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The Balassa-Samuelson model with job separations☆

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ABSTRACT

We incorporate sectoral job separation rates in a small open economy model to examine the Balassa-Samuelson (B-S) effect. Unequal separation rates give rise to compensating wage differentials. We simulate the model for Japan and replicate a feature of its economy that the nontradeables sector has higher wages and a higher separation rate compared to the tradeables sector. With productivity growth in the tradeables sector, labour moves from the tradeables sector to the nontradeables sector if tradeables and nontradeables are complements in consumption. The B-S effect is dampened. With a higher separation rate in the nontradeables sector, higher wages in the nontradeables sector amplifies this labour movement. Nevertheless, unemployment always falls due to a positive income effect. In contrast, the effect of productivity growth in the nontradeables sector is to lower the real exchange rate and *raise* unemployment.

1. Introduction

Balassa (1964) and Samuelson (1964) showed that productivity growth in the tradeables sector leads to a rise in the price of nontradeables since, with perfect labour mobility between sectors, a higher wage in the tradeables sector increases wages in the nontradeables sector. Since the tradeables price is determined in the world market, countries in which productivity grows faster in the tradeables sector should experience an appreciation of their real exchange rate (RER). The effect of tradeables productivity on the RER is called the Balassa-Samuelson (B-S) effect and has attracted much research. It has also interested policymakers since the B-S effect can indicate how purchasing power parity and the relative competitiveness across countries change over time.

While the key B-S prediction linking technological progress in export-oriented industries and an increasing RER seems to be borne out in some countries (for example, Japan according to Ito et al., 1999 and for developing countries according to Choudhri and Khan, 2005), it lacks more widespread applicability. The basic B-S model predicts that a rise in productivity in the tradeables sector should raise the relative price of nontradeables proportionally. However, it is argued in many papers that the B-S model lacks empirical support. This has generated a wide range of explanations.[1] Using panel data for 14 OECD countries, Cardi and Restout (2015) show that the relative price of nontradeables rises by 0.78 per cent with a one per cent rise in relative productivity in the tradeables sector; i.e., not the one per cent rise in the relative price predicted by the basic B-S model. They argue that removing the assumption of frictionless intersectoral labour mobility in the basic model leads to a significant improvement in predictive ability. Specifically, the relative price and wage responses to changes in the

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[1] The empirical literature on the B-S effect has grown enormously. Many papers fail to find evidence of the effect and propose explanations. For example, Bergin et al. (2006) show that allowing tradeability to be driven by technological developments can help explain the larger B-S effect evident in more recent decades. Choudhri and Schembri (2010) parameterise a model in which a productivity improvement in the home tradeables sector increases the relative price of nontraded to traded goods but has an ambiguous effect on the terms of trade. If the productivity improvement lowers the terms of trade, the RER can appreciate or depreciate depending on whether the relative price effect outweighs the terms-of-trade effect. In Bordo et al. (2017) the terms-of-trade adjust in response to productivity changes. The two key determinants of the terms of trade response are the elasticity of substitution between home and foreign traded goods and the differential in the shares of home goods in domestic and foreign consumption of traded goods.

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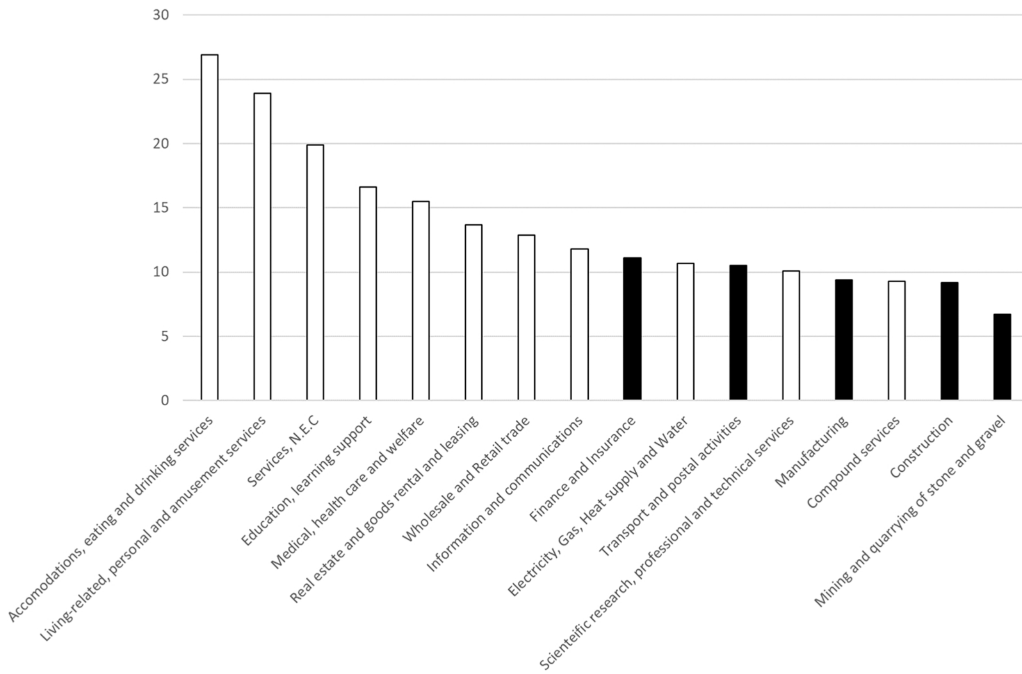

Fig. 1. Annual industry separation rates (%) in Japan, 2018. *Source*: Japanese Ministry of Health, Labour and Welfare (https://www.mhlw.go.jp/toukei/itiran/roudou/koyou/doukou/19–2/dl/gaikyou.pdf). *Note*: Tradeables and nontradeables sectors are represented by black and white bars, respectively.

productivity differential between tradeables and nontradeables are muted. Also, notable is the existence of persistent sectoral wage differentials. In Cardi and Restout (2015), the differentials are driven by imperfect substitutability of labour across sectors.

This study simulates a B-S model that incorporates sectoral job separation rates using Japanese data. Sectoral differences in job separation rates are readily apparent in the data. This feature of sectoral heterogeneity has rarely been discussed in the literature.[2] Fig. 1 shows markedly different industry separation rates for Japan in 2018. Moreover, the separation rate in the nontradeables sector (16.2%) is higher than that in the tradeables sector (9.9%), even if the public sector were to be included.[3] The relatively high separation rate in the nontradeables sector is closely related to a higher proportion of part-time workers. According to the 2018 Survey of Employment Trends conducted by the Ministry of Health, Labour and Welfare (MHLW), the share of part-time workers is 13.6% in the tradeables sector while in the nontradeables sector it is 30.4%. The separation rates for regular and part-time workers are 11.2% and 23.7%, respectively. These differences are a major reason for the separation rates in the tradeables and nontradeables sectors. However, even if we were to only focus on regular workers, the separation rate is still higher in the nontradeables sector (12.3%) compared to the tradeables sector (8.8%).

By incorporating sectoral job separation rates, we can replicate an important feature of the Japanese labour market, i.e., the nontradeables sector has higher wages than the tradeables sector. According to the 2018 MHLW data, the weighted average of the monthly salary is 329 thousand yen in the tradeables sector and 340 thousand yen in the nontradeables sector while the weighted average of the separation rate is 9.9% in the former sector and 16.4% in the latter sector. Here, we used the number of employees to calculate the weighted averages and this difference does not change if we focus only on regular workers. If we focus on the largest sector in each sector, the average monthly wage in Manufacturing (tradeables) is 320 thousand yen while in Wholesale and Retail Trade (nontradeables), it is 346 thousand yen. The separation rate in Manufacturing is 9.4 per cent, while it is 12.9 per cent in Wholesale and Retail Trade. Consistent with these facts, we argue that the separation rate and salaries are positively correlated due to the presence of a compensating wage differential.

