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We explore the effect of technical progress on the endogenously determined range of non-traded goods by using a Ricardian model with continuum of goods. By defining technical progress on the basis of proportional changes in the relative productivity across sectors, we show that the range of non-traded goods decreases if technical progress is unbiased or if it is biased toward the goods that a country has more comparative advantage.

JEL: F1, O3, D2

Keywords: Non-traded good range, technical progress

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Abstract

We explore the effect of technical progress on the endogenously determined range of non-traded goods by using a Ricardian model with continuum of goods. By defining technical progress on the basis of proportional changes in the relative productivity across sectors, we show that the range of non-traded goods decreases if technical progress is unbiased or if it is biased toward the goods that a country has more comparative advantage.

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1 Introduction

A significant portion of GDP for any economy consists of non-traded goods. Thus, it is imparative to study the production pattern of traded vs non-traded goods. Nevertheless, most of the studies that include non-trade goods treat the number of traded and non-traded goods as exogenously given. See, for example, Jones (1974), Batra (1973), and more recently and Oladi and Beladi (2008)).[1] In a seminal paper, Samuelson (1954) indicated that the existence of transportation cost gives rise to non-traded goods, while Dornbusch et al. (1977) showed how transportation cost determines the ranges of traded and non-traded goods in a Ricardian framework with continuum of goods. According to these earlier findings, a reduction in transportation costs leads to a decrease in the number of non-traded goods. In recent times we have witnessed a significant reduction in transportation cost as well as costs associated with various trade policies. However, somewhat paradoxically, we observe that the GDP share of non-traded goods has risen for developed economies during the same time period.

Figure 1 depicts the shares of non-traded goods as a percentage of GDP for a selected group of developed economies. Such a share has risen from about 45% in 1970 to approximately 58% in 2007

[1] See also Beladi and Batra (2004), Long et al. (2005), Oladi and Beladi (2009), and Chakrabarti and Mitra (2010).

for the United States. Similarly, GDP share of non-traded goods has increased from about 39% and 45% in 1970 for the United Kingdom and France to about 63% and 60% in 2007, respectively. These observations clearly suggest that there should be other factors that influence the production pattern of non-traded goods. Particularly, we focus on technical progress as one such factors.

Insert Figure 1 here

In this paper we use a Ricardian continuum of good model (Dornbusch et al. (1977)) to show that technical progress plays a crucial role in determining the number of non-traded goods and that its effect depends on the bias in technical progress.[2] More specifically, we demonstrate that technical progress reduces the number of non-traded goods if technical progress is unbiased or if it is biased toward the goods that a country has more comparative advantage, where technical progress bias is defined on the basis of proportional change in productivity. This is in contrast to an earlier result in Oladi and Beladi (2010), where the bias in technical progress is defined on the basis of an absolute increase in productivity and is shown that the range of non-traded goods will increase if technical progress is unbiased. This latter definition of unbiased technical progress implicitly assumes that technological change is additive. While such a definition is commonly used in the literature, it implies that sectors for which a country has lower comparative advantage will enjoy a higher proportional relative productivity increase. Hence, in the current paper we reconsider the definition of biased versus unbiased technical progress and its implications for non-traded good production pattern.

Our paper is also related to a strand of literature that deals with the effects of technical progress on the real exchange rates, known as Balassa-Samuelson effect (Balassa (1964) and Samuelson (1964)). It suggests that the productivity growth differences between traded and non-traded goods explain the real exchange rate movements. For more recent studies on Balassa-Samuelson effect see Chironi and Melitz (2005).

The structure of the rest of the paper is as follows. We present our framework in Section 2. Section 3 draws the analysis and results. We offer some concluding remarks in Section 4.

[2]Ricardian continuum of good model provides a surprisingly reasonably tractable and yet rich framework to study various issues in trade. As an example, see Marjit and Beladi (2009).

