (unemployed workers also have a share). More specifically, there are two additional forces that can affect the changes in the national price level arising from productivity shocks in the tradable sector. On one hand, the degree of labour market rigidity in the tradable sector weakens the response of workers' wages to productivity shocks, which tends to operate against the standard Balassa-Samuelson effect (see equation (15)). On the other hand, labour market rigidity in the non-tradable sector weakens the response of the price (or workers' wages) to productivity shocks, which tends to strengthen the standard Balassa-Samuelson effect (see equation (16)). Consequently, differences in the degree of labor market rigidities across sectors and countries may lead to deviation from the standard Balassa-Samuelson effect.

When there is no cost associated with recruiting workers in the labor market (i.e., full labor market efficiency), we have $\mu_{CT} = \mu_{CN} = 0$, so that equation (17) simplifies to

$$\hat{p} = \frac{\mu_{LN}}{\mu_{LT}} \hat{A}_T - \hat{A}_N \tag{18}$$

Equation (18) is the original Balassa-Samuelson formulation of the price effects of anticipated productivity shifts. The relative price of non-tradable goods depends on the productivity differential between the tradable and non-tradable sectors. Provided the inequality $\mu_{LN} / \mu_{LT} \geq 1$ holds, faster productivity growth in the tradable sector will push up the price of non-tradable goods over time.

Let a star in the superscript of a variable denote foreign country variables. It is easy to show that the price of non-tradable goods in the foreign country is as follows

$$\hat{p}^* = \frac{\mu_{LN}^*}{\mu_{LT}^*}(1-\mu_{CT}^*)\hat{A}_T^* - (1-\mu_{CN}^*)\hat{A}_N^* \tag{19}$$

We define a country's price index as the geometric average of the prices of tradable and non-tradable goods, with weights σ and $1-\sigma$. Since we take tradables as the numeraire, with a common price of 1 in both countries, the Home-to-Foreign price level ratios is simply proportional to the ratio of the internal relative prices of the non-tradable goods

$$\begin{aligned} \hat{P} - \hat{P}^* &= (1-\sigma)(\hat{p} - \hat{p}^*) \\ &= (1-\sigma)\left\{ \frac{\mu_{LN}}{\mu_{LT}}[(1-\mu_{CT})\hat{A}_T - (1-\mu_{CT}^*)\hat{A}_T^*] - [(1-\mu_{CN})\hat{A}_N - (1-\mu_{CN}^*)\hat{A}_N^*] \right\} \end{aligned} \tag{20}$$

Provided that the non-tradable sector is relatively labor-intensive so that $\mu_{LN} / \mu_{LT} \geq 1$, it follows that the home country will experience real appreciation (a rise in its relative price level) if its labor market efficiency-adjusted productivity advantage in the production of tradables exceeds its labor market efficiency-adjusted productivity advantage in the production of non-tradables. This can be summarized in the following proposition:

Proposition 1: *The greater a home country's labor market efficiency-adjusted productivity advantage is in the production of tradable goods than labor market efficiency-adjusted productivity advantage in the production of no-ntradables, the larger will be a home country's real exchange rate appreciation.*

Proof: From equation (20), we have $\partial(\hat{P}-\hat{P}^*)/\partial[(1-\mu_{CT})\hat{A}_T-(1-\mu_{CT}^*)\hat{A}_T^*]\succ 0$ and $\partial(\hat{P}-\hat{P}^*)/\partial[(1-\mu_{CN})\hat{A}_N-(1-\mu_{CN}^*)\hat{A}_N^*]\prec 0$.

Proposition 1 highlights two conditions that have to be satisfied for a country to experience a real exchange rate appreciation: (1) faster biased technological progress towards a capital-intensive sector; (2) there are search and matching costs in the labor market ($\bar{\gamma}\neq 0$) but the capital-intensive sector is relatively more efficient (lower $(1-\mu_{Ci})$). In contrast, the Balassa-Samuelson model requires only satisfaction of the first condition to experience a real exchange rate appreciation.

Again, if there is no cost associated with recruiting workers in the labor market, we have $\mu_{CT}=\mu_{CN}=0$, so that equation (20) reduces to

$$\begin{aligned}\hat{P}-\hat{P}^* &= (1-\sigma)(\hat{p}-\hat{p}^*)\\ &= (1-\sigma)\left\{\frac{\mu_{LN}}{\mu_{LT}}[\hat{A}_T-\hat{A}_T^*]-[\hat{A}_N-\hat{A}_N^*]\right\}\end{aligned} \tag{21}$$

which is the full employment version of the Ballassa-Samuelson model.

