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Growth and the Real Exchange Rate

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Abstract

This paper uses a general model of international trade to analyze the long run factors: technological change, changes in the endowment of primary factors and market size, which determine the real exchange rate. It is shown that the real exchange rate is positively correlated with economic size as well as technological progress in traded sectors. By contrast, the relationship between endowments of primary factors such as land and mineral deposits and the real exchange rate is ambiguous.

I. Introduction

Since Balassa [1964] and Samuelson [1964], it is widely accepted that the real exchange rate, defined as the relative price of nontraded goods in terms of traded goods, appreciates with economic development. This hypothesis was confirmed empirically by data from the International Comparison Project (see Kravis, Heston and Summers [1982] and Kravis and Lipsey [1988][1]. There are three explanations for the observed positive association between

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1. Other empirical studies in this area include Kravis and Lipsey [1983], Clague [1986], [1989], Officer [1989] and Falvey and Gemmel [1991].

the relative price of nontraded goods and income per capita. They are: (1) the differential technological progress model, (2) the factor proportions model and (3) the increasing return to scale in the traded sector model.

In this paper, we use a general model of trade to synthesize and extend existing results on the relationship between the real exchange rate on the one hand and factor endowments, technological progress and increasing returns to scale on the other. Our objective is to find the weakest set of assumptions where existing results in the literature can be generalized. Previous work, with the important exceptions of Neary [1988] and Falvey and Gemmel [1991], was conducted in restrictive theoretical frameworks such as the Ricardian or the Heckscher-Ohlin models. Neary [1988] provides a completely general model of nontraded price level determination but he does not address details of the relationship between growth and the real exchange rate. While Falvey and Gemmel [1991] examine the relationship between factor endowments and the real exchange rate, they ignore technological change and increasing returns to scale.

The second goal of this paper is to examine real exchange rate effects of growth in a model which allows for a variable stock of capital. Previous research, while explicitly long run in nature, has assumed a fixed stock of capital. But it does not make much sense to analyze the long run effects of technological progress or an increase in size without also taking into account changes in the capital stock. In practice, of course, changes in the endowments of primary factors, technological progress or an increase in size will affect the capital stock. In the model of this paper, such shocks will have direct and indirect effects on the nontraded price level. Take, for example, changes in the endowments of a primary factor such as land. The direct effect is the impact of changes in endowment on the nontraded price level, holding the capital stock constant. The indirect effect is the effect of induced changes in the capital stock on the nontraded price level. Falvey and Gemmel [1991] have shown that the real exchange rate effects of changes in the capital stock are ambiguous. Therefore, it is important to determine whether existing results with regard to technological progress and increasing returns hold when the capital stock is endogenous.

The paper is organized as follows. Section II outlines a model of real exchange rate determination with capital mobility. Then, sections III through five analyze the effects of changes in factor endowments, technological progress and increasing returns to scale on the relative price of nontraded goods. Our results can be summarized as follows. We find that the relative price of nontraded goods is, in general, positively correlated with economic size and technological progress in traded sectors. By contrast, the relationship between endowments of primary factors, such as land and minerals, and the real exchange rate is ambiguous.

II. A Model of Growth and Nontraded Price Level

Consider a small economy which is a price taker in international markets, and produces one nontraded good (services) and N traded goods using M factors of production.[2] It is assumed that there are more factors of production than there are traded goods produced. All markets are competitive and production functions are assumed to display constant returns to scale. Economies, however, differ in the number of traded goods produced, in relative and absolute factor endowments and in the level of technology in the traded and nontraded sectors. Without loss of generality, let us choose one of the traded goods as our *numéraire*.