2 The model

Drawing heavily upon Oladi and Beladi (2010), consider a two-country Ricardian world with a continuum of goods indexed by $z \in [0, 1]$. Let $a(z; \beta)$ and $a^*(z; \beta^*)$ be the labor requirement to produce one unit of good z in the home and foreign countries, respectively, where β and β^* are the productivity parameters in these two countries. We assume throughout this paper that the initial values of these parameters are equal to unity and that the technical progress takes place only in the home country. Thus, to simplify our notation we drop β^* from the unit labor requirement for the foreign country. Let also $A(z; \beta) \equiv a^*(z)/a(z; \beta)$ be the relative labor productivity for the home country. We further assume that $\partial A/\partial z < 0$, $\partial A/\partial \beta > 0$, i.e., the relative productivity is decreasing in the index of goods for the home country and that an increase in productivity parameter for home increases the relative productivity in the home country.

We assume identical iceberg transportation cost in both direction for all goods. The home country produces any good whose unit cost is less than or equal its foreign unit cost after adjusting for transportation costs. Thus, the home country produces good z if:

$$\omega \equiv \frac{w}{w^*} \leq \frac{A(z; \beta)}{g} \tag{1}$$

where w and w^* are the wage rates in the home and foreign countries, respectively. On the other hand, the foreign country produces any good z if:

$$\omega \geq gA(z; \beta) \tag{2}$$

For the borderline goods the inequalities in equations (1) and (2) turn into equalities. Therefore, for any given relative wage ω these two equations determine the ranges of traded and non-traded goods. For instance, if the relative wage is $\bar{\omega}$, home country produces all goods $z \in [0, \bar{z}]$ and imports all goods $z \in (\bar{z}, 1]$, where $\bar{z}$ satisfies equation (1). Similarly, the foreign country produces all goods $z \in [\bar{z}^*, 1]$ and imports all goods $z \in [0, \bar{z}^*)$, where $\bar{z}^*$ satisfies equation (2). Thus, all goods $z \in [\bar{z}^*, \bar{z}]$ are non-traded goods.

To complete the model, consider the demand side of these economies. Let us assume that all consumers in both countries have identical Cobb-Douglas preferences.[3] Let $b(z)$ be the expenditure share of good z and $\lambda(\bar{z})$ ($\lambda^*(\bar{z}^*)$) be the fraction of home (foreign) country's income spent on home (foreign) made goods, including the non-traded goods, i.e.:

$$\lambda(\bar{z}) = \int_0^{\bar{z}} b(z)dz \tag{3}$$

$$\lambda^*(\bar{z}^*) = \int_{\bar{z}^*}^1 b(z)dz \tag{4}$$

Moreover, trade balance requires that:

$$(1 - \lambda(\bar{z}))wL = (1 - \lambda^*(\bar{z}^*))w^*L^* \tag{5}$$

where L and L^* are the fixed endowments of labor in the home and foreign countries, respectively. By simultaneously solving equations (1), (2) and (5), we get the equilibrium values of our endogenous variables ω, $\bar{z}$ and $\bar{z}^*$. For mathematical simplicity we assume that $L = L^*$ with an initial value of $\omega = 1$.

3 The analysis

We now analyze the effect of technical progress on the range of traded and non-traded goods. In Oladi and Beladi (2010), we defined technical progress as the change in productivity parameter and therefore a shift in schedule A. Then, we showed (among other things) that the number of non-traded goods will rise if technical progress is unbiased. We defined the bias in technical progress on the basis of absolute change in relative productivity. Although such a definition of technical progress bias is not uncommon, it is more appealing to consider any bias in technical progress on the basis of proportional changes in relative productivity across sectors. Hence in the present paper we define the proportional change in productivity as $\delta(z) \equiv (\partial A/\partial\beta)/A$, where technical progress is unbiased if $\delta(z) = \sigma$ for constant $\sigma > 0$, implying that the proportional increase in productivity is the same for all goods. Similarly, technical progress is increasingly (decreasingly) biased if $\delta(z)$ is increasing (decreasing) in z. That is, if the higher indexed goods experience higher (lower)

[3] The assumption of identical Cobb-Douglas preferences has been commonly used in continuum of good trade models (see, for example, Dornbusch et al. (1977, 1980), Marjit and Beladi (2009), among others). In addition, we assume social utility function á la Samuelson (1956) where utility function depends on aggregate consumption levels.

proportional increase in productivity than the lower (higher) indexed goods, then the technical progress is increasingly (decreasingly) biased.[4] We now proceed with our analysis.