To further appreciate Proposition 1, we provide the following three corollaries based on equation (21).

Corollary 1: *Even though there is unemployment in the labor market, as long as it takes no frictional cost to fill a new vacancy ($\bar{\gamma}=0$), a country's real exchange rate will appreciate over time if and only if its faster technological progress is biased towards the capital-intensive sector.*

The result of Corollary 1 is the same as that of the full employment version of the Balassa-Samuelson model, though it is cast in an environment with frictional unemployment. It suggests that the impact of labor market flexibility on the real exchange rate is not due to the fact there are frictions in the labor market but because there are related hiring and firing costs to firms due to imperfections in the labor market.

Furthermore, suppose both countries experience unbiased technological progress but the home country has a faster productivity growth, i.e., $\hat{A}_T=\hat{A}_N$ and $\hat{A}_T^*=\hat{A}_N^*$ and $\hat{A}_T$ and $\hat{A}_N$ are higher than $\hat{A}_T^*$ and $\hat{A}_N^*$, the home country may not experience real exchange rate appreciation if the labor market in the tradable sector is seriously distorted, as $(1-\mu_{CT})\hat{A}_T$ may be smaller than $(1-\mu_{CT}^*)\hat{A}_T^*$, as suggested by (20). This gives:

Corollary 2: *If a home country experiences a faster rate of technological progress but has a much lower level of labor market efficiency in the tradable sector, the classic positive relationship between the real exchange rate and sectoral productivity may be reversed, i.e., the home country's real exchange rate may not experience real exchange rate appreciation over time.*

Proof: Since $\hat{A}_T = \hat{A}_N$ and $\hat{A}_T^* = \hat{A}_N^* = \hat{A}$, together with $\hat{A}$ are higher than $\hat{A}^*$**,** equation (20) reduces to $\hat{P} - \hat{P}^* = (1-\sigma)\left\{(\frac{\mu_{LN}}{\mu_{LT}} - 1)[(1-\mu_{CT})\hat{A} - (1-\mu_{CT}^*)\hat{A}^*]\right\}$. $\hat{P} - \hat{P}^*$ may not be positive if $(1-\mu_{CT})\hat{A}_T \le (1-\mu_{CT}^*)\hat{A}_T^*$.

The next corollary focuses on the role of sectoral labor market efficiency in determining the real exchange rate.

Corollary 3: *If both countries experience the same rate of technological progress and achieve the same level of labor market efficiency in their tradable sectors, the real exchange rate between two countries depends not only on their relative rate of technological progress but also their relative labor market efficiency in their non-tradable sectors.*

Proof: Since $\hat{A}_T = \hat{A}_T^*$ and $\mu_{CT} = \mu_{CT}^*$, we have $(1-\mu_{CT})\hat{A}_T$ **=** $(1-\mu_{CT}^*)\hat{A}_T^*$. Equation (19) becomes $\hat{P} - \hat{P}^* = -(1-\sigma)\left\{(1-\mu_{CN})\hat{A}_N - (1-\mu_{CN}^*)\hat{A}_N^*\right\}$

3. Empirical Evidence

This section takes our theory to data. A simple version of the Balassa-Samuelson model with no bias in productivity growth and labor market frictions suggests that countries with faster labor-market-rigidity-adjusted productivity growth will experience real exchange rate appreciation. Compared with the standard Balassa-Samuelson model without unemployment, we seek to establish empirically whether labor-market-rigidity-adjusted productivity growth provides a better fit than the standard Balassa-Samuelson model.

Although data on conventional variables such as the real exchange rate and productivity can be easily collected, data on labor market flexibility are difficult to come by. We thus present two pieces of empirical evidence based on two different datasets, each having its own advantages and limitations. The construction of our first dataset follows closely with what our model suggests in measuring labor market flexibility, yet it comes with a cost as data on job destruction rate, labor market matching efficiency and elasticity of the matching function with respect to unemployment are scanty, in particular for a large set of countries. We are therefore restricted to focus on annual frequency and only for three countries, namely, the United States, the United Kingdom and Japan where relatively high quality data are available. We summarize our collected and estimated labor market flexibility data in Table 1.

