

Real Exchange Rate, Productivity and Labour Market Efficiency: A Generalized Balassa-Samuelson Model

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Abstract We extend the classic Balassa-Samuelson model to an environment with 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 labour market efficiency affects the strength of the structural relationship between real exchange rate and sectoral productivity and has the potential to reverse the positive relationship between the two if the labour market distortion effect in the tradable sector is strong. Our empirical results suggest that controlling for labour market efficiency provides a better fit in estimating the Balassa-Samuelson effect.

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I. Introduction

The relative price of a common basket of goods between two countries, the real exchange rate, is one of the most important prices in an open economy. Notwithstanding its importance in policy making, the real exchange rate determination has been a subject of heated debate since early last century. Two views stand out prominently in the literature. The theory of purchasing power parity (PPP), as articulated by Cassel (1918), postulates that the relative prices of a common basket of goods will be equalized when quoted in the same currency, which implies that real exchange rates should equal 1, or return quickly to 1 when disturbed. This view, which relies heavily on spatial arbitrage in an integrated world economy, is widely referred to as absolute PPP.¹

The model of Balassa (1964) and Samuelson (1964), often referred to as the Balassa-Samuelson model, challenged the theory of PPP and argued that PPP is flawed as a theory of exchange rate. The main thrust of their analysis is that productivity differentials between the tradable and nontradable sectors are the main driving forces in the movement of the relative prices of a common basket of goods and hence the real exchange rate between two countries. The underlying argument is as follows. Although the law of one price (LOP) holds for the tradable goods, it is not the case for nontradable goods. In a fast-growing economy, higher productivity growth in the tradable sector will increase real wages in that sector while the relative price of tradable goods can still remain constant according to the LOP. Since labour is mobile across sectors, an increase in the real wage in the tradable sector will bid up the wage in the nontradable sector which will lead in turn to an increase in the relative price of nontradable goods,

¹Relative PPP, emphasizing arbitrage across time rather than across space, is the weaker statement that changes in national price levels always are equal or, will tend to equality in the long run (Obstfeld and Rogoff 1996).

which leads to an overall rise in the national price level. The upward movement in the national price level will not be matched in the nominal exchange rate so that the real exchange rate between two countries will deviate from the PPP. The insight of the Balassa-Samuelson model is that the sectoral productivity differentials, rather than the PPP, are powerful driving forces behind the movement of the real exchange rate.

Given its significance in policy making, there have been numerous studies, both empirical and theoretical, of the issue of real exchange rate determination, along the lines of absolute or relative PPP and the Balassa-Samuelson model. The first line of this research has been to test empirically whether the theory of PPP holds. While most empirical studies in the 1980s suggested a "collapse of PPP" (Frankel 1981), recent investigations using longer time series and/or multi-country data have produced evidence supporting PPP at least as a long-run equilibrium relationship (Abuaf and Jorion 1990; Lothian and Taylor, 1996; Frankel and Rose 1996; Taylor 2002). However, researchers were puzzled by the exceedingly slow estimated speeds of adjustment of real exchange rates back towards their mean values following shocks, even after taking into account the results of the longer time series and/or multi-country data studies as having provided evidence of significant mean reversion in the real exchange rate.² The high degree of persistence in the real exchange rate, which apparently cannot be accounted for by nominal shocks as nominal shocks will only be effective over a time period at which nominal prices are sticky and cannot be adjusted, has led to the second line of research that stressed the importance of real shocks to the underlying equilibrium real exchange rate (e.g., Engel, 1999, 2000). Empirical investigations of

²The estimated half-life of deviations from PPP is in the range of three to five years which seems too long for adjustment to equilibrium, a phenomenon that Rogoff (1996) has termed the "PPP puzzle".

the effect of productivity shocks (which are real shocks) on the real exchange rate, the so-called Balassa-Samuelson effect, have therefore received renewed attention. These studies 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 nontradables.