We also discuss how sectoral job separation rates impact the B-S effect. Specifically, we show that the standard B-S effect is muted or amplified by labour movement across tradeables and nontradeables sectors. Unlike existing studies, a larger wage gap generated by sectoral separation rates has an additional impact on labour movement as well as the RER. Using Japanese data, we demonstrate that even with labour mobility a positive impact of productivity growth in the tradeables sector can lead to a dampening of the standard B-S effect. One of our conclusions is that introducing sectoral separation rates may improve the empirical predictability of the B-S model.

The next section briefly reviews the literature. Section 3 introduces the model and Section 4 derives the main theoretical propositions. A feature of the model is that wages are higher in the sector with higher separations. We then examine the B-S effect and show that the RER increases (decreases) when there is productivity growth in the tradeables (nontradeables) sector. We decompose the impact on the RER, i.e., the B-S effect, into two effects - a pure productivity effect and a labour reallocation effect. Section 5 calibrates the functional forms and parameters and discusses how the equilibrium values are determined. In Section 6, we simulate how productivity improvements affect unemployment and the RER. Section 7 concludes.

[2] There are several studies of the Japanese labour market that focus on different types of heterogeneity. For example, Esteban-Pretel and Fujimoto (2012) focus on heterogeneity in worker age on order to examine the impact of three types of economic transformation (declining productivity, lower firing costs, and a decline in population growth). Using human capital theory (Becker, 1964), Cairó and Cajner (2018) show that more educated workers experience lower unemployment rates and lower employment volatility because of their lower separation rates. In contrast to these studies, we focus on heterogeneity in separation rates at the sectoral or industry-level.

[3] Unlike most of its OECD counterparts, Japan has a very small fraction of its workforce in the public sector. In fact, at around 6 per cent, Government employment as a percentage of total employment in Japan is the lowest among OECD countries. The OECD average is about 18 per cent. See http://www.oecd.org/gov/gov-at-a-glance-2019-japan.pdf.

2. Literature review

In a similar fashion to Cardi and Restout (2015), Sheng and Xu (2011) also demonstrate that the B-S effect is related to labour market frictions. Specifically, they show that a change in the price of nontradeables may be higher or lower than what is predicted by the B-S model, depending on the relative market matching efficiency between the two sectors. Further, if the relative labour market matching efficiency in the tradeables sector is very low, an increase in tradeables productivity may be more than offset by relatively high frictional costs, thus mitigating the standard B-S effect. Using panel data for Japan, the United Kingdom and United States, they show that labour market frictions are important for understanding the impact of productivity on the RER. Using a larger sample of countries, they find that the B-S effect is significantly smaller for countries in which hiring and firing costs are higher.

In contrast to Cardi and Restout (2015), but similar to Sheng and Xu (2011), labour is mobile across sectors in our model. In other words, we treat the unemployed as belonging to one pool of job seekers and not being tied to a specific industry. Supporting this view, Gomes (2015, p.1427) argues that the unemployed search across all sectors of an economy. When separated from an employer, workers enter the pool of unemployed and do not restrict their job search to only one sector. If unemployed workers can move freely between industries, at least in the medium-run, a *sectoral* unemployment rate is a redundant concept. From this perspective, our model is a long-run model with inter-sectoral labour mobility. Moreover, because we are interested in the determination of unemployment in the steady state, a sectoral unemployment rate is not a natural way to formulate a model. In our model, workers weigh the probabilities of finding a job, the wages on offer and the likelihood of separation. In this regard, our setup is closer to the template B-S model.

Using Japanese data for 1973–1999, Sakata (2002) finds that sectoral shifts of employment are significant, particularly during recessions. He shows that these sectoral shifts are positively correlated with unemployment in the short-run due to the time taken for workers to move to different sectors. In a similar fashion, Ariga and Okazawa (2010) and Kondo and Naganuma (2015) emphasise the sluggish labour reallocation in Japan. Moreover, Sakata (2002) finds no evidence of a long-term relationship between unemployment and sectoral shifts, implying that workers can move to different sectors in the long-run. Higashi (2018) examines job search across Japanese regions. He finds job seekers in local regions compete with their counterparts in neighbouring regions, i.e., there is inter-regional job search.

Intersectoral differences in separation rates generate wage dispersion because sectors with higher job separations cannot attract and hire enough workers without offering higher wages. It is customary to refer to the higher wages as a "compensating wage differential".[4] The differential persists despite the mobility of labour. When workers move across sectors in response to exogenous shocks, changes in the relative supply of tradeables and nontradeables affect the magnitude of the B-S effect. The existence of equilibrium unemployment implies higher real wages in both sectors. Moreover, as observed in Japanese data, wages are relatively higher in the sector with higher separations. Wage changes play an important role in transmitting technology shocks to movements in the RER and unemployment.

[4] Numerous studies provide empirical support for compensating wage differentials. For Japan, Ono and Odaki (2011) show that foreign-owned establishments in Japan pay higher wages to compensate for workers being exposed to higher risk and less employment security. Also, Kniesner and Leeth (1991) investigate compensating wage differentials for fatal injury risk in Australia, Japan and the U.S., and finds a statistically fragile compensating wage differential of between 0% and 1.4% for exposure to the average fatality risk compared to employment in a perfectly safe workplace for Japan.

3. The model

Our model is based on the B-S model with tradeables and nontradeables sectors. To incorporate unemployment, we use the Diamond-Mortensen-Pissarides model to study how workers are matched to jobs in either sector, or possibly left unmatched. Wälde and Weiss (2006), Dutt et al. (2009) and Xu and Sheng (2014) use a similar approach to study the unemployment effects of international competition. Many researchers emphasise that job matching is also crucial for unemployment in Japan.[5] In this paper we explicitly introduce different job separation rates in the tradeables and nontradeables sectors.

3.1. Search and matching

We let N denote the nontradeables sector and T the tradeables sector. Consider a representative firm i in sector I ($I = N, T$), where the evolution of its labour stock is given by

$$\dot{L}_i = \frac{m_I}{V_I} V_i - s_I L_i, i \in I. \tag{1}$$

Here, L_i is the labour stock, V_i represents the vacancies posted by the firm, s_I is the sector-specific separation rate and m_I is the number of job matches.[6] Arguably differences in sectoral demand are likely to be manifested in voluntary and involuntary separations. Moreover, the duration of implicit and explicit contracting relationships is likely to differ across sectors. On the other hand, there is one pool of unemployed workers searching for jobs across sectors. V_I is the sum of vacancies posted by all firms in sector I, i.e., $V_I = \int_{i \in I} V_i di$. Each firm is small so that its behaviour affects neither sector- nor economy-wide variables such as V_N and V_T.

We assume that the number of matches in either sector is determined in the following manner:

$$m_I = \frac{V_I}{V} M(U, V), \tag{2}$$

where U denotes the unemployed labour force and V denotes economy-wide vacancies given as the sum of vacancies in both sectors, i.e., $V = V_N + V_T$. $M(U, V)$ is the economy-wide likelihood of matches and takes the following Cobb-Douglas form as in Petrongolo and Pissarides (2001):

$$M(U, V) = AU^{\alpha} V^{1-\alpha}, \alpha \in (0, 1),$$

where A is a positive constant which captures the matching efficiency and α is the weight on unemployment. (2) indicates that the number of matches in each sector increases when the number of vacancies in the sector becomes larger compared to the economy-wide vacancies, or the economy-wide matching likelihood improves. The former channel implies that an increase in the number of vacancies in one sector decreases the matches formed in the other sector since unemployed workers are mobile across sectors.

We define, respectively, economy-wide and sectoral inverse Bever-

[5] For example, Lin and Miyamoto (2014) shows that a simple search and matching model replicates the behaviour of unemployment and vacancies in Japan in a full information setting. Using Japanese government survey data, Hara (2022) finds that publicly-sponsored job training for the unemployed has positive impacts on their subsequent working status and income.