Totally differentiate equations (1), (2) and (5) to obtain:

$$[1-\lambda(\bar{z})]\frac{d\omega}{d\beta}-\lambda'(\bar{z})\frac{d\bar{z}}{d\beta}+\lambda^{*'}(\bar{z}^*)\frac{d\bar{z}^*}{d\beta}=0 \tag{6}$$

$$\frac{d\omega}{d\beta}-\frac{1}{g}\frac{\partial A}{\partial z}\frac{d\bar{z}}{d\beta}=\frac{A(\bar{z})}{g}\delta(\bar{z}) \tag{7}$$

$$\frac{d\omega}{d\beta}-g\frac{\partial A}{\partial z}\frac{d\bar{z}^*}{d\beta}=gA(\bar{z}^*)\delta(\bar{z}^*) \tag{8}$$

By solving the system of equations (6)-(8), we get:

$$\frac{d\omega}{d\beta}=\frac{-1}{\Omega}[\lambda'(\bar{z})A(\bar{z})\delta(\bar{z})\frac{\partial A}{\partial z}-\lambda^{*'}(\bar{z}^*)A(\bar{z}^*)\delta(\bar{z}^*)\frac{\partial A}{\partial z}] \tag{9}$$

$$\frac{d\bar{z}}{d\beta}=\frac{-1}{\Omega}\left([1-\lambda(\bar{z})]A(\bar{z}^*)\frac{\partial A}{\partial z}g^2\delta(\bar{z})+\lambda'(\bar{z})gA(\bar{z}^*)[\delta(\bar{z}^*)-\delta(\bar{z})]\right) \tag{10}$$

$$\frac{d\bar{z}^*}{d\beta}=\frac{-1}{\Omega}\left([1-\lambda(\bar{z})]A(\bar{z}^*)\frac{\partial A}{\partial z}\delta(\bar{z}^*)-\lambda'(\bar{z})gA(\bar{z}^*)[\delta(\bar{z}^*)-\delta(\bar{z})]\right) \tag{11}$$

where $\Omega=[1-\lambda(\bar{z})](\partial A/\partial z)^2-g\lambda'(\bar{z})\partial A/\partial z+(\lambda^{*'}(\bar{z}^*)/g)\partial A/\partial z>0$. Note from equations (3) and (4) that $\lambda'(\bar{z})>0$ and $\lambda^{*'}(\bar{z}^*)<0$. Moreover, equations (1) and (2) imply that at equilibrium $A(\bar{z};.)/g=gA(\bar{z}^*,.)$. It is clear from equation (9) that $d\omega/d\beta>0$. Next, use equations (10) and (11) to get:

$$\frac{d\bar{z}}{d\beta}-\frac{d\bar{z}^*}{d\beta}=-\frac{A(\bar{z}^*)}{\Omega}\left([1-\lambda(\bar{z})][g^2\delta(\bar{z})-\delta(\bar{z}^*)]\frac{\partial A}{\partial z}+2\lambda'(\bar{z})g[\delta(\bar{z}^*)-\delta(\bar{z})]\right) \tag{12}$$

Clearly, the sign of the right hand side expression in equation (12) crucially depends on the technical progress bias. Thus, we have the following result.

Proposition 1. *The relative wage rate increases in the home country if it experiences technical progress. Moreover, the number of non-traded goods decreases if the technical progress is decreasingly biased or if it is unbiased.*

Let us assume that the relative productivity increases in home country. Initially, the relative wage increases to the full extent of the rise in relative productivity. On the other hand, such a

[4] Here we define sectoral bias rather than factoral bias as in Jones (1996). See also Bond (2005).

rise in productivity results in an increase in the range of home-made goods. In turn, the latter causes a reduction in home relative productivity (a movement along $A(z;.)$) and therefore relative wage, offsetting some of the initial increase in relative wage. Overall, both the relative wage and home-made good range would increase. If technical progress is biased toward the goods for which the home country has more comparative advantage or if it is unbiased, then the home country experiences a greater increase in the range of exported goods than the decrease in its range of imported goods. Consequently, the non-traded good range falls. This result is in sharp contrast to Oladi and Beladi (2010), where the bias in technical progress is defined on the basis of absolute change in relative productivity. Accordingly, the high indexed goods that the home country has lower comparative advantage would experience a higher proportional change in productivity even though the absolute change in relative productivity is the same across all sectors.