Previous work on growth and the real exchange rate has tended to use models where capital is mobile intersectorally but where its total supply is fixed. Of course, the problem with this assumption, as pointed out by Neary [1978], is that over the period where capital is intersectorally mobile the stock of capital is also variable. In this paper, we allow for a variable supply of capital through international capital mobility. More precisely, we assume that the economy faces a perfectly elastic supply of capital. (Alternatively, we could endogenize the capital stock through domestic savings by means of a multi-sector growth model as in Manning and Markusen [1991]. While the short run dynamics associated with each assumption differ, the long run comparative statics are similar.[3])

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2. Extending the model to allow for more than one nontraded good, as in Neary [1988], complicates the model without changing the results.
3. Manning and Markusen [1991] amd Manning, Markusen and Melvin [1993] discusss the properties of trade models where savings and investment are endogenized

We assume that the economy consists of a single representative household whose behavior is summarized by its expenditure function $e(\cdot)$, given in equation (1). This function shows the minimum expenditure necessary to achieve a given level of utility. In equation (1), p_s is the price of the nontraded good, p is a vector of traded goods prices, x is a vector of traded goods consumed, x_s is the consumption of the nontraded good and U is a scalar representing welfare. Note that one element of p, the *numéraire*, is equal to one. Finally, all goods are normal. For future reference, recall that the first derivative of the expenditure function with respect to the *i'th* price, denoted by $e_i(\cdot)$, provides the compensated demand function for the *i'th* good.

$$e(p, p_s; U) \equiv \underset{x,x_s}{\text{Min}}\ px + p_s x_s \ \ s.t.\ U = U(x, x_s) \tag{1}$$

Given our assumptions, national income may be represented by the GNP or revenue function $g(\cdot)$.

$$g(p, p_s; v) \equiv \underset{x,x_s}{\text{Max}}\ pX + p_s X_s \quad s.t.\ f(X, X_s, v) = 0 \tag{2}$$

In (2), X is a vector of traded outputs, X_s is the output of nontraded goods, v is a vector of factor supplies and $f(\cdot)$ is the production possibility set. The first derivative of the GNP function with respect to the *i'th* price, denoted by $g_i(\cdot)$, provides the output supply function for this good.[4]

To introduce capital mobility, we assume that there is one mobile factor "capital" that is in perfectly elastic supply at the world rate of return r.[5] Also, we divide the capital stock, k, into a fixed endowment owned by domestic nationals, $\bar{k}$, and that owned by non-nationals, k^*.

It is convenient to represent the production side of this economy by the *variable factor supply revenue function*. This function, defined in (3), was introduced by Neary [1985]. As used in (3), it measures national income excluding capital payments. Furthermore, this function has the standard properties of a revenue function. In particular, its derivative with respect to

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by means of the neoclassical growth model. Neary [1985] provides the details for an economy facing a perfectly elastic supply of capital from abroad.

4. For formal details of the GNP and expenditure functions, see Dixit and Norman [1980] and Woodland [1982].

5. The results generalize in a straightforward fashion to the many factor case.

an output price, $\tilde{g}_i$, is the supply function for that good while its derivative with respect to the rental rate of capital, $\tilde{g}_r$, gives minus the demand function for capital.[6] Note that $\tilde{v}$ in (3) is defined as a vector of primary factors of production and therefore excludes capital.

$$\tilde{g}(p, p_s, r; \tilde{v}) = \underset{k}{\mathrm{Max}}\ [g(p, p_s; v) - rk] \tag{3}$$

Equation (4) sets expenditure equal to national income.[7]

$$e(p, p_s, U) = \tilde{g}(p, p_s, r; \tilde{v}) + r\bar{k} \tag{4}$$

The second condition for equilibrium, clearing in the nontraded goods market, is given by (5) where $e(\cdot)$ and $\tilde{g}_s(\cdot)$ are the first derivatives of the expenditure and GNP functions with respect to the price of nontraded goods.

$$e_s(p, p_s; U) = \tilde{g}(p, p_s, r; \tilde{v}) \tag{5}$$

Equation (6) sets the domestic price of the *i'th* traded good equal to the world price. Since world prices are fixed, the real exchange is determined by movements in the nontraded price level.

$$p_i = p_i^* \tag{6}$$

Notice that this model is based on a general specification of technology and preferences. Consequently, we cannot expect the sharp or unambiguous results of simpler models. Our goal, therefore, is to find the weakest set of assumptions under which earlier results can be obtained.