There is also renewed interest in incorporating the Balassa-Samuelson channel into newly developed open-economy macroeconomic models (see for example, Betts and Kehoe 2005 and Burstein et al. 2005). Several recent attempts have intended to update or extend the Balassa-Samuelson model, but the underlying mechanisms of these models are very different in spirit from that proposed by Balassa and Samuelson. 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 (2004) 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 (2005) develops 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. He demonstrates that such a model can deliver endogenously time-varying correlations between incomes and prices.

In this paper, we revisit the classic Balassa-Samuelson model by extending it to an environment with unemployment. To the best of our knowledge, our paper is the first to develop a model that integrates the 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.³ Unlike other theoretical models, the traditional Balassa-Samuelson channel, i.e., sectoral productivity differentials affecting real exchange rate movements, is still operative in our generalized model. Our paper adds to the literature on the Balassa-Samuelson effect by introducing a labour market institution variable, which opens a new dimension for a real shock (labour market institution), through interactions with productivity variables, to affect the real exchange rate behavior. A focus on frictional labour 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 labour market institutions when countries integrate more and more with each other. It is also made possible theoretically thanks to the advancement of recent developments in the theory of unemployment.

The recent development of micro-based models of unemployment has emphasized that unemployment may arise endogenously as a result of labour market frictions as it

³For an introduction to the theory of search, see Ljungqvist and Sargent (2000).

takes time and other resources for an unemployed worker to find a job and for a firm to fill a vacancy (see for example, McCall 1970; Diamond 1982; Mortensen 1982; Pissarides 1985; Shimer 1996; Mortensen and Pissarides 1999 and Pissarides 2000). This is in contrast to the assumption in the classic Walrasian equilibrium theory where a smooth and instantaneous adjustment in, for example the wage, in a centralized labour market will always lead to full employment, as assumed in the Balassa-Samuelson model. Emphasis on labour market frictions and the development of search theory, along with other micro-based models of unemployment, open the possibility of studying the problem of unemployment in a general equilibrium framework. Thanks to advancements in research on theories of unemployment, in particular search theory, we are able to integrate a simple model of search into the classic Balassa-Samuelson model to study the price effects of sectoral productivity differentials under a more general and realistic environment where departure from the classic Walrasian frictionless economy is the norm rather than the exception (Yashiv 2006).

Our paper contributes to bridging a gap between the theory of real exchange rate and search-theoretical models of the labour market.⁴ 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 labour market efficiency across sectors and between countries, which highlights a new and potentially important channel for the transmission of various shocks to labour market institutions to real exchange rate, i.e., labour market institutions matter; (3) in fact, there is the

⁴See Rogerson, Shimer and Wright (2006) for a recent survey on the search-theoretical models of labour market. Earlier surveys include McCall (1976), Mortensen (1986) and Mortensen and Pissarides (1999).

potential to reverse the classic positive relationship between sectoral productivity and the real exchange rate, if certain conditions are met; (4) most importantly, we are able to specify explicitly an empirically testable equation for the relationship between real exchange rate, sectoral productivity and labour market efficiency. Our empirical results suggest that controlling for labour market efficiency 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 labour market efficiency across sectors and between countries. We summarize the main results in a proposition and several lemmas and corollaries. In section 4, we discuss our empirical results. The final section concludes.

II. The Model

To extend the Balassa-Samuelson model to an environment with unemployment, we integrate the textbook Balassa-Samuelson model as in Obstfeld and Rogoff (1996) with a simple search model of, for example, Pissarides (2000). By putting the Balassa-Samuelson model in a frictional economy, we are able to show that the structural relationship between real exchange rate and sectoral productivity, as suggested in the original Balassa-Samuelson model, may have to be altered quantitatively to take into account the difference in institutional environments in labour markets across both the tradable and non-tradable sectors and between countries, which has significant implications for an empirical estimation of real exchange rate and purchasing power parity

(PPP).