[6] In an online appendix (https://halshs.archives-ouvertes.fr/halshs-01252478), Cardi and Restout (2015) develop a search unemployment model based on different search costs across sectors. Their findings with respect to the RER and the wage differential are comparable with ours. However, they don't pursue that particular model empirically due to the difficulty of calibrating search parameters at a sectoral level (footnote 15, p.256).

idge ratios as.[7]

$$\theta = \frac{V}{U} \text{ and } \theta_I = \frac{V_I}{U}. \tag{3}$$

Therefore, the economy-wide inverse Beveridge ratio is $\theta = \theta_N + \theta_T$. Accordingly, the number of matches in either sector can be rewritten as

$$m_I = V_I A \theta^{-\alpha}. \tag{4}$$

Hence, the total number of matches in the economy corresponds to $M(U, V)$ as follows:

$$m_N + m_T = M(U, V). \tag{5}$$

3.2. Vacancy posting

Instantaneous profits are total revenue net of labour costs and the cost of posting job vacancies

$$\pi_i = p_i F_i(a_i, L_i) - w_i L_i - \gamma V_i,$$

where γ is the vacancy cost, p_i is the price, w_i is the wage and a_i is the productivity of each firm.[8] We consider the constant relative risk aversion production function $F_i(a_i, L_i) = \nu_i^{-1} a_i L_i^{\nu_i}$ where $\nu_i \in (0, 1)$.[9] Therefore, the elasticity of output with respect to labour and the elasticity of output with respect to productivity are ν_i and 1, respectively. Note that the price of tradeables, p_T, is exogenous in a small open economy, but that the price of nontradeables, p_N, is endogenous. The firm's optimisation problem is $\max_{V_i} \int_0^\infty \pi_i(t) e^{-rt} dt$, where r is the discount rate.[10] The current value Hamiltonian is $H = \pi_i + \Lambda_i \dot{L}_i$ where Λ_i is the co-state variable, which represents the evaluation of hiring an additional worker. Using (1), the first-order conditions are obtained as

$$\Lambda_I m_I = \gamma V_I \tag{6}$$

$$\Lambda_I = \frac{p_I F'_{IL} - w_I}{r + s_I} + \frac{1}{r + s_I} \dot{\Lambda}_I, \tag{7}$$

where $F'_{IL} = dF_I / dL_I$. Note that firms are homogeneous within sectors and the equilibrium values of the endogenous variables depend only on the sector to which firms belong. The transversality condition is $\lim_{t \to \infty} e^{-rt} \Lambda_I L_I = 0$. Combining (4) and (6), we have

$$\Lambda_I = \frac{\theta^\alpha \gamma}{A}, \tag{8}$$

so that the co-state variable is the same for both sectors in the equilibrium ($\Lambda_N = \Lambda_T$).

3.3. Wage determination

The probabilities of being matched to sectors N and T are, respectively, m_N/U and m_T/U. Let z be the value of unemployment benefits, and E_N and E_T the discounted returns of being employed in each sector. In equilibrium, a job seeker's permanent payoff, rE_U, must equal the sum of unemployment benefits and the gain from changing the employment status occurring with the probability of being matched, $M(U, V)/U$. Therefore,.[11]

$$rE_U = z + \frac{M(U, V)}{U} \left[\frac{m_N}{M(U, V)} (E_N - E_U) + \frac{m_T}{M(U, V)} (E_T - E_U) \right]. \tag{9}$$

In equilibrium, a job seeker's permanent payoff for being employed, rE_I, must equal the sum of the wage income and the expected gain from being separated. That is,

$$rE_I = w_I + s_I (E_U - E_I) \tag{10}$$

Rearranging (10), we have

$$E_I - E_U = \frac{1}{r + s_I} w_I - \frac{r}{r + s_I} E_U. \tag{11}$$

Given the worker's payoff $E_I - E_U$ and the steady state value of hiring an additional worker Λ_I, the Nash product S_i is defined as $S_I = (E_I - E_U)^\beta \Lambda_I^{1-\beta}$, where $\beta \in (0, 1)$ is the worker's bargaining power. The wage is determined so that this Nash product is maximised. The first order condition implies

$$E_I - E_U = \frac{\beta}{1 - \beta} \Lambda_I. \tag{12}$$

Here, we use the assumption that agents are small and act non-strategically so that the negotiated wage does not affect E_U, i.e., $dE_U / dw_I = 0$. (12) indicates that the worker captures a larger payoff compared to the producer when its bargaining power is high. (3), (4), (8), (9), (11) and (12) jointly imply the following sectoral wage setting equation.[12]

$$w_I = z + \frac{\beta \gamma}{1 - \beta} \left\{ \frac{\theta^\alpha (r + s_I)}{A} + \theta \right\}. \tag{13}$$

Wages in both sectors are increasing in the inverse Beveridge ratio,θ. That is, wages increase in total labour demand and decrease in unemployment, i.e., wages in each sector can be represented by a wage-setting curve. Moreover, wages differ across sectors in the standard compensating differentials sense, wages are higher in the sector with higher separations. The following Proposition summarises the finding for sectoral wage differences.[13]

[7] The Beveridge curve, or UV curve, is widely used to depict the relationship between the job vacancies rate and the unemployment rate, and is an indicator of the degree of labour market slack. Improvements in job matching lower the ratio of U to V because a more efficient matching process leads to vacancies being filled more quickly, reducing the number of workers looking for jobs.

[8] For tractability, we treat separation rates as exogenous. It should be noted that separation rates and job stability are distinct from layoff or job loss rates. Job stability typically incorporates information about both (involuntary) layoff rates and (voluntary) quit rates. The stability of average job durations or retention rates may reflect the fact that higher layoff rates tend to be associated with lower quit rates over the business cycle.

[9] In the discussion paper version of this study (Gaston and Yoshimi, 2020), we develop the model without a functional form assumption for $F_i(a_i, L_i)$.

[10] In this formulation, L_i is the state variable and V_i the control variable.

[11] The unemployment benefit could be treated endogenously, e.g., z depends on the sectoral wage or on the weighted average of nominal wages. However, we treat z as an exogenous or policy variable, the usual practice in the search literature. For example, as in Acemoglu (2001), z influences sectoral wages, search, unemployment and the sectoral distribution of jobs.

[12] Of course, there are many possible amenities and disamenities that contribute to wages and wage differentials. For example, (13) could be written as:$w_I = z + \frac{\beta_I \gamma_I}{1-\beta_I} \left\{ \frac{\theta^\alpha (r+s_I)}{A_I} + \theta \right\}$.Increases in β_I or γ_I would increase wages, while a higher A_I would decrease wages. In turn, these effects are offset by changes in θ, whereby increases in β_I or γ_I lower θ, while a higher A_I increases θ. Our focus on s_I is partly driven by data considerations. For example, data on sectoral job hiring costs or matching efficiency are unavailable making any empirical investigation purely speculative.

[13] Appendix A numerically shows that θ decreases in s_T and ρ, and increases in s_N (see Figs. A1-A3). Thus, according to Eq. (13), the wage in the tradeables sector (w_T) is increasing in s_N, and decreasing in ρ while the wage in the nontradeables sector (w_N) is increasing in s_N, and decreasing in s_T and ρ. The correlation between w_T and s_T is ambiguous. Nevertheless, from Proposition One, the correlations between the wage gap ($\widetilde{w}$) and these three parameters are clear: $\widetilde{w}$ increases in s_N, and decreases in s_T and ρ, when $s_N > s_T$.

Proposition. One (Compensating wage differentials). *Wages are higher in the sector with higher separations.*

Proof. $\tilde{w} = w_N - w_T = \frac{\beta\gamma\theta^{\alpha}(s_N - s_T)}{A(1-\beta)}$.