III. Factor Endowments and Nontraded Prices

We analyze in this section the relationship between factor endowments and the nontraded price level. Ohlin's classic treatise *Interregional and International Trade* [1933] showed that the positive correlation between nontraded goods price levels and income per capita across countries could be explained by differences in factor proportions. Recently, Kravis and

6. Neary [1985] provides a proof.

7. Throughout the paper we ignore taxes, subsidies and other distortions.

Lipsey [1983], Bhagwati [1984], Clague [1985], Neary [1988] and Falvey and Gemmel [1991] among others, have formalized the Ohlin factor proportions model.

We begin by examining the real exchange rate effects of an increase in a primary factor termed "land" denoted by L. Totally differentiating (4) and using (5), yields (7) which shows that an increase in land raises income. Following the trade literature, we define changes in real income, dy, as $e_u dU$ where e_u is the inverse of the marginal utility of income.

$$dy = \tilde{g}_L dL \tag{7}$$

In (7) $\tilde{g}_L$ is the marginal product of land which, under competition and constant returns to scale, is equal to its market return r_L. Solving (5) and (7) for the nontraded price level, we obtain (8) where $\tilde{g}_{sL}$ is the Rybczynski term for nontraded goods with respect to labor. Note that e_{sy}, the marginal propensity to spend on nontraded good, is equal to (e_{su}/e_u). Finally $(\tilde{g}_{ss} - e_{ss})$, the slope of the excess supply function for services, is positive.

$$dp = (\gamma r_L + \pi_L)dL \tag{8}$$

$$where\ \pi_L = \frac{\tilde{g}_{sL}}{\tilde{g}_{ss} - e_{ss}} \quad \gamma = \frac{e_{sy}}{\tilde{g}_{ss} - e_{ss}} > 0$$

Equation (8) has a simple interpretation. On the demand side, an increase in the supply of land raises income which, assuming nontraded goods are normal, also increases the demand for services. This effect is given by the first term in parenthesis.[8] Second, the increase in land also changes the supply of services. Unfortunately, there is little that can be said about the sign of π_L as the Rybczynski parameter, $\tilde{g}_{sL}$, cannot be signed.[9] It can be positive or negative depending on the properties of the model. Indeed, as shown by Ethier [1984] at least one Rybczynski term must be positive and at least one

8. Of course, with protection or other distortions the relationship between factor supplies and the nontraded price level is further complicated because factor accumulation can reduce income.

9. Using (2), the Rybczynski parameter, $\tilde{g}_{sL}$, can be shown to equal $(g_{sL} + g_{sK}dK)$ where g_{sL} and g_{sK} are Rybczynski terms for the constrained revenue function with respect to land and capital. These effects correspond to the direct and indirect effect of an increase in the endowment of land.

must be negative. In general, no presumption exists as to its sign. Thus, contrary to a widespread impression in the Dutch Disease literature, there is not even a presumption that increases in the supply of factors specific to traded sectors will increase the nontraded price level. To sum up, there are no general results with respect to changes in the endowment of the primary factors such as land, labor or mineral resources and the nontraded price level.[10]

IV. Differential Technological Progress and the Nontraded Price Level

The doctrine that technological progress occurs at a faster rate in the commodity producing or traded sectors of an economy is an old one.[11] Cairnes [1874], Taussig [1906] and [1926], Harrod [1933], Balassa [1964], Samuelson [1964] and Bhagwati [1984] have argued that technological progress increases the nontraded price level. We can incorporate technological progress into the GNP function by introducing a shift parameter τ. The GNP function now becomes $g(p, p_s, r; \tilde{v}; \tau)$. At this level of generality, however, few results are possible. To simplify matters, first assume that technological change is Hicks neutral or product augmenting. In this case, the revenue function becomes $\tilde{g}(\tau p, p_s, r; \tilde{v})$ where τp is a vector with elements $\tau_i p_i$. Recall that product augmenting technological change is identical to an increase in output price, *i.e.* a rise in the world price. Therefore, $\tilde{g}_{\tau i}(\cdot) = \tilde{g}_i(\cdot)$. Using this result, totally differentiating (4), and solving for the effects of technological progress in the *i'th* traded sector on income, (9) is obtained. Not surprisingly, technological progress increases income.

