Diskussionspapiere
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Discussion Paper No. 95

Technical Progress, Innovation and Product Differentiation in a Ricardian Trade Model with a Continuum of Goods

by
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Abstract*

The Ricardian model is often considered of limited use and scope for the explanation of trade flows, as it cannot account for various important aspects of real world trade such as innovation goods or intra-industry trade. This is basically due to the fact that the Ricardian model is usually presented in the two-good, two-country form. However, using a Ricardian model with a continuum of goods does not only allow an analysis of the effects of technical progress or the production of new, innovative goods. It is also possible to explain intra-industry trade solely within the general setting of a Ricardian model.

* I wish to thank Fritz Franzmeyer, Michael Kohlhaas, Dieter Schumacher, Florian Straßberger and Christian Weise for valuable discussions and helpful comments in the preparation of this paper. Remaining errors in the paper rest with the author.

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1 Introduction

The basic relationship between international trade and technology can be examined by means of two approaches. A general Ricardian trade model provides information as to the optimal international division of labour and the wage differential between the home and foreign country. The assumption on the supply side is that the technological capability of the countries is different which results in differing productivity rates in the production of a good. Differences between the countries are, therefore, only based on the technology differences. In contrast to the neo-classical model, in which the necessary technology for the production of a good is freely available everywhere, the differing international availability of technology in the Ricardian model is the cause of differing labour productivity. The model does not attempt to explain the emergence of those differences, though. This is a subject of the second group of approaches in which, *inter alia*, the technology-gap theory[1], the product cycle theory[2] and the considerations as to the importance of innovations[3], technology transfer[4] and future markets[5], feature. This discussion paper interprets these theories into a formal Ricardian trade model and analyses the interaction of technology, trade and wage levels on the one hand, and the aforementioned explanations as to the reasons for comparative advantages on the other.

This discussion paper examines the basic relationship between international trade and changes in the technological capability of the home country relative to that of a foreign country. The Ricardian model developed by Dornbusch, Fischer and Samuelson (1977) is employed to do this. The use of a continuum of goods greatly simplifies the analysis of trade and welfare effects of technical progress or of

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[1] cf. Posner (1961) and Hufbauer (1966).

[2] cf. Vernon (1966, 1979) and Hirsch (1967).

[3] cf. Schumpeter (1939,1968), Mensch (1975) and Freeman, Clark and Soete (1982).

[4] cf. Krugmann (1979) and Klodt (1990).

[5] cf. Lafay (1976), Nussbaum (1984) and Seitz (1990).

technology transfers in comparison to the traditional explanations[6]. Furthermore, availability goods and differentiated products can be incorporated into the Ricardian model - something which is not possible with traditional approaches.

2 The Ricardian Model with a Continuum of Goods

It would be wrong to assume that the Ricardian model developed by Dornbusch, Fischer and Samuelson (DFS model) is widely known, so it will now be briefly described[7]. Following that, the influence of process innovation which increases productivity and of technology transfer is analysed.

2.1 The Supply Side of the Model

The DFS model begins with the following assumptions. In both the home and foreign country goods are produced - as in all Ricardian models - with one production factor, namely labour[8]. Both countries can produce all goods, but different technology is employed. This has the result that the unit labour requirement (a_1, ..., a_n) of the home country could be different to that of the foreign country (a^*_1, ..., a^*_n) for every good which could in principle be produced. In accordance with these assumptions, the goods are indexed in such a way that the relative unit labour requirements are ranked in order of diminishing home country comparative advantage.

$$a_1^*/a_1 > \ldots > a_i^*/a_i > \ldots > a_n^*/a_n$$

---

[6] The model has very much increased in popularity in recent years and has been modified and extended by various authors. It is now regarded as the **formal** standard model in explaining foreign trade on the basis of technological gaps. cf.: Cimoli (1988, 1991), Cimoli and Soete (1992), Collins (1985), Dosi and Soete (1983), Dosi, Pavitt and Soete (1990), Krugman (1979, 1986) and Wilson (1980).

[7] The description is heavily based on that of Dornbusch, Fischer and Samuelson; readers who are already familiar with the model, could miss out this section.

[8] This can also be interpreted as a bundle of production factors in fixed combination.

In much the same way as in the case of a limited number of goods just discussed, when the model is extended to a continuum of goods, products can also be ranked in order of diminishing home country comparative advantage and indexed on an interval between 0 and 1. On each point of the interval, therefore, there is an associated product z, and for each product there is an unit labour requirement in both of the countries, a (z) and a^* (z). The international productivity differential for good z is therefore defined as:

$$A\ (z) \equiv \frac{a^*(z)}{a\ (z)} \quad A'(z) < 0 \tag{1}$$

The negative sign of the first derivation shows that the goods along the interval 0, 1 are ranked according to diminishing home country lead in productivity. Accordingly, A (z) is shown in figure 1 as a downward sloping schedule.

Which goods are now produced in the home country and which are produced abroad depends on the relationship between the domestic and foreign wage level. The unit cost for a certain good z at home equals wa (z), where w is the wage rate for domestic labour. The unit costs of the foreign country for the same good z are w^*a^* (z). The home country will therefore produce all those goods for which the domestic unit labour costs are less than foreign unit labour costs or for which the relative productivity of labour is greater than the relative wage rate. Therefore, a certain good z will be produced at home if

$$a\ (z)\ w \leq a^*\ (z)\ w^* \tag{2}$$

or

$$\frac{w}{w^*} \leq \frac{a^*\ (z)}{a\ (z)}$$

or

$$A\ (z) \geq \frac{w}{w^*} \tag{2'}$$

The international relative wage rate or the relative domestic wage rate ω is defined as in equation (3)

$$\omega \equiv w/w^* \tag{3}$$

If ž is defined as the good for which the production costs at a given relative wage, ω, are equal in both countries, then home produced goods (= domestic exports) fall into the following category:

$$0 \leq z \leq \check{z}\ (\omega) \tag{4}$$

Conversely, the foreign country will produce those goods which fall into the following category:

$$\check{z}\ (\omega) \leq z \leq 1 \tag{4'}$$

The threshold value of function A (z) or the borderline good ž is defined in equation 5,

$$\check{z} = A^{-1}\ (\omega) \tag{5}$$

whereby A^{-1} (ω) is the inverse function of A (z).