It should be noted that the range of non-traded goods would change after technical progress, so that some non-traded goods become tradable while some tradeable goods become non-tradeable. That is, borderline goods for both countries shift. Specifically, the borderline good will be a higher indexed goods for both countries. Therefore, the range of non-traded goods strictly changes. The above proposition states that the number of non-traded goods will decrease because the index of borderline good for the home country increases less than that of foreign country.[5]

Now assume that technical progress is increasingly biases. It follows from the definition of increasingly biased technical progress that $\delta(\bar{z}) - \delta(\bar{z}^*) > 0$. Thus, the sign of equation (12) will be positive if g is sufficiently large. That is, the effect of such a type of technical progress on non-traded goods depends also on the size of transportation cost. Therefore, we formally conclude the following proposition.

Proposition 2. *The number of non-traded goods increases if technical progress is increasingly biased and the transportation cost is sufficiently small.*

If the transportation cost is small enough (i.e., g is large), then the range of exported goods for the home country rises while the imported good range falls. However, the latter is greater the former. This is due to the fact that the latter range of goods experience a greater percentage increase in their relative productivity compared with the latter range in the home country. In

[5]We thank an anonymous reviewer who brought this to our attention.

other words, technical progress is proportionally lower for the goods that the country has more comparative advantage than for the goods for which the country has less comparative advantage. Thus, such a biased technical progress affects the imported goods more than the exported goods. Therefore, the home country experiences a smaller increase in the range of exported goods than that the decrease in the range of imported goods, resulting in an increase in the range of non-traded goods (given that transportation cost is sufficiently small). The second condition of the above proposition is important. To see this, , assume on the contrary that the transportation cost is large enough such that $g^2\delta(\bar{z}) < \delta(\bar{z}^*)$. Then, the first expression in parentheses in equation (12) will be positive. This can result in $d\bar{z}/d\beta < d\bar{z}^*/d\beta$. In this case, when transportation cost is sufficiently large, the effect of technical progress biased toward the (potential) import competing sectors will be dampened by high transportation cost. Thus, the number of imported goods falls less than the increase in exported goods. Therefore, the number of non-traded goods can fall, restoring the results of Proposition 1.

As in Dornbusch et al. (1977, 1980) we have used a social utility function á la Samuelson (1956) where utility function depends on aggregate consumption levels.[6] This approach is widely used in neoclassical international trade literature. We also assume Cobb-Douglas preferences. This results in constant expenditure share for all goods and makes the demand side of our framework simple and tractable. This assumption is also widely used in economics literature (particularly in continuum of good model and its extensions).[7]

4 Conclusion

By utilizing a two-country Ricardian model with continuum of goods (Dornbusch et al. (1977)), we examined the effects of technical progress on the range of non-traded goods that arise due to the existence of transportation cost. We re-defined the definition of bias in technical progress, whereby technical change is said to be (cross-sectorally) unbiased if all production sectors of an economy experience the same proportional technical improvement. As our main result, we showed that the

[6] We are grateful to an anonymous referee for bringing this point to our attention.

[7] Another widely used alternative formulation of the demand side is to assume C.E.S. utility function as in Melitz (2003). Melitz (2003) showed that, as an application of two stage budgeting, the aggregate consumption quantity index is $C = [\int_0^1 c(z)^\theta dz]^{1/\theta}$. Similarly, the price index is given by: $P = [\int_0^1 p(z)^{1-\sigma} dz]^{1/(1-\sigma)}$, where $\sigma = 1/(1-\theta)$. It can then be shown that the expenditure share for any good $z \in [0,1]$ is $b(z) = (p(z)/P)^{1-\sigma}$. Thus, the expenditure shares can change.

range of non-traded goods will fall if technical progress takes place in one country and if such progress is either unbiased or biased toward the goods for which the country has more comparative advantage. On the other hand, we illustrated that if technical progress is biased toward the goods that a country has more comparative disadvantage and if transportation cost is sufficiently small, then the range of non-traded goods will increase.

Our set-up and definition of bias in technical progress can be used and extended to study the effects of biased technical progress on prices along the lines of Balassa-Samuelson effect. Another, perhaps less appealing extension of our paper is to use factor endowment continuum of good model (Dornbusch et al. (1980)). Lastly, not the least, one can empirically test our propositions.

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Figure 1: Non-trade good share of GDP