3.4. The price of nontradeables

Assume that the representative consumer has constant elasticity of substitution preferences given by

$$C = \left[\psi^{\frac{1}{\rho}} c_N^{1-\frac{1}{\rho}} + (1-\psi)^{\frac{1}{\rho}} c_T^{1-\frac{1}{\rho}}\right]^{\frac{1}{1-\frac{1}{\rho}}}, \ \psi \in (0,1), \ \rho > 0$$

where c_N and c_T are the consumption of nontradeables and tradeables, respectively. ρ is the elasticity of substitution between tradeables and nontradeables. As ρ approaches infinity (zero) tradeables and nontradeables become perfect substitutes (complements) in consumption. Consumer's cost minimisation leads to the following demand functions

$$c_N = \psi\left(\frac{p_N}{P}\right)^{-\rho} C, \ c_T = (1-\psi)\left(\frac{p_T}{P}\right)^{-\rho} C.$$

The price index is defined as $P \equiv \left[\psi p_N^{1-\rho} + (1-\psi)p_T^{1-\rho}\right]^{\frac{1}{1-\rho}}$. With homothetic preferences the income expansion path is linear, with the relative demand for nontradeables given by

$$\left(\frac{\Psi c_T}{c_N}\right)^{\frac{1}{\rho}} = \frac{p_N}{p_T} \equiv p, \ \text{where } \Psi \equiv \frac{\psi}{1-\psi},$$

The ratio of the price of nontradeables to the price of tradeables, p, is customarily referred to as the RER.[14] Market clearing conditions of tradeables and nontradeables are $\overline{L}c_N = F_N$ and $\overline{L}c_T = F_T$, respectively.[15] We treat tradeables as the numeraire (i.e., $p_T = 1$). Economy-wide, the demand for nontradeables ($\overline{L}c_N$) is written as

$$\overline{L}c_N = \frac{\Psi Y}{\Psi p + p^{\rho}}.$$

where national income, Y, is the sum of all factor income - profits plus wage income. It follows that $Y = pF_N + F_T$. Note that unemployment benefits, zU, are simply a transfer of income to the unemployed (e.g., these transfers are funded by a lump-sum tax on factor income). Moreover, the cost of posting vacancies, γV_I, is modelled by Mortensen and Pissarides (1999, p.2574) as a flow cost (e.g., recruitment costs).[16]

Since the total consumption and the domestic production of nontradeables are equal, i.e., $\overline{L}c_N = F_N$, then the price of nontradeables is

$$p = \left(\frac{\Psi F_T}{F_N}\right)^{\frac{1}{\rho}}. \quad (14)$$

In other words, p is determined by *domestic* demand and supply. The primary effect of relative productivity growth in the tradeables sector is to raise the production of tradeables, increase national income and the demand for all goods and services. Hence, the RER increases as in standard B-S models. In the next section, we show that labour movement and the wage gap may reinforce or counteract the effect on the RER.

3.5. Steady state condition

In the steady state, the total number of entrants to and exits from the unemployment pool are equal, i.e.,[17]

$$m_N + m_T = s_N L_N + s_T L_T. \quad (15)$$

The labour market equilibrium condition is

$$\overline{L} = L_N + L_T + U. \quad (16)$$

Using (3)-(5), (15) and (16), we obtain the following relation

$$A\theta^{1-\alpha}(\overline{L} - L_N - L_T) = s_N L_N + s_T L_T. \quad (17)$$

In the steady state, $\dot{\Lambda} = 0$. Therefore (7) becomes

$$\Lambda_I = \frac{p_I F'_{IL} - w_I}{r + s_I}. \quad (18)$$

From (8), (13) and (18),

$$p_I F'_{IL} = z + \frac{\gamma\theta^{\alpha}(r+s_I)}{(1-\beta)A} + \frac{\beta\gamma\theta}{1-\beta}. \quad (19)$$

Conditions (14), (17) and (19) for $I = N, T$ jointly determine the equilibrium levels of L_N, L_T, θ and p (note $p_T = 1$ and $p = p_N$).

As an aside, note from (18) and $\Lambda_N = \Lambda_T$ that

$$\frac{F'_{TL} - w_T}{r + s_T} = \frac{pF'_{NL} - w_N}{r + s_N}. \quad (20)$$

For the case with equal separation rates ($s_N = s_T = s$), Proposition One implies that $w_N = w_T$. It follows that L_N and L_T are determined by $pF'_{NL} = F'_{TL}$. This condition is familiar from the Ricardo-Viner model.[18] More generally, (20) implies that labour moves across sectors so that the marginal contribution of labour over wage cost weighted by the inverse of the sum of the discount rate and the sectoral separation rate is equalised. Importantly, the equilibrium is stable. For example, if $(F'_{TL} - w_T)/(r + s_T) < (pF'_{NL} - w_N)/(r + s_N)$, then firms in the nontradeables sector post vacancies and workers move to that sector, thereby restoring equilibrium.[19]

4. How productivity affects the real exchange rate and unemployment

In this section, we show the comparative statics of productivity growth in each sector for the RER and unemployment.

[14] In some empirical studies the RER is defined as the ratio of the domestic price level to the foreign price level. Our definition is consistent with a small open economy setup. The prices of tradeables and nontradeables consumed in the foreign country are exogenous to the home country, thus the only important element in the RER is the ratio of the nontradeables price to the tradeables price.

[15] We ignore international borrowing and lending for present purposes, i.e., we assume balanced trade. See Kohli and Natal (2014) for a discussion of the comparative statics with, and without, the balanced trade assumption in an aggregate production framework.

[16] A *flow* cost is neither a one-time or lump-sum payment, nor is it a deadweight loss which would reduce national income. In the present case, it is a payment at rate γ until each vacancy is filled.

[17] It is theoretically possible that a sector could disappear as a result of all the workers moving into the other sector in the steady state. To eliminate this possibility, it is sufficient to assume that the elasticity of substitution between tradeables and nontradeables in consumption (ρ) is strictly less than infinity. In other words, we focus on the range of ρ where the Inada (1963) condition holds.

[18] The Ricardo-Viner model, also known as the specific factors model, is an extension of the Ricardian model. It is commonly used to study the movement of workers from one sector (or industry) to another, while another factor is assumed fixed, or specific, in the medium run. In the present case, productivity is sector-specific.

[19] From (20), note that a shock causing such a temporary inequality results in the labour movement reducing the gap between the sectoral marginal products. Alternatively stated, if $(F'_{TL} - w_T)/(r + s_T) < (pF'_{NL} - w_N)/(r + s_N)$ occurs as a result of a temporary shock, from (18) the benefit of hiring an additional worker (Λ) becomes higher in the nontradeables sector. The returns to being employed in that sector increase, as implied by (12). Consequently, workers are attracted to the sector and (20) is restored.

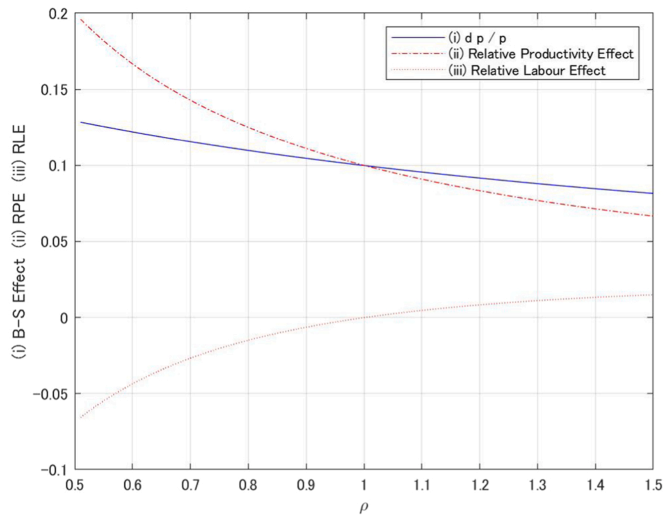

Fig. 2. Decomposing the B-S effect for a productivity improvement in the tradeables sector. *Note*: Computation uses the parameter values shown in the uppermost panel of Table 1, as well as $s_T = 0.025$, $s_N = 0.04$. We assume 10 per cent improvement of the tradeables productivity ($da_T/a_T = 0.1$).