An increase in the relative wage rate has the result that the home country can no longer produce those goods which have only a modest productivity lead relative to abroad more cost effectively then the foreign country can. Production is transferred to the foreign country. Just how many goods are effected depends on the extent of the edge on productivity[9] and the wage increase at home relative to that abroad.

[9] This is reflected in the gradient of the A(z) curve. The steeper the curve, the greater the lead or backwardness in productivity from good to good respectively in relation to abroad.

Figure 1

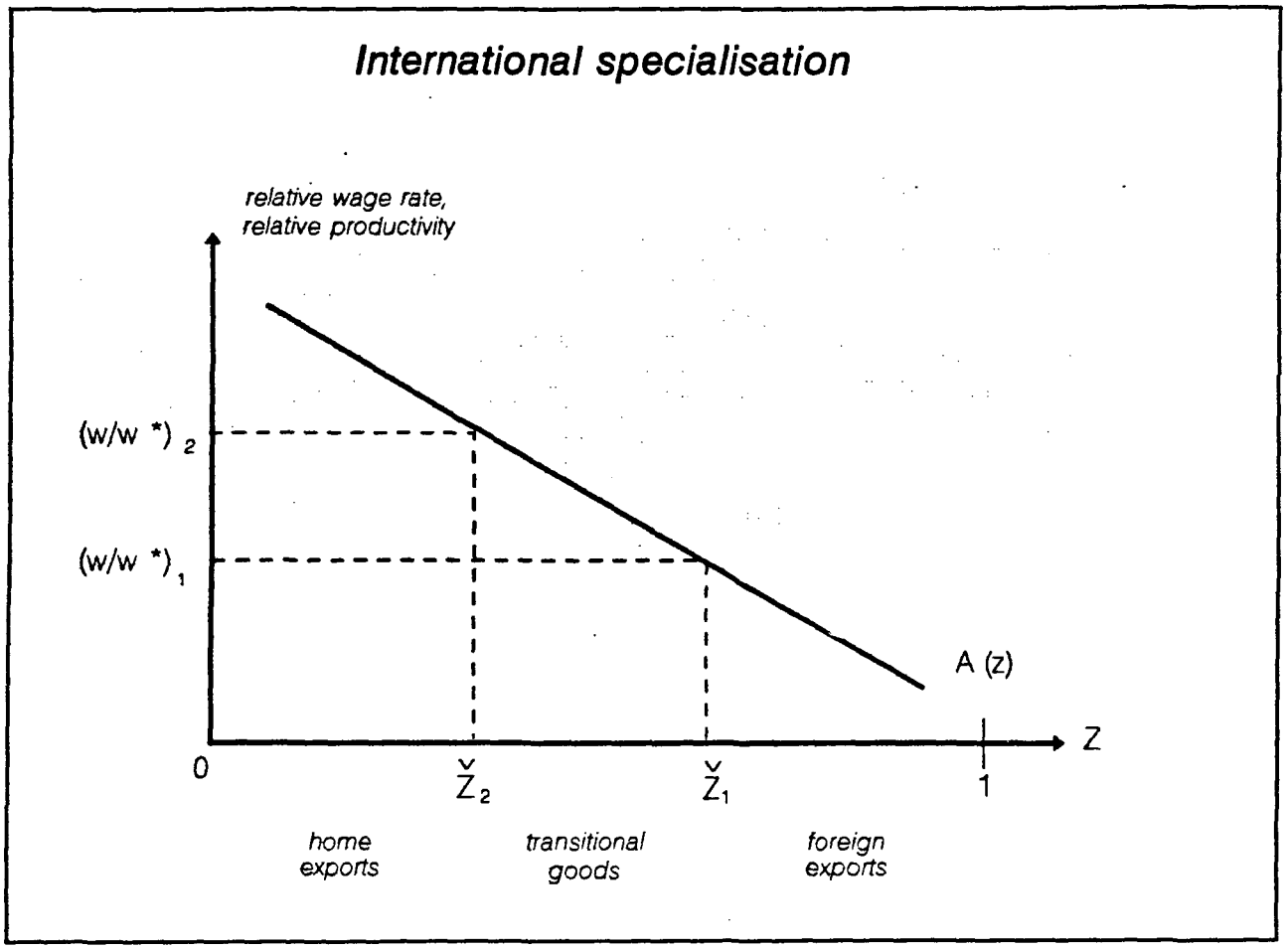


Figure 1 presents this fact graphically. With a given relative wage rate of $(w/w^*)_1$, all goods to the left of $\check{z}_1$ are produced at home and exported from there, all goods right of $\check{z}_1$ are produced abroad. If the relative wage rate rises from $(w/w^*)_1$ to $(w/w^*)_2$, then production of the goods lying between $\check{z}_1$ and $\check{z}_2$ transfers from the home co ıntry to abroad - the goods become transitional goods.

In a Ricardian model, the price of a good is determined by the unit labour costs. The relative price of a good z in terms of some other good z' is equal to the ratios of the domestic unit labour costs (if both goods are produced at home):

$$\begin{aligned} P(z) / P(z') &= wa(z) / wa(z') \\ &= a(z) / a(z'); \\ z \leq \check{z},\ z' &\leq \check{z} \end{aligned} \qquad (6)$$

The relative price of a domestic good z in terms of a foreign good z'' is as following:

$$
\begin{aligned}
P(z) / P(z'') &= wa(z) / w^{*} a^{*}(z'') \\
&= \omega a(z) / a^{*}(z''); \\
z &< \check{z} < z''
\end{aligned}
\qquad (7)
$$

The supply side of the model is thereby fully defined. For every relative wage rate there is an efficient international division of labour which is determined by the borderline good ž (ω). Furthermore, the relative wage rate determines the relative price as well (see equations 6 and 7). The resulting specialisation pattern is efficient; the world as a whole is on its production possibility curve.