The economy

Consider a small open economy that produces two composite goods, tradable goods (T) priced in international markets and nontradable goods (N) priced in the domestic market. The production technology of tradables and nontradables is characterised by constant returns to scale (CRS) production functions of the capital (K_i) ($i = T, N$) and labour (L_i) employed,

$$Y_i = A_i F(K_i, L_i) = A_i L_i f(k_i) \quad (1)$$

where Y_i where is output in the tradable and nontradable sectors respectively, and the A 's are productivity shifters.

Output per unit of labour, $y_i \equiv Y_i/L_i$, can then be written as,

$$y_i = A_i f(k_i), \quad (2)$$

which make use of the condition of CRS where $k_i \equiv K_i/L_i$ is capital-labour ratio in sector i . The production function $F(\bullet)$ exhibits positive and diminishing marginal products with respect to each input. Both labour and capital are perfectly mobile across sectors domestically. Labour mobility insures that workers earn the same wage w in either sector. In addition, only capital can move freely internationally.

We now depart from the standard full employment assumption as in the Balassa-Samuelson. 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 labour market.

We now specify job matching, job creation, job destruction, and wage determination in general equilibrium.

Matching

Suppose the number of matches between firms and workers, m , 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 $mZ = m(Zu, Zv)$. 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 .

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

$$rV_T = -\gamma + q(\theta_T)(J_T - V_T). \quad (3)$$

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 $J_T = \gamma/q(\theta_T)$. 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

$$r(J_T + k_T) = A_T f(k_T) - w - \lambda J_T, \quad (4)$$

where λ is the job destruction rate which leads to the loss of J_T but not k_T . 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 in (4). We can write the firm's first-order condition with respect to capital as

$$A_T f'(k_T) = r, \tag{5}$$

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 (5) and the equilibrium job creation condition $J_T = \gamma/q(\theta_T)$ into (4) 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 additional worker, the marginal product of labor, is equal to marginal cost, i.e., the market wage, after adjusting for the recruitment cost,

$$A_T(f(k_T) - k_T f'(k_T)) = w + \frac{(r + \lambda)\gamma}{q(\theta_T)}. \tag{6}$$

If there is no recruitment cost so that $\gamma = 0$, the last term on the right hand side of equation (6) becomes zero and (6) is the familiar Euler equation for labor in a full-information, frictionless labor market.

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 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

$$rU_T = b + \theta_T q(\theta_T)(E_T - U_T). \quad (7)$$

Equation (7) 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 $q(\theta_T)(E_T - U_T)$.⁵ rU_T can be interpreted as the annuity (permanent income) that an unemployed worker expects to receive during search.

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

$$rE_T = w + \lambda(U_T - E_T). \quad (8)$$

Equation (8) has a similar interpretation to (7). 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 $\lambda(U_T - E_T)$.

Combining (7) and (8), we can solve for permanent income of an unemployed and an employed worker as follows

$$rU_T = \frac{(r + \lambda)b + \theta_T q(\theta_T)w}{r + \lambda + \theta_T q(\theta_T)}, \quad (9)$$

$$rE_T = \frac{\lambda b + [r + \theta_T q(\theta_T)]w}{r + \lambda + \theta_T q(\theta_T)}. \quad (10)$$

⁵The 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, Shimer and Wright (2006).

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 and E_T^j and J_T^j are from (4) and (8).

The solution to the above first-order maximization problem satisfies

$$E_T^j - U_T = \beta(J_T^j + E_T^j - V_T - U_T), \quad (11)$$

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 (11) can be solved for w . By substituting (4) and (8) in (11), and making use of the equilibrium condition $V_T = 0$, we have

$$w = (1 - \beta)rU_T + \beta(A_T f(k_T) - rk_T). \quad (12)$$

Substituting (11) in (7) and making use of $J_T = \gamma/q(\theta_T)$ we can derive another equation

$$rU_T = b + \frac{\beta}{1 - \beta}\gamma\theta_T, \quad (13)$$

Substituting (13) in (12), we have

$$w = (1 - \beta)b + \beta\gamma\theta_T + \beta(A_T f(k_T) - rk_T), \quad (14)$$

where $\gamma\theta_T$ is the average recruiting cost for each unemployed worker.