$$dy = \tilde{g}_i \, d\tau_i \tag{9}$$

Equation (10) gives the impact of technological progress in the *i'th* traded sector on the nontraded price level. On the demand side, this raises the demand for nontraded goods by increasing real income. The income effect

10. A similar conclusion is reached by Falvey and Gemmel [1991] for models in which the capital stock is fixed.
11. For empirical evidence that this is in fact the case, see Baumol, Blackman and Wolff [1985].

is given by the first term in (10). But the effects on the supply of services depend on whether services and the expanding sector are substitutes or complements in general equilibrium supply *i.e.* on the sign of θ_i. This sign is determined by general equilibrium cross effect in supply, $\tilde{g}_{si}$.[12] From the properties of the revenue function we know that the supply function is homogeneous of degree one in prices. Also, from convexity, we know that the own price effect is positive. It follows that cross effects in supply are, on average, negative which in turn ensures that θ_i is positive. Thus, there is a presumption that Hicks neutral technological progress in the *i'th* traded sector increases the nontraded price level. Furthermore, if technological progress occurs at the same rate in all traded sectors, the nontraded price level necessarily increases. Since these results hold with and without capital mobility, it follows that the direct effects must outweigh the indirect effects if they work in opposite directions.

$$dp_s = (\gamma\tilde{g}_i + \theta_i)d\tau_i > 0 \tag{10}$$

$$\theta_i = \frac{-\tilde{g}_{si}}{\tilde{g}_{ss} - e_{ss}}$$

Technological change can also be modelled as taking the form of factor augmentation. Here, the revenue function becomes $\tilde{g}(p, ps, r; \beta v)$ where βv is a vector of primary factor endowments whose *j'th* element is $\beta_j v_j$. Recall that factor augmenting technical change is identical to an increase in factor supplies. But, we have seen that the relationship between endowments of primary factors and the nontraded price level is ambiguous. From this it is clear that the impact of factor augmenting technological progress on the relative price of nontraded goods is also ambiguous. In conclusion, it can be shown that the effects of factor augmenting technical change occurring in the traded sector is also uncertain.

The results of this section may be summarized as follows. The relationship between technological progress and the nontraded price level is sensitive to assumptions about the nature of technological progress. While there is a presumption that product augmenting technical progress in the *i'th* traded sec-

12. In fact the $\tilde{g}_{si}$, term is equal to $(g_{si} + g_{sK}dK)$ corresponding to the direct and indirect effect of an increase in the *i'th* price.

tor raises the nontraded price, no such presumption can be established as to the effects of factor augmenting technical change for the *j'th* factor.

V. Market Size and the Nontraded Price Level

The role of increasing returns to scale in the growth process has attracted renewed interest since Romer [1986] and Lucas [1988]. Less well known is the fact that with increasing returns to scale, as emphasized by Panagariya [1988], the absolute size of an economy plays a crucial role in nontraded price level determination. To obtain unambiguous results concerning increasing returns to scale and the real exchange rate, we again have to impose structure on the model. Consider an economy where increasing returns to scale are present in the traded sectors.[13] Define an increase in size as an equal increase in the endowment of all factors of production, including domestically owned capital. Let us go further and assume that increasing returns to scale are external to each firm in the traded sector but are internal to the traded sector as a whole.[14] There are constant returns to scale in the nontraded section. Given these assumptions, it can be shown that the effect on the real exchange rate of an increase in size are formally

13. Evidence that increasing returns to scale exist for the manufacturing sector is provided by Caballero and Lyons [1990, 1992]. For most economies, tradables are concentrated in manufacturing.

14. If there were increasing returns at the industry level, this good might be produced entirely in one country. This would violate the small economy assumptions of the model.