4.1. Linearising the model

Linearising (17) and (19) for $I = N, T$, we have (noting that we consider changes in a_N and a_T below).[20].

$$d\theta = R_N dL_N + R_T dL_T \tag{21}$$

$$F'_{NL}dp + pF''_{NL}dL_N + pF''_{NLa}da_N = Q_N d\theta \tag{22}$$

$$F''_{TL}dL_T + F''_{TLa}da_T = Q_T d\theta, \tag{23}$$

where $F''_{IL} = dF'_{IL}/dL_I$ and $F''_{ILa} = dF'_{IL}/da_I$. (14) is linearised as

$$\frac{dp}{p} = \underbrace{\rho^{-1}\left(\frac{da_T}{a_T} - \frac{da_N}{a_N}\right)}_{\text{(i)Relative Productivity Effect (RPE)}} + \underbrace{\rho^{-1}\left(\nu_T\frac{dL_T}{L_T} - \nu_N\frac{dL_N}{L_N}\right)}_{\text{(ii)Relative Labour Effect (RLE)}} \tag{24}$$

Expression (i), Relative Productivity Effect (*RPE*), captures the productivity effect when the sectoral allocation of labour is unchanged. For example, the RER appreciates if productivity grows relatively more in the tradeables sector. Expression (ii), Relative Labour Effect (*RLE*), captures the effect on the RER of labour reallocation across sectors.[21] While the basic B-S model also captures a reallocation effect arising from the labour mobility across sectors, the presence of the wage gap amplifies or reduces the *RLE* in our model. For example, if, as in our baseline case, tradeables and nontradeables are complements higher productivity in the tradeables sector causes labour to flow to the nontradeables sector from the tradeables sector, i.e., a negative *RLE*. In addition, if the separation rate is higher in the nontradeables sector, the wage in the nontradeables sector rises faster than that in the tradeables sector as implied by the proof of Proposition One. This expansion of the wage gap motivates workers to move from the tradeables sector to the nontradeables sector. As a result, the negative impact of the *RLE* is amplified and the *RPE* is muted by the widening wage differential. This secondary impact caused by the wage gap has not been discussed in the literature.[22]

Using (21) to eliminate $d\theta$, (22)-(24) can be rearranged as

$$G_{11}dp - G_{12}dL_N - G_{13}dL_T = -H_{11}da_N \tag{25}$$

$$-G_{22}dL_N - G_{23}dL_T = -H_{22}da_T \tag{26}$$

$$\rho dp + G_{32}dL_N - G_{33}dL_T = -H_{31}da_N + H_{32}da_T. \tag{27}$$

(25−27) jointly provide comparative statics of p, L_N and L_T for productivity changes in both sectors.[23]

4.2. The effect of productivity growth

In a model with full employment, an expansion of the tradeables sector can only occur by drawing labour from the nontradeables sector. With the existence of unemployment, Eq. (24) makes clear that this need not necessarily occur. Clearly, the rise in the RER could raise national income sufficiently for the nontradeables sector to also expand. While the effect of productivity growth in the tradeables sector on the RER is always positive, the effect of tradeables productivity growth on labour demand in each sector is ambiguous.[24] In other words, the sign of the *RLE* in (24) is indeterminate. But since tradeables productivity growth increases the RER, the *RPE* is never fully offset by the *RLE*. This occurs because the latter effect is a secondary or feedback impact and is always smaller than the primary former effect, even if the correlation between the two effects is negative.

In the next section, we show that in the baseline case in which the separation rate is higher in the nontradeables sector, and where tradeables and nontradeables are complements in consumption, with productivity growth in the tradeables sector the *RLE* and the *RPE* take opposite signs. Wages in both sectors rise with tradeables productivity ($dw_N/da_T > 0$ and $dw_T/da_T > 0$). It is also shown that the inverse Beveridge ratio rises with tradeables productivity, as an improvement in the marginal productivity of labour makes the labour market relatively tighter ($d\theta/da_T > 0$). Hence, the wage differential becomes higher, i.e.,

$$\frac{d\widetilde{w}}{da_T} = \frac{\beta\gamma\alpha\theta^{\alpha-1}(s_N - s_T)}{(1-\beta)A}\frac{d\theta}{da_T} > 0.$$

The RER falls with growth in nontradeables productivity, i.e., $dp/da_N < 0$.[25] From (24), this occurs independently of whether separation rates differ between the sectors. Hence,

Proposition. Two (Productivity changes and real exchange rate). *The real exchange rate, p, appreciates (depreciates) with improvements in*

[20] The definitions of positive coefficients Q_I and R_I are given in Appendix B.

[21] We assume the perfect labour mobility between sectors from a long-run perspective. Introduction of sluggish movement of labour (or, the cost for job change) may affect our results for the B-S effect. Specifically, the *RLE* is expected to be muted if the labour mobility is imperfect. As Fig. 2 shows below, under our parameter settings, the dynamics of the RER (i.e., the B-S effect) is mostly determined by the *RPE* while the *RLE* partially offsets the *RPE*. Therefore, the B-S effect may be amplified if we were to introduce imperfect labour mobility. Notwithstanding, the sign of the change in the RER does not change.

[22] We can rewrite the B-S Eq. (24) using wage changes as (C1) in Appendix C. (C1) implies that, same as the *RPE* in (24), the RER rises when the productivity gap ($da_T/a_T - da_N/a_N$) rises. Moreover, the RER rises with a fall and a rise in wages in the tradeables and nontradeables sectors, respectively. For the effect of wage changes on the RER, there are two channels. One is that labour demand decreases in the sector when its wage increases. These changes in the labour demand impact the RER through the *RLE*. The other is that a productivity improvement in either sector impacts the wage gap, and workers move to the sector with the relatively higher wage. This latter channel amplifies or reduces the former impact. Nevertheless, the overall sign of the impact of wages on the RER becomes consistent with that of the former impact because the former channel always dominates the latter channel when the signs of these channels differ from one another.

[23] The G's and H's are positive and defined in Appendix B.

[24] Appendix D provides the proof for these effects. Specifically, (D2), (D3) and (D4) present dp/da_T, dL_N/da_T and dL_T/da_T, respectively.

[25] See (E1) in Appendix E for dp/da_N. For the effect of nontradeables productivity growth on labour demand in the nontradeables (dL_N/da_N) and tradeables (dL_T/da_N) sectors, see (E2) and (E3), respectively.

Table 1
Parameter and equilibrium values.