Finally, since job creation $u_T\theta_Tq(\theta_T)Z$, 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:

$$u_T = \frac{\lambda}{\lambda + \theta_Tq(\theta_T)}. \quad (15)$$

Equation (15) shows that search generated unemployment rate in the tradable sector is positively related to job destruction rate (λ) but negatively associated with the probability of an unemployed worker encountering a job opportunity ($\theta_Tq(\theta_T)$). Equation (15) 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.

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, (5) and (6) respectively, the equilibrium in wage bargaining (14), and the labor market equilibrium condition (15), which are re-written as

$$A_T f'(k_T) = r, \quad (5)$$

$$A_T(f(k_T) - k_T f'(k_T)) = w + \frac{(r + \lambda)\gamma}{q(\theta_T)}, \quad (6)$$

$$w = (1 - \beta)b + \beta\gamma\theta_T + \beta(A_T f(k_T) - rk_T), \quad (14)$$

$$u_T = \frac{\lambda}{\lambda + \theta_Tq(\theta_T)}. \quad (15)$$

Similarly, the equilibrium conditions for the nontradable sector can be written as follows.

$$pA_N g'(k_N) = r, \quad (5')$$

$$pA_N(g(k_N) - k_N g'(k_N)) = w + \frac{(r + \lambda)\gamma}{q(\theta_N)}, \quad (6')$$

$$w = (1 - \beta)b + \beta\gamma\theta_N + \beta(A_N g(k_N) - rk_N), \quad (14')$$

$$u_N = \frac{\lambda}{\lambda + \theta_N q(\theta_N)}. \quad (15')$$

Both sets of four equations for the tradable and nontradable sectors consist of a recursive system that can be solved easily for four unknowns, i.e., k , θ , w and u .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 (6) and differentiate them, which yields

$$\frac{dA_T}{A_T} + \frac{A_T f'(k_T) k_T}{A_T f(k_T)} \frac{dk_T}{k_T} = \frac{rk_T}{A_T f(k_T)} \frac{dk_T}{k_T} + \frac{w}{A_T f(k_T)} \frac{dw}{w} + \frac{(r+\lambda)\bar{\gamma}}{q(\theta_T)} \frac{dA_T}{A_T f(k_T)} \quad (16)$$

where the recruitment cost is assumed to be proportional to the worker's productivity

$\gamma = A_T \bar{\gamma}$.⁷ We adopt the convention that a "hat" above a variable denotes a logarithmic derivative: $\hat{X} \equiv d \log X = dX/X$ for any variable X restricted to some positive values.

⁶For 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 .

⁷The recruitment cost is made proportional to the productivity on the ground 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 labour 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 labour flow characteristics such as market tightness and search efforts may experience different recruiting cost for each vacancy due to different labour market institutional arrangements.

Let $\mu_{LT} = w/A_T f(k_T)$ and $\mu_{CT} = \frac{(r+\lambda)\bar{\gamma}/q(\theta_T)}{A_T f(k_T)}$ be the labour's share and the share of recruitment cost out of the income generated in the tradable sector respectively.

Then (16) reduces to

$$(1 - \mu_{CT})\widehat{A}_T = \mu_{LT}\widehat{w}. \quad (17)$$

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 labour market efficiency, as defined below.

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

There are three labour market variables that are important in determining the labour market efficiency. The first factor is the recruitment cost $\bar{\gamma}$. The higher the recruitment cost $\bar{\gamma}$, the less efficient is the labour 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 the job destruction rate, together with a lower job creation rate imply a less efficient labour market institution. We summarize the relationship between these three labour market variables and a country's labour market efficiency as follows.