2.2 The Demand Side of the Model

To be able to determine the efficient international division of labour (i.e. the borderline good ž) the relative wage rate must be determined in addition to the productivity differential resulting from technology. This model assumes that consumers of the world spend a constant and positive share of their income on each good. Consequently, each good z is subject to a given share b_i - identical in both countries - of total demand (uniform Cobb-Douglas utility functions or uniform homothetic demand). By analogy with the many-good case in which the budget shares are defined as:

$$
b_i = P_i C_i / Y \qquad b_i = b_i^{*}
$$

$$
\sum_{1}^{n} b_i = 1
$$

the demand side for a continuum of goods and a given b (z) can be described as following:

$$
\begin{aligned}
b(z) &= P(z) C(z) / Y > 0 \\
b(z) &= b^{*}(z) \\
\int_{0}^{1} b(z)\, dz &= 1
\end{aligned}
\qquad (8)
$$

Y denotes total income, C (z) the demand for good z and P is the price of good z. It follows that the share of the domestic and foreign income which is allocated to home produced goods is an increasing function of the threshold value ž, i.e. increases with a growing number of products.

The share of total income which is spent on goods in which the home country has a comparative advantage is defined as:

$$\delta(\check{z}) \equiv \int_0^{\check{z}} b(z)\,dz > 0 \qquad (9)$$
$$\delta'(\check{z}) = b(\check{z} > 0)$$

As was the case for the supply side, the interval (0,ž) denotes the range of goods in which the home country has a comparative advantage. Since the share δ (ž) of world income is spent on domestically produced goods, it follows that the share of world income which is spent on foreign produced goods is the complement to 1.

$$1-\delta(\check{z}) \equiv \int_{\check{z}}^{1} b(z)\,dz \qquad (9')$$
$$0 \leq \delta(z) \leq 1$$

2.3 Efficient International Division of Labour and Equilibrium Relative Wage Rate

To derive the equilibrium relative wage rate and the relative good prices associated with an efficient international division of labour, we next describe the conditions for market equilibrium. Total expenditure on home produced goods is δ (ž) of total world income. As labour is the only production factor in this model, all of this expenditure passes to domestic workers in the form of wages. Therefore, world income can be defined as total domestic wages plus total foreign wages ($wL + w^*L^*$). The domestic goods market is then in equilibrium when the domestic labour

income wL, in other words, the value of home produced goods, equals world expenditure on domestically produced goods:

$$wL = \delta\ (\check{z})\ (wL + w^{*}L^{*}) \tag{10}$$

Rearranging equation 10 so that the relative domestic wage rate $w/w^{*} = \omega$ is on the left gives:

$$\omega = \frac{\delta\ (\check{z})}{1 - \delta\ (\check{z})}\ (L^{*} / L) = B\ (\check{z};\ L^{*} / L) \tag{10'}$$

The B ( ) curve represents the demand side in the model (cf. figure 2). In connection with equation 9 the result is that the B ( ) curve starts at zero and approaches infinity as ž approaches 1. The upward slope of the B ( ) curve can be economically explained as following: if the number of home produced goods increases with a constant relative wage rate, then the demand for domestically produced goods (labour) increases; at the same time, the demand for foreign goods (labour) falls. In order to bring the domestic goods market back into equilibrium, then, with a given supply of labour at home and abroad, there has to be an increase in the domestic wage rate relative to the foreign wage rate in order to combat the excess demand for domestic products. The demand curve is consequently an increasing function of the number of produced goods and relative wage rates which is depicted in figure 2 as the B (z,L*/L) curve. The larger the foreign country in comparison to the home country, the greater the demand of the foreign country for goods from world production, and the further left the B ( ) curve will lie. Large countries produce and export a wide variety of goods. As this also includes a high proportion of goods which are produced with a lower rate of labour productivity, the average productivity is lower than in smaller countries which are limited to a small variety of goods which are produced with a relatively higher rate of labour productivity. Consequently, the relative wage rate in smaller countries is c.p. higher than in larger countries.

Alternatively, the B ( ) curve can also be interpreted as a trade balance equilibrium. If equation 10 is formulated as stated, then the trade balance form of this equation results:

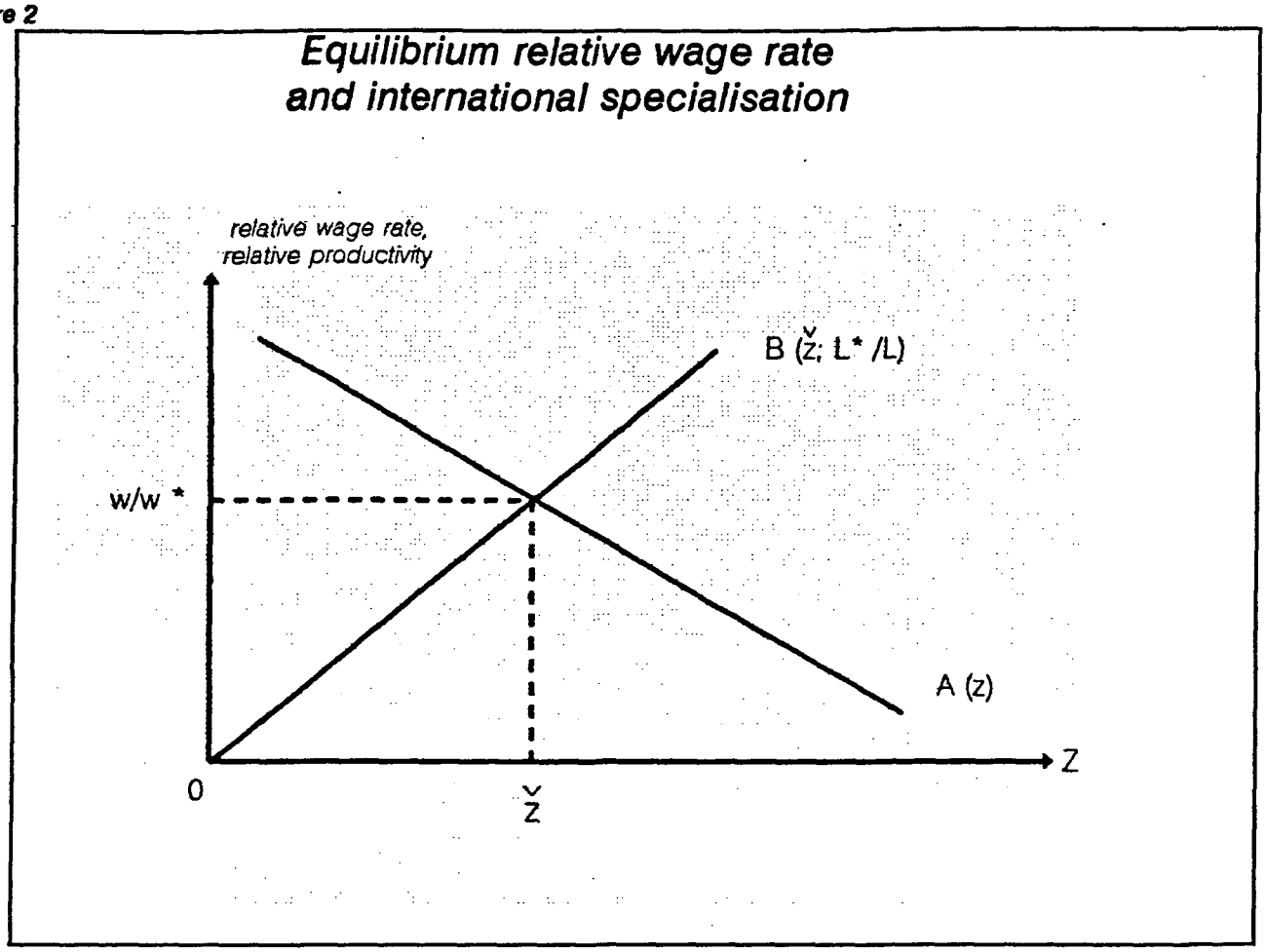
$$[1 - \delta(\check{z})]\, wL = \delta(\check{z})\, w^{*} L^{*} \qquad (10'')$$

Equation 10'' implies that the trade balance is in equilibrium when imports are equal to exports. In this interpretation the B ( ) curve is upward sloping because an increase in the number of home produced goods with a constant relative wage rate would reduce imports and increase exports. The resulting trade imbalance would then have to be corrected by an increase in the domestic wage rate relative to abroad. This would increase domestic demand for imports and reduce exports and hence bring the balance-of-trade back into equilibrium.

The supply and demand sides are therefore defined in the model. The A (z) function describes what division of labour will result between home and abroad with a given relative wage rate, ω. The B (z,L^{*}/L) function describes which relative wage ω will result with a given pattern of international division of labour. Combine these two pieces of information and the relative wage rate and the efficient international specialisation can be simultaneously determined through the interaction of supply and demand. If equation 5, which depicts the conditions for efficient specialisation, is used as a function of the relative wage rate in equation 10' then the solution is that of a relative wage rate whereby the international division of labour is efficient, there is balance-of-trade equilibrium and full employment is attained:

$$\dot{\omega} = A(\check{z}) = B(\check{z};\, L^{*} / L) \qquad (11)$$

Figure 2



The equilibrium relative wage rate $\dot{w}$, as defined in equation 11, is attained at the intersection of the A ( ) and B ( ) curves in figure 2. The borderline good ž divides - as before - the total range of goods into two groups. All goods between 0 and ž are produced in the home country and exported. All goods to the right of ž are produced abroad and imported from there[10].

This model shows that both the equilibrium relative wage rate and the efficient structure of international specialisation are determined by the technology employed, demand and the relative size of the country[11].

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[10] After the equilibrium relative real wage rate is determined with equation 11, the relative prices of goods can be determined by using equations 6 and 7.

[11] The relative size is determined by the relative labour force.

3 Technical Progress

Technical progress appears in various forms. It can, on the one hand, come about in the form of product and process innovation itself or it can be transferred by the exchange of technology. This section looks at process innovations and technology transfers which increase productivity - product innovations are subsumed under availability goods and looked at in section 4.

3.1 Productivity Growth through Process Innovation

The impacts of productivity growth through process innovation on international specialisation, real income and the relative wage rate can be examined with the DFS model. In doing so, it is assumed that productivity growth through process innovation finds expression in a uniform increase of labour productivity for all goods in one of the two countries. In this case it is assumed that productivity increases in the foreign country. Due to the fact that the increase in productivity effects all goods, the foreign unit labour requirement in each industry (or for every good) falls by the same percentage x[12]. The foreign country can now offer some goods more cost effectively at the prevailing relative wage rate than the home country, and production of those goods shifts to the foreign country. The demand for foreign labour also increases thereby, however, which then makes the relative wage rate of the foreign country rise and the shift in production does not take place to the same extent as it would if there were a constant relative wage rate. The net effect is that the home country produces a smaller variety of export goods and its welfare worsens relatively speaking because of a decrease in the relative wage rate (= factoral terms of trade).

[12] If technical progress, which was different for each good, were to be included, then the goods would have to be re-numbered.