Common parameters													
ρ	0.81	r	0.019×10^{-2}	α	0.6	ν_T	0.55	ν_N	0.6	γ	0.5		
$\bar{L}$	1	ψ	0.6	A	1.15	β	0.6	z	0.6				
Panel A. Zero separations													
($s_T = 0.0001$, $s_N = 0.0001$, $a_T = 1$, $a_N = 1$)													
L_T	0.3674	L_N	0.6325	U	0.0001	w_T	1.5691	w_N	1.5691				
$\tilde{w}$	0	p	1.3065	w_N/p	1.2010	θ	1.2918						
Panel B. Positive separations													
($s_T = 0.025$, $s_N = 0.04$, $a_T = 1$, $a_N = 1$)													
L_T	0.3600	L_N	0.6135	U	0.0265	w_T	1.5711	w_N	1.5824				
$\tilde{w}$	0.0113	p	1.3180	w_N/p	1.2005	θ	1.2695						
Panel C. Zero separations and higher productivity in the tradeables sector													
($s_T = 0.0001$, $s_N = 0.0001$, $a_T = 1.1$, $a_N = 1$)													
L_T	0.3628	L_N	0.6371	U	0.0001	w_T	1.7358	w_N	1.7358				
$\tilde{w}$	0	p	1.4495	w_N/p	1.1975	θ	1.5140						
$BS = (p_{PanelC} - p_{PanelA})/p_{PanelA} = 0.1095$													
Panel D. Positive separations and higher productivity in the tradeables sector													
($s_T = 0.025$, $s_N = 0.04$, $a_T = 1.1$, $a_N = 1$)													
L_T	0.3561	L_N	0.6190	U	0.0250	w_T	1.7367	w_N	1.7492				
$\tilde{w}$	0.0124	p	1.4621	w_N/p	1.1964	θ	1.4879						
$BS = (p_{PanelD} - p_{PanelB})/p_{PanelB} = 0.1093$													
Panel E. Positive separations and higher productivity in the nontradeables sector													
($s_T = 0.025$, $s_N = 0.04$, $a_T = 1$, $a_N = 1.1$)													
L_T	0.3645	L_N	0.6090	U	0.0266	w_T	1.5624	w_N	1.5736				
$\tilde{w}$	0.0112	p	1.1881	w_N/p	1.3245	θ	1.2580						
$BS = (p_{PanelE} - p_{PanelB})/p_{PanelB} = -0.0986$													

Note: We discuss how the values of the common parameters are determined in Section 5. Equilibrium values are displayed to four decimal places.

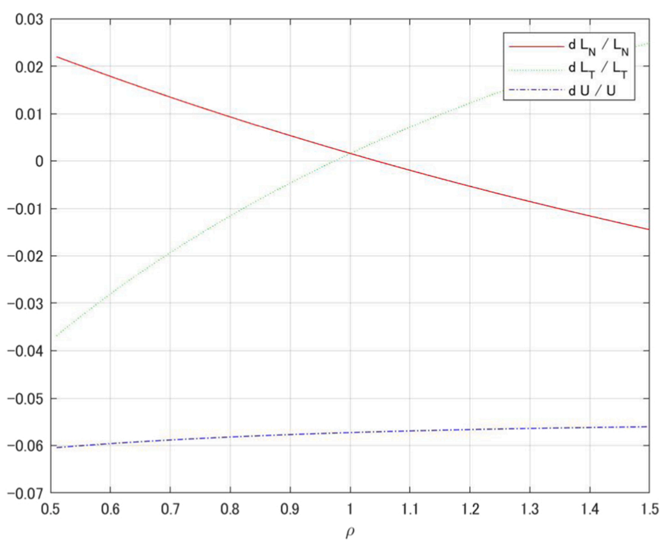

Fig. 3. Response of labour demand and unemployment to productivity growth in the tradeables sector. *Note*: Computation uses the parameter values shown in the uppermost panel of Table 1, as well as $s_T = 0.025$, $s_N = 0.04$. We assume 10 per cent improvement of the tradeables productivity ($da_T/a_T = 0.1$).

technological progress in the tradeables (nontradeables) sector.

Proof. dp/da_T and dp/da_N have positive and negative signs, respectively.

As shown in Appendix D, the effects on the sectoral labour demands are indeterminate. The sign of the effect on unemployment is also indeterminate. The effect of nontradeables productivity growth on labour demand in both sectors is also ambiguous. Notwithstanding, as shown in Appendix E, the impact on nontradeables labour demand is of opposite sign to labour demand in the tradeables sector. In simulations of the model, we show that the changes in labour demand can be positive or negative.

5. Numerical simulations

Simulations are used to illustrate the key features of the model and to obtain quantitative implications. As a preliminary, Eqs. (14), (16) and (19) can be combined to eliminate p and θ to obtain

$$\left(\frac{\Psi F_T}{F_N}\right)^{\frac{1}{\rho}} F'_{NL} - \frac{r+s_N}{1-\beta}\frac{\gamma}{A}\left[\frac{s_N L_N + s_T L_T}{A(\bar{L}-L_N-L_T)}\right]^{\frac{\alpha}{1-\alpha}} - z - \frac{\beta\gamma}{1-\beta}\left[\frac{s_N L_N + s_T L_T}{A(\bar{L}-L_N-L_T)}\right]^{\frac{1}{1-\alpha}} = 0, \tag{28}$$

$$F'_{TL} - \frac{r+s_T}{1-\beta}\frac{\gamma}{A}\left[\frac{s_N L_N + s_T L_T}{A(\bar{L}-L_N-L_T)}\right]^{\frac{\alpha}{1-\alpha}} - z - \frac{\beta\gamma}{1-\beta}\left[\frac{s_N L_N + s_T L_T}{A(\bar{L}-L_N-L_T)}\right]^{\frac{1}{1-\alpha}} = 0. \tag{29}$$

These two equations jointly determine the steady-state values of L_N and L_T.

The model is simulated using Japanese quarterly data. We use the definition of tradeable and nontradeable industries given by Mano and Castillo (2015) (see Fig. 1), the separation rates are $s_N = 0.04 > s_T = 0.025$.[26] We follow Hirakata et al. (2014) and use $\psi = 0.60$. As in Cardi and Restout (2015), the elasticity of substitution between tradeables and nontradeables for Japan is $\rho = 0.81$ implying a moderate degree of complementarity.[27]

For the other exogenous parameters, we follow Miyamoto (2011) by

[26] The separation rate data are for 2018 and from the MHLW. See https://www.mhlw.go.jp/toukei/itiran/roudou/koyou/doukou/19–2/dl/gaikyou.pdf. Annual rates are divided by four. In most of the related literature, the public sector is ignored (although see Burdett, 2012 and Gomes, 2015). Moreover, as noted above, public sector employment in Japan is extremely small. The data indicate that the separation rate for industries (depicted in Fig. 1) varies from 0.017 (Mining) to 0.067 (Accommodation, eating and drinking services). In Appendix F, we show the case where the separation rate is higher in the tradeables sector than the nontradeables sector ($s_N < s_T$).

[27] The elasticity of substitution is important for understanding the effects of productivity growth on the RER and unemployment. We discuss this parameter further in Section 6.2.

setting $\alpha = 0.6$, $\beta = 0.6$ and $z = 0.6$.[28] Since the ten-year Japanese government bond yield for 2018 was 0.076 per cent, then $r = 0.019 \times 10^{-2}$.[29] We set the total labour supply and initial productivity in both sectors to 1 for analytical convenience (i.e., $\overline{L} = 1$ and $a_T = a_N = 1$). We follow Cardi and Restout (2015) in setting the elasticity of output with respect to labour in the respective sectors to $\nu_N = 0.60$ and $\nu_T = 0.55$ for Japan. These elasticities generate a productivity differential, whereby the tradeables sector is approximately 30 per cent more productive than the nontradeables sector. The scale parameter in the matching function, $A = 1.15$,[30] and the cost of posting vacancies, $\gamma = 0.5$, are set so that the simulations result in something close to the actual unemployment rate (2.4% in 2018) and the inverse Beveridge ratio (1.12 in 2018) for Japan.[31] Parameter and equilibrium values are shown in Table 1.