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

Similarly, the equilibrium condition of (6') for the nontradable sector, after log-differentiation, can be written as follows

$$\widehat{p} + (1 - \mu_{CN})\widehat{A}_N = \mu_{LN}\widehat{w}. \quad (18)$$

Substituting $\widehat{w} = (1 - \mu_{CT})\widehat{A}_T/\mu_{LT}$ from (17) in (18) yields

$$\widehat{p} = \frac{\mu_{LN}}{\mu_{LT}}(1 - \mu_{CT})\widehat{A}_T - (1 - \mu_{CN})\widehat{A}_N. \quad (19)$$

Equation (19) implies that the relative price of nontradable goods depends on labour market efficiency-adjusted productivity differential in the tradable and nontradable sectors. As a country's price index is an average of the prices of tradable and nontradable goods, we thus have the following:

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

When there is no cost associated with recruiting workers in the labour market (i.e., full labor market efficiency), we have $\mu_{CT} = \mu_{CN} = 0$, so that equation (19) simplifies to

$$\widehat{p} = \frac{\mu_{LN}}{\mu_{LT}}\widehat{A}_T - \widehat{A}_N. \quad (20)$$

Equation (20) is the original Balassa-Samuelson formulation of the price effects of anticipated productivity shifts. The relative price of nontradable goods depends on the productivity differential between the tradable and nontradable sectors. Provided the inequality $\mu_{LN}/\mu_{LT} \geq 1$ holds, faster productivity growth in the tradable sector will push up the price of nontradable 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 nontradable goods in the foreign country is as follows

$$\widehat{p}^* = \frac{\mu_{LN}^*}{\mu_{LT}^*} (1 - \mu_{CT}^*) \widehat{A}_T^* - (1 - \mu_{CN}^*) \widehat{A}_N^*. \quad (21)$$

We define a country's price index as the geometric average of the prices of tradable and nontradable 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 nontradable goods

$$\begin{aligned} \widehat{P} - \widehat{P}^* &= (1 - \sigma)(\widehat{p} - \widehat{p}^*) \\ &= (1 - \sigma) \left\{ \frac{\mu_{LN}}{\mu_{LT}} (1 - \mu_{CT}) \widehat{A}_T - (1 - \mu_{CT}^*) \widehat{A}_T^* \right. \\ &\quad \left. - [(1 - \mu_{CN}) \widehat{A}_N - (1 - \mu_{CN}^*) \widehat{A}_N^*] \right\}. \end{aligned} \quad (22)$$

If we assume that the nontradable 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 labour market efficiency-adjusted productivity advantage in the production of tradables exceeds its labor market efficiency-adjusted productivity advantage in the production of nontradables. This can be summarized in the following proposition:

Proposition 1 *The greater a home country's labour market efficiency-adjusted productivity advantage is in the production of tradable goods than labour market efficiency-adjusted productivity advantage in the production of nontradables, the larger will be a home country's real exchange rate appreciation.*

In fact, equation (21) 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 $(1 - \mu_{Ci})$).⁸ 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 labour market, we have $\mu_{CT} = \mu_{CN} = 0$, so that equation (20) reduces to

$$\begin{aligned} \widehat{P} - \widehat{P}^* &= (1 - \sigma)(\widehat{p} - \widehat{p}^*) \\ &= (1 - \sigma)\left\{\frac{\mu_{LN}}{\mu_{LT}}\widehat{A}_T - \widehat{A}_T^* - [\widehat{A}_N - \widehat{A}_N^*]\right\}, \end{aligned} \quad (23)$$

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 labour market, as long as it takes no recruitment 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 labour market efficiency on the real exchange rate is not due to the fact there are frictions in the labor market but because there are related recruitment costs to firms due to the frictions, a result that is consistent with Shimmer (1996) in the context of a labor market model.

⁸From an empirical perspective, it is noteworthy that developing countries are always characterized with more serious distortions in the capital intensive sector, such as natural monopoly, government intervention to subsidize the sector that does not have comparative advantage, and so on.