Figure 3

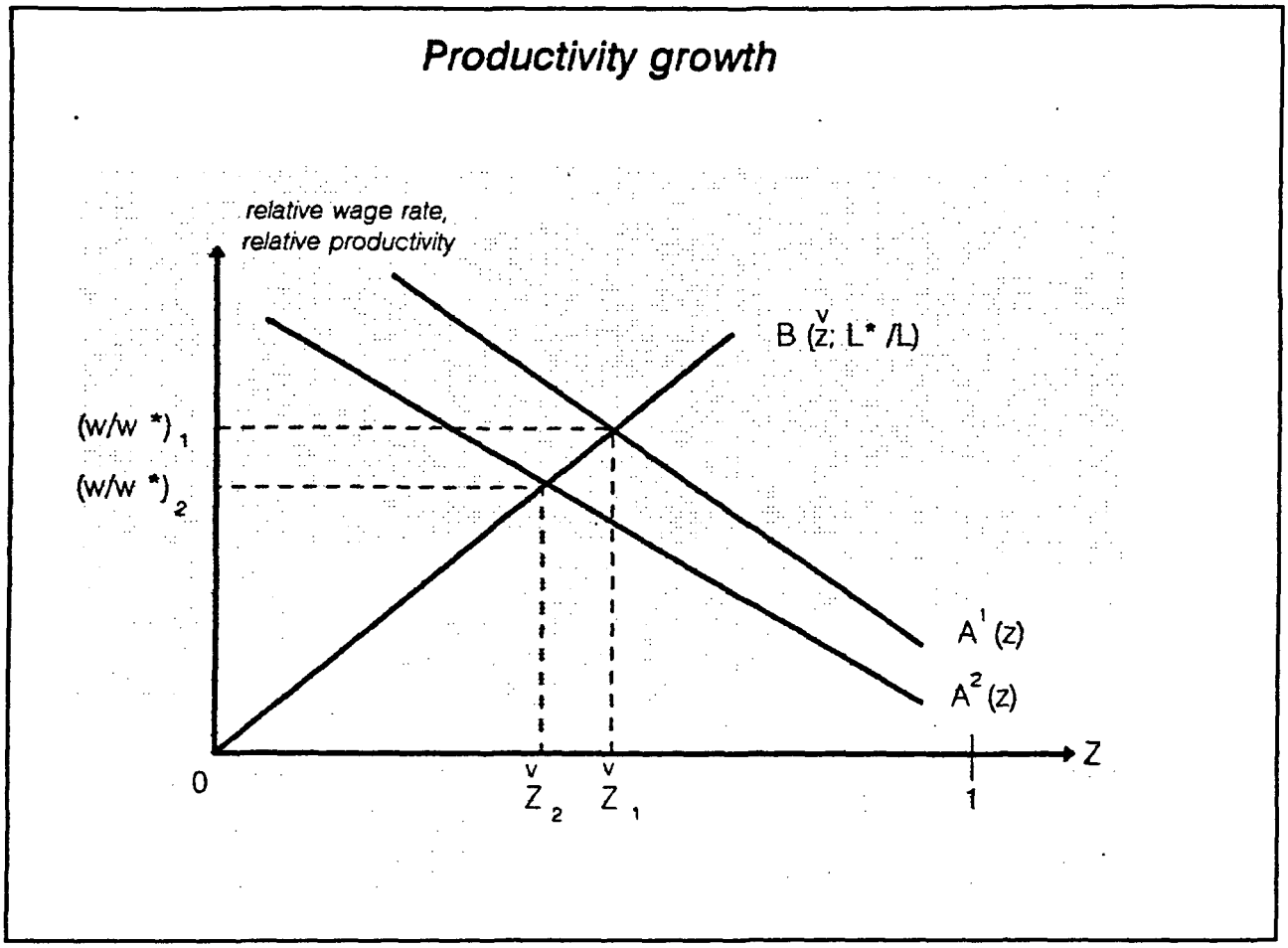


Figure 3 illustrates this situation. The A^1 (z) curve shifts downwards by the value of the percentage increase in productivity[13]. This shift is depicted in figure 3 by the transition of curve A^1 (z) to curve A^2 (z). The relative domestic wage rate falls from $(w/w^*)_1$ to $(w/w^*)_2$ and the transitional goods between $\check{z}_1$ and $\check{z}_2$ will be produced in the foreign country.

Welfare Effects of Technical Progress

Because the domestic wage rate has fallen relative to that in the foreign country, one could be tempted to assume that productivity growth abroad is only of use to the foreign country. This is not the case, however - on the contrary. Although the relative position of the home country has worsened, on a whole it does profit

[13] The rotation of the A curve is due to the equal percentage increase in productivity for all goods.

because international trade ensures that the price decreasing effect of productivity growth is also transferred to the home country.

As figure 3 shows, the relative wage rate in the home country does not fall as sharply as the foreign unit labour requirement (^ depicts the rate of change:)

$$\hat{\omega} > \hat{a}^{*}(z) \quad \text{or} \quad \frac{(w / w^{*})^{1}}{(w / w^{*})^{2}} > \frac{a^{1^{*}}(z)}{a^{2^{*}}(z)} \tag{12}$$

This means that foreign goods (in terms of units of domestic labour) are now cheaper. As is also to be seen in figure 3, the home produced goods can be divided into three groups:

Export goods	$(z < \check{z}_2)$:	Goods which are exported in both situations
Import goods	$(z > \check{z}_1)$:	Goods which are imported in both situations
Transitional goods[14]	$(\check{z}_2 < z < \check{z}_1)$:	Goods which are originally exported and afterwards are imported

In this way, the change in real wages can be examined in terms of the prices of these three product groups. The domestic real wage (in terms of export good prices) remains unchanged, because the domestic price for export goods have changed proportionally to the domestic wage rate.

$$p_1(z) = w_1 \cdot a(z)$$

$$p_2(z) = w_2 \cdot a(z)$$

Because a (z) is unchanged, then

$$\left(\frac{w}{p(z)}\right)_1 = \left(\frac{w}{p(z)}\right)_2$$

[14] In the case of this product group, the comparative advantage is transferred from the home country to the foreign country because of the increase in productivity.