Panel A contains estimates of the values for the 'usual' full employment case, i.e., with zero industry separation rates.[32] Panel B contains estimates for our job separations model, with $s_N = 0.04 > s_T = 0.025$. Unemployment is 2.65 per cent and a slack labour market is reflected in a lower inverse Beveridge ratio. Employment in the tradeables sector is smaller than it is in the nontradeables sector consistent with the actual labour employment shares in the two sectors. To retain workers in the sector with a higher separation rate, the nominal wage is higher in the nontradeables sector and the wage differential is positive. Moreover, the employment-weighted real wage is also higher, consistent with the higher unemployment.[33]

Our model replicates the wage differential between tradeables and nontradeables sectors in Japan quantitatively. As we discussed in the introductory section, the weighted average of the monthly salary is 329 thousand yen in the tradeables sector and 340 thousand yen in the nontradeables sector according to the 2018 MHLW data. Thus, the nominal wage is approximately 3.3 per cent higher in the nontradeables sector. In our numerical simulation, according to Panel B of Table 1, the nominal wage in the nontradeables sector (w_N) is approximately 0.7 per cent higher than that in the tradeables sector (w_T). Thus, the B-S model developed in this paper, with the higher separation rate in the nontradeables sector, does not fully explain the cause of higher wages in this sector.

We can consider several potential factors for this quantitative lack of model's predictability. For example, among all industries the highest salary is observed for the finance and insurance industry. This industry is classified as a nontradeables sector and raises the average salary of that sector. Workers in this industry may have specific and unique skills compared to workers in other industries. We do not consider worker heterogeneity within sectors and across industries in our model in order to focus on the role of industry-specific separation rates. In addition, we do not assume the cost of job switching for workers between the tradeables and nontradeables sectors. If it is costly for workers to move between sectors, companies in one sector have to offer higher wages to attract more workers from another sector.

6. Simulating the Balassa-Samuelson effect

In this section, we simulate the B-S effect using the parameter settings in Section 5. In particular, we focus on how changes in the allocation of labour impact the magnitude of the effect of productivity changes on the RER. We also examine the impact of productivity growth in the nontradeables sector on unemployment in order to augment the recent policy discussion on the promotion of productivity improvement in that sector.

6.1. Productivity growth in the tradeables sector

Consider $da_T/a_T = 0.1$ and $da_N/a_N = 0$ (i.e., the 'usual' B-S thought experiment). The results are shown in Table 1, the full employment case in Panel C and the job separation case when $s_T = 0.025$ and $s_N = 0.04$ in Panel D. We obtain the magnitude of the B-S effect by calculating the growth rate of p between panels C and A (D and B) for the full employment case (the job separation case). The B-S effect (i.e., dp/p) is shown as *BS* in the panels, and 10.95 per cent and 10.93 per cent for the full employment case and job separation case, respectively. Notably, the B-S effect is larger than the rate of productivity growth in the tradeables sector in both cases because we assume that the elasticity of substitution is lower than one. In the full employment case, the B-S effect equals the rate of productivity growth in the tradeables sector if we assume the Cobb-Douglas case where the elasticity of substitution is one as shown in Eq. (24).

To examine how labour movement affects the B-S effect it is instructive to decompose the results into the *RPE* and *RLE*, as shown in Eq. (24). The *RPE* is identical for both the full employment and job separation cases. Since $dL_N/L_N > 0 > dL_T/L_T$, the *RLE* is negative and offsets the positive *RPE* in both cases. In the job separations case, the unemployment rate decreases by 0.15% points, even though the nontradeables sector has a higher separation rate. This occurs because of the significantly higher wage in the tradeables sector. Comparing the *RLE*

[28] The weighted average of nominal wages defined as $\overline{w}^n \equiv (w_N L_N + w_T L_T)/(L_N + L_T)$ is 1.5691 in Panel A, which is approximately 2.6 times larger than the unemployment benefit z. However, the unemployment benefit in Japan ranges between 45% and 80% of the wage in the previous job. Thus, $z = 0.6$ might be too low. We also simulated our model with $z = 0.95$, so that z becomes roughly 60% of $\overline{w}^n$, and found that, while unemployment is higher, that the main results are unchanged.

[29] We use the simple average of the ten-year government bond yield for 2018 reported by Ministry of Finance on a daily basis (https://www.mof.go.jp/jgbs/reference/interest_rate/index.htm).

[30] Kano and Ohta (2005) estimate the matching function using annual panel data covering 47 Japanese prefectures from 1972 to 1999. Their weight on unemployment (α in our notation) is 0.56,while we use 0.6 in our simulations. It should be noted that they find the weight on vacancies is 0.302, thus the sum of these weight is not unity, implying rejection of constant returns to scale in the matching function. Nevertheless, we maintain the assumption of constant returns to scale for the tractability of the model, as well as consistency with the bulk of the extant literature.

[31] The value of γ varies extremely widely across papers. Miyamoto (2011) uses $\gamma = 0.313$ for Japan. In a well-known paper, Hagedorn and Manovskii (2008) use $\gamma = 0.584$ and $z = 0.955$. The latter choice was driven by a view that z should include the utility of leisure time as well as the unemployment benefit replacement rate. In contrast, our z is approximately 38 per cent of the employment-weighted *nominal* wage defined by $\overline{w}^n \equiv (w_N L_N + w_T L_T)/(L_N + L_T)$. The net unemployment benefit replacement rate in 2010 was 23 per cent for Japan, 34 per cent for the United States and 41 per cent for Australia (see: https://www.cesifo-group.de/ifoHome/facts/DICE/Labour-Market/Labour-Market/Unemployment-Benefit-Schemes/unemployment-benefit-replacement-rates/fileBinary/unemployment-benefit-replacement-rates.xls). The inverse Beveridge ratio has exceeded 1 for Japan since 2014, and averages 1.12 for the last ten years. Active policy intervention and stimulus (so-called *Abenomics*) coupled with Japan's declining birth-rate has resulted in a higher ratio of vacancies to unemployment compared to other countries, such as the United States.

[32] In Appendix G, we illustrate the determination of equilibrium labour inputs based on (28) and (29). To solve the model, we use the Trust-Region Dogleg method and the *fsolve* command in MATLAB. Japan's unemployment rate in 2018 (2.4%) is used for the initial value of the unemployment rate. Labour shares in the nontradeables and tradeables sectors are 74.9% and 25.1%, respectively, according to MHLW data. Thus, in the unemployment case, initial values are $L_T = (1 - 0.024) \times 0.251 = 0.245$ and $L_N = (1 - 0.024) \times 0.749 = 0.731$. In the full-employment case, we employ initial values $L_T = L_N = 0.49999$. In panels A and C of Table 1, we employ nearly-zero separation rates ($s_T = s_N = 0.0001$) in order to obtain convergence of the solution. As a result, the unemployment rate is effectively zero.

[33] The employment-weighted *real* wage is $\overline{w} \equiv ((w_N/p)L_N + w_T L_T)/(L_N + L_T)$. In the full employment case, $\overline{w} = 1.336$, while it is $\overline{w} = 1.338$ with positive separation rates.

between the two cases, the contraction in the tradeables sector is smaller and expansion of the nontradeables sector is greater for the job separations case. This occurs because the expansion of the nontradeables sector is partly facilitated by unemployed workers finding work in that sector. This implies that the B-S effect is smaller in the job separations case.

The sectoral wage gap widens in response to a tradeables productivity shock. As the separation rate is higher in the nontradeables sector than the tradeables sector, a productivity improvement in the tradeables sector leads to a relative rise in the wage in the nontradeables sector. A higher wage in the nontradeables sector motivates workers to move to this sector, leading to a rise in the supply of the nontradeables. As a result, a rise in the nontradeables price (i.e., the RER) is muted. In other words, the widening wage gap amplifies the negative *RLE* in our simulation. This mechanism has not been previously discussed in the literature since most of the B-S research assumes equal wages across sectors.

6.2. The role of substitutability

The importance of the substitutability or complementarity of tradeables and nontradeables for the B-S model is well-known (e.g., Hamano, 2014; Cardi and Restout, 2015). For example, a rise in the nontradeables price leads to lower demand for nontradeables. As a result, if tradeables and nontradeables are substitutable, the tradeables sector may attract labour from the nontradeables sector. Consequently, a fall in the supply of the nontradeables amplifies a rise in the nontradeables price. Hence, if tradeables and nontradeables are substitutes (complements), the RER will rise more (less) than proportionately. This section shows that our model replicates this feature.