Furthermore, suppose both countries experience unbiased technological progress but the home country has a faster productivity growth, i.e., $\widehat{A}_T = \widehat{A}_N$ and $\widehat{A}_T^* = \widehat{A}_N^*$ and \widehat{A}_T and \widehat{A}_N are higher than \widehat{A}_T^* and \widehat{A}_N^* , the home country may not experience real exchange rate appreciation if the labour market in the tradable sector is seriously distorted, as $(1 - \mu_{CT})\widehat{A}_T$ may be smaller than $(1 - \mu_{CT}^*)\widehat{A}_T^*$, as suggested by (21). This gives:

Corollary 2 *If a home country experiences a faster rate of technological progress but has a much lower level of labour market efficiency in the tradable sector, the classic positive relationship between 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.*

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

Corollary 3 *If both countries experience the same rate of technological progress and achieve the same level of labour 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 labour market efficiency in their non-tradable sectors.*

Proof: Since $\widehat{A}_T = \widehat{A}_T^*$ and $\mu_{CT} = \mu_{CT}^*$, we have $(1 - \mu_{CT})\widehat{A}_T = (1 - \mu_{CT}^*)\widehat{A}_T^*$. Equation (21) becomes $\widehat{P} - \widehat{P}^* = (1 - \sigma)[(1 - \mu_{CN})\widehat{A}_N - (1 - \mu_{CN}^*)\widehat{A}_N^*]$.

III. Empirics

This section takes our theory to data. A simple version of the Balassa-Samuelson model with no bias in productivity growth and search unemployment suggests that countries with faster labor-market-efficiency-adjusted productivity growth will experience real exchange rate appreciation. Compared with traditional BS model without unemployment, we seek to establish empirically: (1) whether labor-market-efficiency-adjusted productivity growth fits the BS prediction better; (2) the extent of RER appreciation after adjusting labor market efficiency.

Although data on conventional variables such as real exchange rate and productivity can be easily collected, data on labor market variables are scanty. In particular, to measure labor market efficiency, we need data on unit labor recruiting and firing cost, job destruction rate, labor market matching efficiency and elasticity of the matching function with respect to unemployment. Given the availability of these labor market efficiency data, we are restricted to focus at 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 efficiency data in Table 1.

We consider the following two empirical specifications:

$$\begin{aligned} (1) \quad & \ln RER_{ij} = constant + \beta_1 D\ln PRODU_{ij} + \eta_{ij} \\ (2) \quad & \ln RER_{ij} = constant + \beta_1 D\ln PRODA_{ij} + \eta_{ij} \end{aligned}$$

Where $\ln RER_{ij}$ is the logarithm of real exchange rate between country i and j , $D\ln PRODU_{ij}$ is the difference in the logarithm of productivity growth between country i and j without adjustment of labour market efficiency, and $D\ln PRODA_{ij}$ the difference in the logarithm of productivity growth between country i and j with

adjustment of labor market efficiency.

Figure 1 displays the three series, real exchange rate, unadjusted productivity and labor-market-efficiency-adjusted productivity growth for two pairs of countries, Japan and the United States as well as UK and the United States (Panel (1) and (2)). Casual inspection suggests that the adjusted productivity series follows the real exchange rate series more closely.

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 panel data method. The results supports our theoretical prediction. The regression of real exchange rate on labor-market-efficiency-adjusted productivity growth performs better than that of 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. Moreover, the coefficient for adjusted productivity growth is substantially lower than that for unadjusted productivity growth, suggesting that using unadjusted productivity growth to predict real exchange rate movements may provide biased results.

To check whether our results are robust to alternative specifications, we run panel regression 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 significantly at 1 percent level. We have also tested the joint significance of the year dummies and the tested result indicates that they are jointly significant.