in other words, in terms of export good prices, the domestic real wage has remained constant. The domestic real wage, in terms of import good prices, increases. Because the price of import goods is dependent upon the foreign wage rate then:

$$p\ (z) = w^*\ a^*\ (z)$$

or

$$\frac{w}{p\ (z)} = \left(\frac{w}{w^*}\right) \cdot \left(\frac{1}{a^*(z)}\right)$$

Because the relative wage rate of the home country does not fall as sharply as the foreign unit labour requirement (see equation 12) then:

$$\left(\frac{w}{p\ (z)}\right)_2 > \left(\frac{w}{p\ (z)}\right)_1$$

in other words, in terms of import good prices the domestic real wage has increased. The domestic real wage also increases in view of transitional goods. Before the home country lost its comparative advantage in these goods, transitional goods were domestically produced export goods and the real wage:

$$\left(\frac{w}{p\ (z)}\right)_1 = \frac{1}{a\ (z)}$$

Now that the transitional goods are imported, the price and real wage emerge analogous to import goods: now the relative wage rate of the home country does not fall as sharply as the foreign unit labour requirement ratio though. Thereby

$$\left(\frac{w}{w^*}\right) \cdot \frac{1}{a^*\ (z)} = \left(\frac{w}{p\ (z)}\right)_2 > \left(\frac{w}{p\ (z)}\right)_1 = \frac{1}{a\ (z)}$$

In terms of prices for transitional goods the domestic real wage has increased likewise.

It can be shown that the real wage in the foreign country has increased in terms of prices of all three product groups[15]. In terms of export goods, its real wage rises because of the increase in productivity; its real wage in terms of import goods rises because of an increase in the relative domestic wage rate. The transitional goods, which were produced at home first of all and now in the foreign country, would have - in terms of units of foreign labour - become cheaper, even if production had not been transferred abroad. Because this has happened, however, it has to be even cheaper to produce the goods in the foreign country.

CHANGE IN REAL WAGES DUE TO PRODUCTIVITY GROWTH ABROAD

(in terms of units of export, import and transitional goods)

	in prices of export goods	in prices of import goods	in prices of transitional goods
home	constant	↑	↑
foreign	↑	↑	↑

The following can thus be concluded: an increase in productivity increases the relative wage rate in the country in which there was productivity growth; on the whole the other country also profits because real wage increase, in terms of prices of import and transitional goods, and stays the same in prices of export goods. This absolute improvement in the real wage can, in end effect, be traced back to the fact that the other country also profits from productivity growth because of international trade.

[15] cf. Krugman (1986, p. 161).

3.2 Technology Transfer

Countries can not only produce technology, they can purchase it externally as well. This section analyses the impacts of being a country supplying technology and of being one which receives technology.

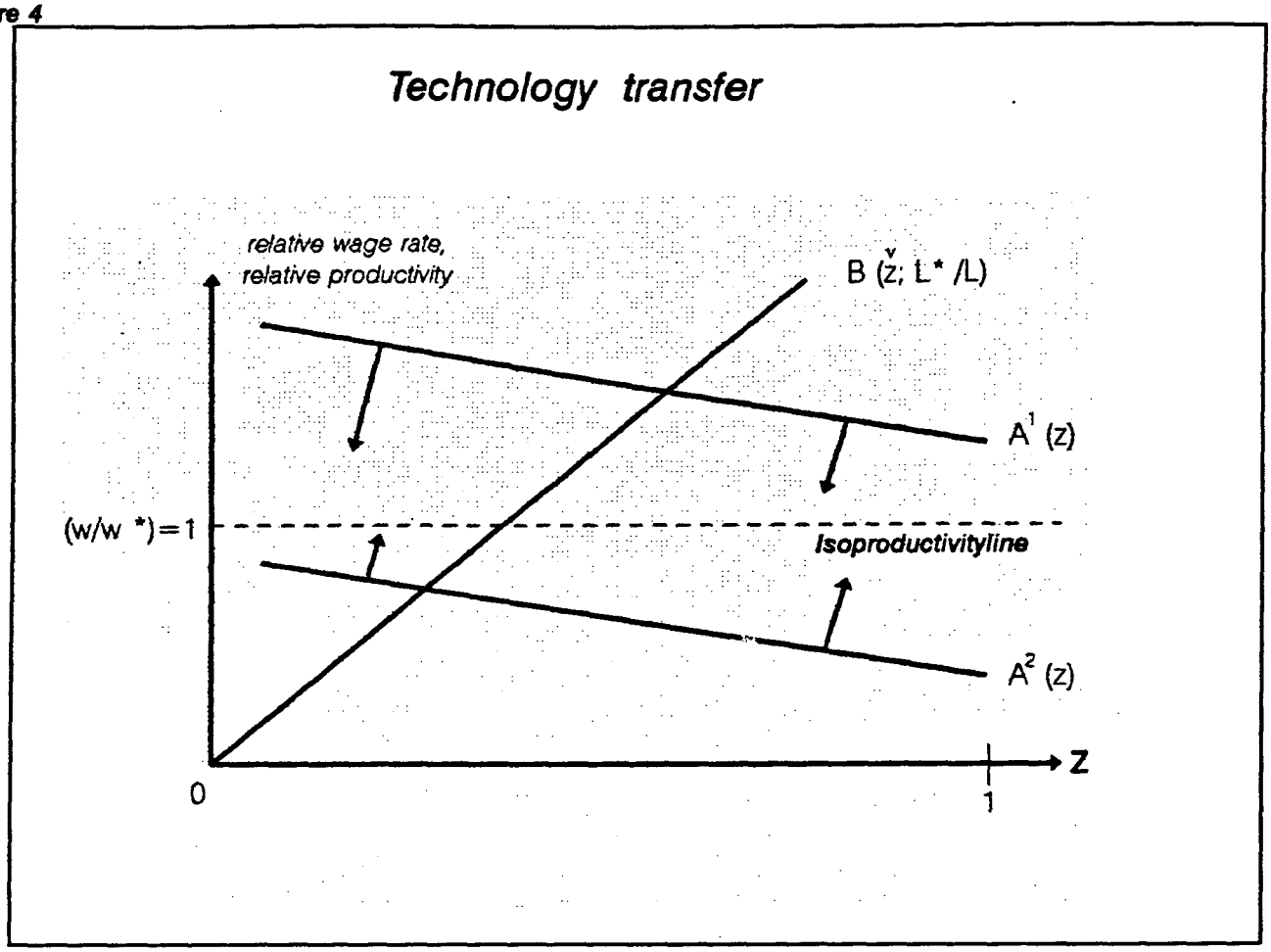
In the Ricardian model used here the different productivity levels of the countries are explained by a different distribution of the production technology employed. An equalisation of these productivity differences by technology transfer also causes an alignment of the domestic and foreign wage rate. Countries with lower technological know-how increase their labour productivity by receiving technology. They can thereby offer more goods than before on the world market. The relative wage rate of lower technological countries increases through the increasing demand for labour. Conversely, the productivity edge of the high technology countries is lowered relatively, but not in absolute terms. If labour productivity levels become exactly the same, in other words, every good at home and abroad is produced with the same technology, then the nominal wage rates, prices and real wages are the same at home and abroad. International specialisation can then no longer be determined with this model[16].