We follow the literature by considering the following two empirical specifications:

$$LnRER_{ijt} = \beta_0 + \beta_1 LnPRODU_{ijt} + \eta_{ijt} \tag{M1}$$

$$LnRER_{ijt} = \beta_0 + \beta_1 LnPRODA_{ijt} + \eta_{ijt} \tag{M2}$$

where $LnRER_{ijt}$ is the difference in the logarithm of the real exchange rate between country *i* and *j* at time *t*, $LnPRODU_{ijt}$ is the logarithm of the ratio of productivity growth between country *i* and *j* at time *t* without adjustment of labor market rigdities, and $LnPRODA_{ijt}$ the difference in the logarithm of the ratio of productivity growth between country *i* and *j* at time *t* with adjustment of labor market rigidities. We use data for the US as the basis (*j*).

Table 2 presents the empirical results from a panel regression. With data for three countries over the period between 1979 and 1996, we estimate Model (1) and (2) with the fixed-effect panel data method. This method is equivalent to taking the first difference of the variables, which removes any country-specific and year-specific effects that may have potential correlations with the productivity variable. The results support our theoretical prediction. The regression of the real exchange rate on labor-market-rigidity-adjusted productivity growth performs better than that of the real exchange rate on unadjusted productivity growth, with R^2 in Model (2) more than double that in Model (1) (from 0.237 to 0.565). The coefficients for productivity growth all have the expected sign and are significant at the 1 percent level.

To check whether the above results are robust to alternative specifications, we run panel regressions with year dummies to control for business cycle effects. The results are presented in the last two columns of Table 2. Again, Model (2) with adjusted productivity growth performs better than that of Model (1) with unadjusted productivity growth. The R^2 in Model (2) is 0.478 while that in Model (1) is 0.164. The coefficients on productivity growth have the expected sign and are all significant at the 1 percent level. We have also tested the joint significance of the year dummies and the result indicates that they are jointly significant.

With data for only three countries, one might argue that the above results are limited. We therefore construct our second dataset which uses labor firing costs to proxy for the degree of labor market ridgidity yet encompassing a large set of countries. We make use of a newly available dataset published in *Doing Business in 2006* by the World Bank, which is also used by Helpman and Itskhoki (2007). We use the labor firing cost as a proxy for labor market rigidity. Although data for the labor firing cost are available for one year (2005) only in the World Bank dataset, it covers more than one hundred countries. More importantly, the dataset indicates that there are vast differences in labor market flexibility across countries. For example, the firing cost for the US is 0 (weeks of salary) while that for the UK and China is 34 and 90 (weeks of salary) respectively. Data for other variables such as nominal exchange rate, inflation (GDP deflator) and productivity (GDP per capita as a proxy) are taken from *World Economic Outlook* database published by the International Monetary Fund. We aim to examine the significance of differences in labor market rigidity in affecting the relationship between productivity and real exchange rate. Formally, we perform a cross-sectional regression analysis of changes in real exchange rates on changes in productivity with/without adjusting for the degree of labor market rigidities. Both changes are calculated between 2003 and 2004.

Table 3 presents the empirical results of the cross-sectional regression. We perform two regressions, one without accounting for the effect of labor market rigidity (Model (3)) and the other controlling for the degree of labor market rigidity (Model (4)).

$$DLnRER_{ij} = \beta_0 + \beta_1 DLnPRODU_{ij} + \eta_{ij} \quad \text{(M3)}$$

$$DLnRER_{ij} = \beta_0 + \beta_1 DLnPRODA_{ij} + \beta_2 Dummy * DLnPRODA_{ij} + \beta_3 Dummy + \eta_{ij} \quad \text{(M4)}$$

Our dependent variable, $DLnRER_{ij}$, is the difference in the logarithm of country *i*'s real exchange rate against the United Kingdom between 2004 and 2003. $DLnPRODU_{ij}$ denotes the difference in the logarithm of country *i*'s productivities between 2004 and 2003. The labor market rigidity dummy variable, *Dummy*, equals 1 if a country has a higher firing cost than that of the United Kingdom which is 1 by default. We interact the labor market rigidity dummy variable with the productivity variable to control for the effect of differences in labor market institutions across countries. Again, our results suggest that Model (4) which controls for the effect of labor market rigdities performs better than that of Model (3) without appropriate control, with the R^2 in Model (4) being 0.73 while that in Model (3) is 0.60. The coefficients on productivity growth have the expected sign and are all significant at the 1 percent level.