15. Following Panagariya [1988] and Helpman [1984] the output of each sector can be represented as $X_i = h(X)F(V_i)$ where V_i is a vector of inputs used in this industry, $F(\cdot)$ is a constant returns to scale production function and $h(X)$ is a positive function with an elasticity with respect to output lying between zero and unity and X is a vector of traded good outputs. Therefore, increasing returns are external to the firm but internal to the traded sector. The GNP function is given by equation (1a), output of the *i'th* sector by equation (2a) and the supply function for the nontraded good by equation (3a). Equation (11) can be obtained from equations (1a) to (3a) in conjunction our earlier results.

$$g(\cdot) = \tilde{g}(ph(X), p_s, r; \bar{v}) \quad (1a)$$

$$X_i = \tilde{g}_{p_i h_i}(ph(X), p_s, r; \bar{v})h_i(X) \quad (2a)$$

$$X_s = \tilde{g}_s(ph(X), p_s, r; \bar{v}) \quad (3a)$$

identical to an increase in size *combined with* product augmenting technological progress in the traded sector for an economy with constant returns to scale.[15] Using this correspondence, the income effect of an increase in size is given by (11) where the subscript T is used to denote the traded sector. To obtain this result, note that, with constant returns to scale, the GNP function is homogeneous of degree one in factor supplies. In addition, we normalize initial endowments of domestic factors, including capital, at unity.

$$dy = ydv + \tilde{g}_T d\tau_T \tag{11}$$

The impact of an increase in size on the nontraded price level is given by (12). Since substitutability between traded goods and the nontraded sector necessarily holds in supply, then $\theta_T > 0$. From (8), observe that a sufficient condition for the price of services to rise with an increase in size is that the elasticity of the total demand for services, denoted by η_s, is greater than or equal to unity.[16] (To obtain (12), the initial quantity of nontraded goods is normalized at unity.) Normality is sufficient to ensure that this condition is satisfied. We therefore conclude that the real exchange rate appreciates with size, as suggested by Panagariya [1988].

$$dp_s = \frac{\eta_s - 1}{\tilde{g}_{ss} - e_{ss}} dv + (\theta_T + \gamma\tilde{g}_T) d\tau_T \tag{12}$$

There are two points that should be borne in mind when interpreting this result. To begin with, it is by no means clear why there should be increasing returns in the traded sector but not in the nontraded sector. Second, this result is also dependent on the form that increasing returns to scale takes. If increasing returns arise from externalities produced from the employment of a certain factor, as in the Lucas [1988] model of growth and human capital, it can be shown that there is no presumption that an increase in country size appreciates the nontraded price level.

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16. The parameter η_s includes the effects of an increase in population as well as an increase in income per capita. Implicitly, we have assumed that the household has increased in size. Alternatively, we could handle population changes by multiplying the expenditure function in (1) by N where N is the population. This is the procedure adopted by Falvey and Gemmel [1991]. The results are unchanged.

V. Summary and Conclusion

Using a general model of trade, we have re-examined the conditions where growth leads to an increase in the nontraded price. The results suggest that the relative price of nontraded goods is positively correlated with economic size and rates of technological progress in traded sectors. By contrast, the relationship between endowments of primary factors such as land and minerals, and the real exchange rate was shown to be theoretically ambiguous. These results are shown to hold with and without capital mobility.

References

Balassa, Bela [1964], "The Purchasing Power Parity Doctrine: A Reappraisal," *Journal of Political Economy* 72; pp. 584-596.

Baumol, William, Sue, Blackman, and Edward Wolff [1985], "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence," *American Economic Review* 75; pp. 806-817.

Bhagwati, Jagdish [1984], "Why are Services Cheaper in the Poor Countries," *Economic Journal*, 94; pp. 279-286.

Caballero, Ricardo and Richard Lyons [1990], "Internal Versus External Economies in European Industry," *European Economic Review* 34; pp. 805-830.