Figure 4 illustrates this situation in a graph. From the standpoint of a high technology country, the A (z) curve lies relatively high, for example, A^1 (z)[17]. This cuts the B (z) line above the iso-productivity line $(w/w^*) = 1$. Because of technology transfer, the A (z) curve shifts towards the iso-productivity line, the relative wage rate falls for the high technology country. If the home country is a low technology country, then the A (z) curve lies below the iso-productivity line, for example, A^2 (z); because of technology transfer and the associated increase in productivity, it

[16] Taking transport and transaction costs into consideration the international "division of labour" would be such that each country would only produce what it needed for itself.

[17] The figure assumes that high technology country shows a higher labour productivity in the production of all goods, so that A (z) lies above the iso-productivity line (horizonal dotted line). If one were to assume that the low technology country can produce some goods more productively than the high technology country then A (z) would cut through the iso productivity line.

Figure 4



shifts towards the iso-productivity line, the relative wage rate increases. If both countries use the same technology in the production of the goods, then the A (z) curve would cover the iso-productivity line[18].

The conclusions drawn from the Ricardian model that at the universal availability of technology leads to a world wide alignment of wages concurs with the factor price equilisation theorem based on the Heckscher-Ohlin model which implies that international trade leads to an equalisation of wages and interest rates between the trading countries.

[18] If one were to assume the A (z) curve cuts through the iso-productivity line (see previous footnote) then technology would have to flow in both directions to have this result. Otherwise a country would maintain its productivity edge for those goods which it produces comparatively productively.

4 Extensions of the Model

In this section, the Ricardian model is extended to include availability goods and differentiated products. The existence of both of these types of goods is often used from a theoretical stand as an argument for the limitations of the Ricardian model because it assumes homogeneous products which can, in principle, be produced in all countries. As will be shown, the handling of availability goods and differentiated products is quite easily possible with the introduction of the continuum of goods into the Ricardian model[19].

4.1 Availability Goods

Up until now, the assumption has been that the internationally tradable goods under consideration here can be produced both in the home country and abroad - now we will assume that a certain group of goods can only be produced in one of the countries. Reasons for this are, on the one hand, the availability of natural resources and, on the other, the production of new, innovated goods[20]. These availability goods can not be produced in another country because the necessary technology for their production is not available there and can not (yet) be purchased on the world market. Establishing the production of availability goods in the home country leads to a redistribution of world demand. Because availability goods as well as Ricardian goods[21] are in demand, there is smaller share of demand for Ricardian goods in both of the countries. On the other hand, the rest of demand automatically goes on home produced availability goods, thereby demand for domestic labour increases and the effects previously described come into being: the relative wage rate in the home country increases, the number of home produced Ricardian goods falls. New here, however, is that additional availability goods are now produced in the home country.

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[19] Another critisism often aimed at the Ricardo model is its limitation to the production factor, labour. This critisism is investigated in the appendix.

[20] For details, see Kravis (1956).

[21] The term "Ricardian goods" implies those goods which can in principle be produced in both countries and international specialisation is determined on the basis of demand and the relative productivity of labour.