4. Conclusion

It is well known that there exist significant differences in labor market institutions across countries. How would this difference affect the relationship between the real exchange rate and productivity? We extend the classic Balassa-Samuelson model to an environment with search unemployment. We show that there is an important role for the labor market institutional environment to play in determining the magnitude of the effects of sectoral productivity differentials on real exchange rate. In particular, there is the potential that the standard Balassa-Samuelson effect may not hold, if certain conditions are met. Accounting for a country and/or a sector's degree of labor market rigidity is therefore important in determining the relationship between real exchange rate and sectoral productivity. Our empirical evidence supports our proposition that adjusting for the degree of labor market rigidity provides better fits for estimating the impact of productivity on real exchange rate.

Reference

Alessandra G. and J. Kaboski (2004), "Violating Purchasing Power Parity," Federal Reserve Bank of Philadelphia Working Paper 04-19.

Asea, P. and E. Mendoza (1994), "The Balassa-Samuelson Model: a General Equilibrium Appraisal," *Review of International Economics*, 2 (3): 191-200.

Balassa, B. (1964), "The Purchasing-Power Parity Doctrine: a Reappraisal," *Journal of Political Economy*, 72: 584-96.

Bergin, P., R. Glick and A. Taylor (2006), "Productivity, Tradability, and the Long-Run Price Puzzle," *Journal of Monetary Economics*, forthcoming.

Blanchflower, D. G. and S. M. Burgess (1996), "Job Creation and Job Destruction in Great Britain in the 1980s," *Industrial and Labor Relations Review*, 50(1): 17-38.

Blanchard, O. and P. Diamond (1989), "The Beveridge Curve," *Brookings Papers on Economic Activity*, 1: 1-60.

Canzoneri, M., R. Cumby and B. Diba (1999), "Relative Labor Productivity and the Real Exchange Rate in the Long Run: Evidence for a Panel of OECD Countries," *Journal of International Economics*, 47(2): 245-66.

Coles, M. G. and E. Smith (1998), "Marketplaces and Matching," *International Economic Review*, 39(1): 239-54.

De Gregorio, J., A. Giovannini and H. Wolf (1994), "International Evidence on Tradable and Nontradables Inflation," *European Economic Review*, 38: 1225-44.

Diamond, P. A. (1982), "Wage Determination and Efficiency in Search Equilibrium," *Review of Economic Studies*, 49: 217-27.

Fitzgerald, D. (2003), "Terms-of-Trade Effects, Interdependence and Cross-Country Differences in Price Levels," mimeo, Harvard University.

Froot, K. and K. Rogoff (1995), "Perspectives on PPP and Long-Run Real Exchange Rates," in G. Grossman and K. Rogoff, eds., *Handbook of International Economics*, Amsterdam: North Holland, 3: 1647-88.

Genda, Y. (1998), "Job Creation and Destruction in Japan, 1991-1995," *Journal of the Japanese and International Economics*, 12(1): 1-23.

Ghironi, F. and M. Melitz (2005), "International Trade and Macroeconomic Dynamics with Heterogeneous Firms," *Quarterly Journal of Economics*, 120(3): 865-915.

Helpman, E. and O. Itskhoki (2007), "Labor Market Rigidities, Trade and Unemployment," NBER Working Paper No.13365, Cambridge MA: National Bureau of Economic Research.

Kano, S. and M. Ohta (2003), "Estimating a Matching Function and Regional Matching Efficiencies: Japanese Panel Data for 1973-1999," *Japan and the World Economy*, 17: 25-41.

Kano, S. and M. Ohta (2004), "Long-Run Matching Relationship in the Japanese Labor Market," *Empirical Economics*, 29: 921-37.

Ljungqvist, L. and T. Sargent (2000), *Recursive Macroeconomic Theory*, MIT Press.

Lothian, J. and M. Taylor (2004), "Real Exchange Rates over the Past Two Centuries: How Important is the Harrod-Balassa-Samuelson Effect?" The Frank J. Petrilli Center for Research in International Finance Working Paper No.04011, the Fordham University.

McCall, J. J. (1970), "Economics of Information and Job Search," *Quarterly Journal of Economics*, 84: 113-26.

Melitz, M. J. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 7(16): 1695-1725.

Mortensen, D. T. (1982), "The Matching Process as a Non-Cooperative/Bargaining Game," in J. J. McCall, ed., *The Economics of Information and Uncertainty*, University of Chicago Press (Chicago IL).

Mortensen, D. T. and C. A. Pissarides (1999), "New Developments in Models of Search in the Labor Market," in O. Ashenfelter and D. Card, eds., *Handbook of Labor Economics*, 3, Amsterdam: North-Holland.