Caballero, Ricardo and Richard Lyons [1992], "External Effects in U.S Procyclical Productivity," *Journal of Monetary Economics* 29; pp. 209-225.

Cairnes, J. E. [1874], *Some Leading Principles of Political Economy Newly Expounded,* New York.

Clague, Christopher [1985], "A Model of Real National Price Levels," *Southern Economic Journal* 51; pp. 998-1017.

Clague, Christopher [1986], "Determinants of the National Price Level: Some Empirical Results," *Review of Economics and Statistics* 68; pp. 320-323.

Clague, Christopher [1989], "The National Price Level: Theory and Estimation: A Comment," *Journal of Macroeconomics* 11; pp. 375-381.

Dixit, Avinash and Victor Norman [1980], *The Theory of International Trade: a Dual General Equilibrium Approach*, Cambridge: Cambridge

University Press.

Ethier, Wilfred [1984], "Higher Dimensional Issues in Trade Theory," Ronald Jones and Peter Kenen (eds) *Handbook of International Economics* Vol. 1, Amsterdam, North Holland.

Falvey, Rodney and Norman Gemmel [1991], "Explaining Service-Price Differences in International Comparisons," *American Economic Review* 81; pp. 1295-1309.

Helpman, Elhanan [1984], "Increasing Returns, Imperfect Markets, and Trade Theory," R. Jones and P. Kenen (eds), *Handbook of International Economics*, North Holland, Amsterdam.

Harrod, Roy F. [1933], *International Economics*, Cambridge Economic Handbooks, London, Nisbet and Cambridge University Press.

Kravis, I, Alan. Heston, and R. Summers [1982], *World Product and Income: International Products of Real Gross Product*, John Hopkins University Press, Baltimore.

Kravis, Ian and Robert Lipsey [1983], "Towards an Explanation of National Price Levels," *Princeton Studies in International Finance*, No. 52.

Kravis, I and R. Lipsey [1988], "National Price Levels and the Price of Tradables and Nontradables," *American Economic Review* 78; pp. 474-478.

Lucas, Robert E., Jr. [1988], "On the Mechanics of Economic Development," *Journal of Monetary Economics* 23; pp. 3-42.

Manning, Richard and James Markusen [1991], "National Product Functions in Comparative Steady-State Analysis," *International Economic Review* 32; pp. 613-624.

Manning, Richard, James Markusen and James Melvin [1993], "Dynamic Nonsubstitution and Long Run Production Possibilities," Horst Herberg and Ngo Van Long ed., *Trade Welfare and Economic Policies*, University of Michigan Press, Anne Arbor.

Neary, J. Peter [1978], "Short Run Capital Specificity and the Pure Theory of International Trade," *Economic Journal* 88; pp. 488-510.

Neary, J. Peter [1985], "International Factor Mobility, Minimum Wage Rates and Factor Price Equalization: A Synthesis," *Quarterly Journal of Economics* 3; pp. 551-570.

Neary, J. Peter [1988], "Determinants of the Equilibrium Real Exchange Rate," *American Economic Review*, 78; pp. 210-215.

Officer, Lawrence [1989], "The Nontraded Price Level: Theory and Estimation," *Journal of Macroeconomics* 11; pp. 351-373.

Ohlin, Bertil [1933], *Interregional and International Trade*, Harvard University Press, Cambridge Mass.

Panagariya, Arvind [1988], "A Theoretical Explanation of Some Stylized Facts of Economic Growth," *Quarterly Journal of Economics*, 103; pp. 509-526.

Romer, Paul [1986], "Increasing Returns and Long-Run Growth," *Journal of Political Economy* 114; pp. 1002-1037.

Samuelson, Paul [1964], "Theoretical Notes on Trade Problems," *The Review of Economics and Statistics* 46; pp. 145-154.

Taussig, Frank [1906], "Wages and Prices in Relation to International Trade," *Quarterly Journal of Economics* 31; pp. 380-403.

Taussig, Frank [1927], *International Trade*, New York.

Woodland, A. [1982], *International Trade and Resource Allocation*, North Holland, Amsterdam.