IV. Conclusion

In this paper, we generalize the classic Balassa-Samuelson model to an environment with frictional unemployment to examine the relationship between real exchange rate, sectoral productivity and labor market institutional environment. The classic Balassa-Samuelson model is shown to be a special case of our more generalized model with frictional 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 fact, there is the potential to reverse the classic positive relationship between sectoral productivity and real exchange rate, if certain conditions are met. Accounting for a country and/or a sector's labor market efficiency is therefore important in furthering our understanding of the relationship between real exchange rate and sectoral productivity. Most importantly, we are able to derive a closed form relationship between real exchange rate, sectoral productivity and labor market efficiency, which has significant implications on empirical estimation of real exchange rate and purchasing power parity (PPP). Our empirical tests from a simple panel regression suggests that: (1) adjusting for the labor market efficiency provides better fits for estimating the impact of productivity on real exchange rate; (2) the degree of the impact is lower compared with no adjustment in labor market efficiency.

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Table 1 Parameters for labor market efficiency variable: U.S., Japan and UK

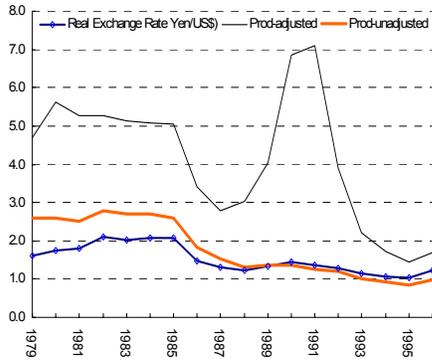
| Parameter | U.S. | Japan | UK |
|---|------------------------|----------------------|---------------------|
| Unit recruiting cost ($\bar{\gamma} = \gamma/ Af(k)$) | 0.054 | 0.354 | 0.50 |
| Job destruction rate (λ) | 0.10 ⁽¹⁾ | 0.04 ⁽²⁾ | 0.07 ⁽³⁾ |
| Interest rate (r) | one year discount rate | | |
| | Federal Reserve | Bank of Japan | Bank of England |
| Matching function | | | |
| Matching efficiency a | 0.126 ⁽⁷⁾ | 0.079 ⁽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) Shimmer (2005); (2) Genda (1998); (3) Blanchflower and Burgess 1996; (4) Kano and Ohta 2003, 2004; (5) Pissarides 1986; (6) Coles and Smith 1996; (7) Authors' estimate. The procedures that we used to estimate job matching efficiencies for the US, Japan and UK is 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 efficiency for each country a_t from the equation $a_t = m(U_t, V_t)/U_t^\alpha V_t^{1-\alpha}$. We then take the average of a_t as the job matching efficiency for each country. For the period between 1979-1996, our estimates of job matching efficiency for US is 0.126 and for Japan 0.079. 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 labour 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 efficiency of 0.094.

Sources: Authors' calculations.

Figure 1 Real Exchange Rate and Productivity:

(1) Japan and the United States



Panel (2) UK and the United States

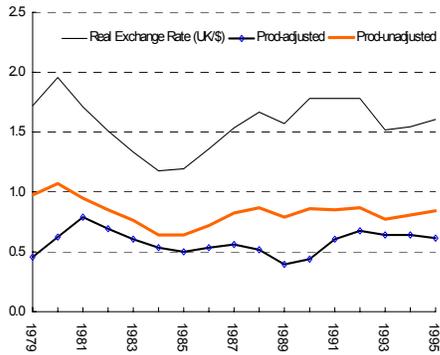


Table 2 Results from Panel Regression

| Parameter | Model (1) | Model (2) | Model (1) | Model (2) |
|-----------------|---------------------|----------------------|---------------------|----------------------|
| <i>Cons.</i> | -2.08*** (0.019) | -2.04*** (0.074) | -2.08*** (0.05) | -1.65*** (0.09) |
| <i>DLnPRODU</i> | -0.56*** (0.041) | | -0.449*** (0.05) | |
| <i>DLnPRODA</i> | | -0.327*** (0.073) | | -0.397*** (0.054) |
| Year dummies | No | No | Yes | Yes |
| Obs. | 36 | 36 | 36 | 36 |
| R^2 | 0.237 | 0.565 | 0.164 | 0.478 |

Note: *** Significant at 1% level. Standard errors are in parentheses. Hausman tests on both specification are in favor of fixed effect model.

Sources: Authors' calculations.