Pissarides, C. A. (1985), "Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages," *American Economic Review*, 75: 676-90.

Pissarides, C. (1986), "Unemployment and Vacancies in Britain," *Economic Policy*, 3: 499-559.

Pissarides, C. A. (2000), *Equilibrium Unemployment Theory*, 2nd ed., Cambridge, MA, MIT Press.

Rogerson, R., R. Shimer and R. Wright (2005), "Search-Theoretic Models of the Labor Market: a Survey," *Journal of Economic Literature*, XLIII(4): 959-88.

Rogoff, K. (1996), "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, 34(2): 647-68.

Samuelson, P. A. (1964), "Theoretical Notes on Trade Problems," *Review of Economics and Statistics*, 46 (5): 145-54.

Shimer, R. (2005), "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 95(1): 25-49.

World Bank (2006), "Doing Business in 2006: Creating Jobs," World Bank Online Publication, http://www.worldbank.org/publications/.

Table 1. Parameters for Labor Market Flexibility Variable: U.S., Japan and UK

Parameter	U.S.	Japan	UK
Unit recruiting cost $(\bar{\gamma} = \gamma / Af(k))$			
Job destruction rate (λ)	0.10 (1)	0.04 (2)	0.07 (3)
Interest rate (*r*)		one year discount rate	
	Federal Reserve	Bank of Japan	Bank of England
Matching function			
Matching flexibility *a*	0.13 (7)	0.08 (7)	0.09 (7)
Elasticity of the matching function *w.r.t.* unemployment (α)	0.72 (1)	0.69 (4)	0.71 (5)

Note: (1) Shimer (2005); (2) Genda (1998); (3) Blanchflower and Burgess 1996; (4) Kano and Ohta 2003, 2004; (5) Pissarides 1986; (6) Coles and Smith 1998; (7) Authors' estimate. The procedures that we used to estimate job matching efficiencies for the US, Japan and the UK are as follows. With data on numbers of vacancies, unemployed workers and job matching for each period ($m(U_{it}, V_{it})$), we can estimate annual job matching flexibility for each country a_t from the equation $a_t = m(U_{it}, V_{it}) / U_t^{\alpha} V_t^{1-\alpha}$. We then take the average of a_t as the job matching flexibility for each country. For the period between 1979-1996, our estimates of job matching flexibility for the US is 0.13 and for Japan 0.08. However, since the UK data on job matching between vacancies and unemployed workers are not available for the period under study, we use estimates from the latest labor market data as a proxy (see http://www.econstats.com/uk/uk_unem___14m.htm for the latest data on job vacancies, job replacement and matching rates). We estimate that the average matching rate $q(\theta_t)$ in 2005 is about 18.5 per cent, which implies a job matching flexibility of 0.10.
Sources: Authors' calculations.

Table 2. Results from Panel Regression: (M1) and (M2)

	(1)	(2)	(3)	(4)
Constant	-2.08***	-2.04***	-2.08***	-1.65***
	(0.02)	(0.07)	(0.05)	(0.09)
LnPRODU	-0.56***		-0.45***	
	(0.04)		(0.05)	
LnPRODA		-0.33***		-0.40***
		(0.07)		(0.05)
Year dummies	No	No	Yes	Yes
Observations	36	36	36	36
R^2	0.237	0.565	0.164	0.478

Note: The dependent variable is the logarithm of the real exchange rate between country *i* and *j*.*** represents significant at the 1% level. Standard errors are in parentheses. The results are from fixed-effect panel regressions.
Sources: Authors' calculations

Table 3. Results from Cross-Section Regression: (M3) and (M4)

	(3)	(4)
Constant	0.05***	0.06***
	(0.01)	(0.01)
DLnPROD	-1.32***	-0.49***
	(0.44)	(0.38)
Dummy *D*LnPROD*		-1.26***
		(0.40)
Dummy		-0.01
		(0.02)
Observations	138	138
R^2	0.598	0.729

Note: The dependent variable is the difference in the logarithm of country *i*'s real exchange rate between 2004 and 2003. *DLnPROD* denotes the difference in the logarithm of country *i*'s productivity between 2004 and 2003. Labor market inflexibility dummy variable, *Dummy*, equals 1 if a country has a higher firing cost than the United Kingdom which is 1 by default. *** indicates significant at the 1% level. Robust standard errors are in parentheses.
Sources: Authors' calculations