Fig. 2 shows how substitutability is related to the response of the RER to higher tradeables productivity. We decompose the B-S effect into the *RPE* and *RLE*. The *RPE* is always positive, while the sign of the *RLE* depends on ρ. As we discussed in the previous subsection, the *RLE* is negative and reduces the B-S effect in our benchmark case ($\rho = 0.81$). The *RLE* changes sign at $\rho = 1.002$ where tradeables and nontradeables are slightly more substitutable than the Cobb-Douglas case ($\rho = 1$).[34]

In Fig. 3, we show the changes in sectoral labour demands and unemployment when productivity in the tradeables sector grows. When a_T rises, the RER and the marginal productivity of labour in the tradeables sector both increase. When ρ is sufficiently small, labour demand in the nontradeables sector expands more compared to the tradeables sector and the nontradeables sector draws labour from the tradeables sector. Notably, the wage in the nontradeables sector grows more than the wage in the tradeables sector, and this movement of labour is amplified. While both marginal products increase, the value of the marginal product in the nontradeables sector rises relatively more. As Fig. 3 shows, when the domestic substitutability in consumption of tradeables and nontradeables is greater, a higher nontradeables price leads to a shift in demand from nontradeables to tradeables. Moreover, the tradeables sector draws labour from the nontradeables sector. This amplifies the magnitude of the B-S effect through a rise in the *RLE*. Unemployment falls because the tradeables sector attracts more labour than the nontradeables sector sheds.

Interestingly, there is only a very small range, [0.98, 1.04], in which the positive income effect increases the labour demand in both sectors. Included in this range is the Cobb-Douglas case (i.e., $\rho = 1$). Also notable from Fig. 3 is that the improvement in unemployment is more modest with a higher ρ, although the sign of dU/U is always negative.

6.3. Productivity growth in the nontradeables sector

The focus on service sector productivity has become an important

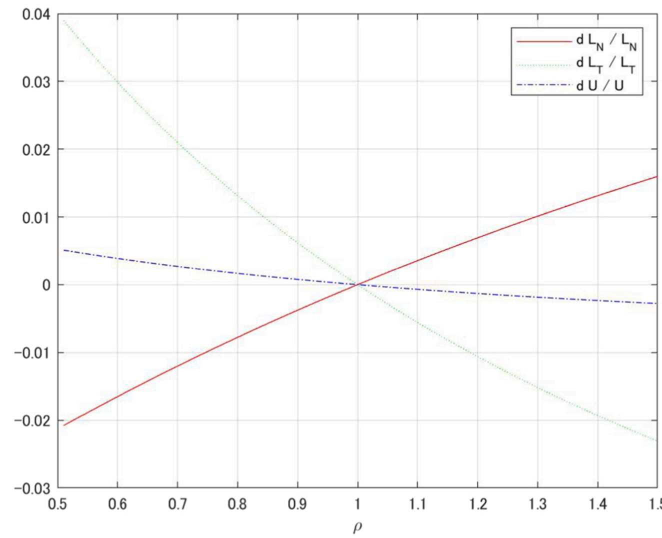

Fig. 4. Response of labour demand and unemployment to productivity growth in the nontradeables sector. *Note*: Computation uses the parameter values shown in the uppermost panel of Table 1, as well as $s_T = 0.025$, $s_N = 0.04$. We assume 10 per cent improvement of the nontradeables productivity ($da_N/a_N = 0.1$).

policy agenda in Japan as its economy has faced sluggish economic growth for decades. For example, the *Service Productivity and Innovation for Growth* (SPRING) was established in 2007 to promote innovation in the service sector.[35] Also, researchers have investigated the determinants of productivity in the nontradeables sector and the influence of productivity growth in this sector on the country's economic growth.[36] As an additional contribution of this paper for the policy discussion in Japan, we examine how nontradeables productivity growth affects the RER and unemployment.

Panel E of Table 1 shows the equilibrium values of endogenous variables with higher productivity in the nontradeables sector. Therefore, comparing panels B and E of this table, we illustrate how nontradeables productivity growth affects the RER under the benchmark parameter setting. The RER decreases with 9.86 per cent from Panel B to Panel E. The *RPE* is negative in this case as shown in (24). The *RLE* is positive as the labour input increases in the tradeables sector and decreases in the nontradeables sector, respectively ($dL_T/L_T = 0.0125$ and $dL_N/L_N = -0.0073$). Accordingly, the *RPE* is muted by the *RLE* as in the case of tradeables productivity growth.

Notably, unemployment *increases* ($dU/U = 0.0038$) under the benchmark parameter setting. This outcome is sensitive to the value of ρ. Fig. 4 shows how ρ is related to the dynamics of labour demand and unemployment. There are two important differences compared to the case of growth in tradeables productivity. First, there is *no* value of ρ for which both sectors expand their labour demand. This indicates that a fall in the nontradeables price mitigates the positive impact of productivity growth on national income. In other words, the overall income effect is smaller in the case of nontradeables productivity growth. Moreover, the signs of dL_T/L_T, dL_N/L_N and, more importantly, dU/U reverse at $\rho = 1$.

[34] This threshold value of ρ equals 1 when we employ homogeneous parameter values for both sectors ($s_T = s_N$ and $\psi = 0.5$).

[35] SPRING awards prizes to service sector companies that achieve outstanding productivity improvements. It also makes recommendations to promote innovation in the service sector. For example, in 2018 SPRING recommended that the service industry more ambitiously implement information technology to improve labour productivity in order to counteract the shrinking workforce caused by the declining birth-rate and aging population in Japan.

[36] For example, Morikawa (2011) investigates the determinants of service industry productivity using Japanese establishment-level data and finds significant economies associated with population density.

When $\rho < 1$, e.g., as in our benchmark case, labour demand in the tradeables sector grows, but not by enough to compensate for the contraction in nontradeables labour demand. When ρ is small, the falling nontradeables price leads to a reduction in national income. Consequently, the fall in nontradeables labour demand is not fully offset by higher tradeables labour demand. Since tradeables and nontradeables are complements in consumption, unemployment expands with productivity growth in the nontradeables sector.[37]

7. Concluding comments

A feature of the Japanese economy is that the nontradeables sector has higher wages and a higher separation rate compared to the tradeables sector. We replicated these features using a Balassa-Samuelson (B-S) model with industry-specific job separations. In contrast to the predictions of the basic B-S model, empirically the real exchange rate does not respond proportionally to changes in productivity growth in the tradeables sector. Using simulations based on Japanese data, we showed that the basic B-S effect is muted by changes in the sectoral wage differential and reallocation of labour. For our baseline case, in which tradeables and nontradeables are complementary in consumption, we showed that the usual effect of higher productivity in the tradeables sector is significantly reduced. We argued that it is important to consider how changes in the wage differential impact the movement of labour between sectors to understand the B-S effect.

Our model also has important insights for unemployment. Of contemporary interest, given the growing involvement of the public sector (and the growth of services, more generally) in the domestic economy, is the possibility that unemployment may rise with productivity growth in the nontradeables sector. In order to reduce unemployment, an implication is that the government should consider policies that encourage productivity improvement in those nontradeables industries whose output is more substitutable for the output of the tradeables sector.

Data availability

Data will be made available on request.

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[37] The fact that productivity growth in the tradeables sector is more beneficial than productivity growth in the nontradeables sector for lowering unemployment also arises in the context of a three-sector Dutch disease model (exports, import-competing and services) (Gaston and Rajaguru, 2013). In other words, productivity growth in the nontradeables sector (which includes the government sector) may increase unemployment.