Figure 5

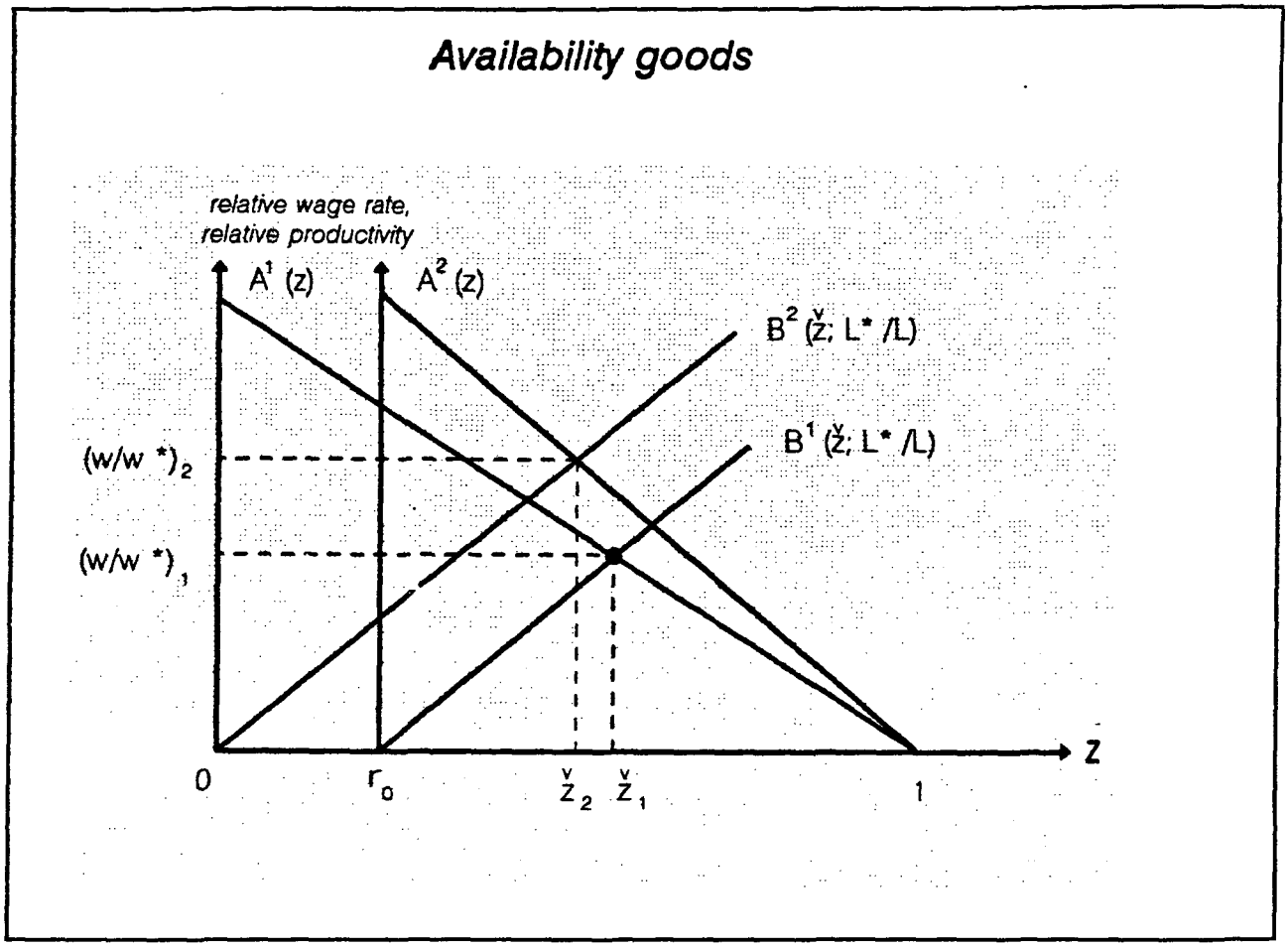

Figure 5 shows the situation under the assumption that the home country takes up the production of availability goods. The continuum of goods is split into two areas. Between r_0 and 1 lie the Ricardian goods,[22] for which a specialisation structure emerges according to the familiar pattern. Availability goods lie in the range between 0 - r_0. The A ( ) curve shifts to the right because the relative unit labour requirement have remained constant and the Ricardian goods are to the right of r_0. The B ( ) curve shifts upwards because for every Ricardian good z the share of world demand apportioned to availability goods has already been "used". The relative wage rate increases from $(w/w^*)_1$ to $(w/w^*)_2$.

[22] The productivity lead of the home country in innovation goods is "infinity". Consequently they lie to the left of the Ricardian goods.

4.2 Differentiated Products

Up until now, the assumption has been that the produced goods are homogeneous. Product differentiation can be viewed as a situation where two or more products are perceived as close, but not perfect substitutes by consumers.[23] We now suppose that the producers differentiate their goods from those of their competitors.[24] This can occur in a number of ways.[25]

a) Quality or vertical differentiation: The essence of vertical differentiation is that products may be ranked by consumers according to quality. If the prices of the products were the same, each consumer would prefer the best product.

b) Product range or horizontal differentiation: In this case a good is characterised by certain core attributes which are combined in different proportions. If the prices of the products were the same, every version of the good would be consumed.

In reality, firms use both differentiation strategies simulteanously although with different intensities. While the car market is characterised in essence by vertical differentiation, firms do also differentiate their products horizontally. In the clothing or footwear industry, horizontal differentiation is prevalent although quality differences do exist.[26]

A particularly useful approach for the purpose of this paper is to divide the market of a good into different segments according to quality. Within a segment, elasticity

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[23] See Eaton and Lipsey (1989) for a comprehensive treatment.

[24] In the course of the following explanation, the term "product" will be used to indicate a specific version of a good.

[25] A third category would be new products. This case was treated in the previous section. We focus on differentiating Ricardian goods.

[26] Cf. Grimwade (1989), pp. 118-120.

of substitution is high and competition takes place through horizontal differentiation. Between segments, the elasticity of substitution is low and products from one segment hardly compete with products from other segments. For example, low tar cigarettes would compete with other low tar cigarettes, but not with the high tar or menthol cigarettes.[27] This allows us to treat each market segment as one Ricardian good in the sense used so far in the paper.

Assume that the efforts to horizontally differentiate lead to a greater or lesser deployment of labour in the production of a good, whereby a greater input of labour finds expression in better design or a greater number of functions, but not quality.[28] The various versions of a good are therefore produced with different rates of labour productivity. The domestic and foreign unit labour requirements (a_i and a_i^*) can therefore be regarded as the average value for all versions of a good. Individual products have unit labour requirements which could lie above or under the average[29].

There are limits on the efforts of the producers to differentiate their products, though. If a producer uses too little labour, the product may not satisfy the minimum standards demanded by the consumers. The producer can not sell his version of the good although he would be price competitive at a given wage rate. Conversely, a greater deployment of labour leads to a product which is very much superior in function, and design, etc. With the prevailing relative wage rate, however, the product would be so expensive that it could not be sold. For the producers it follows, therefore, that their efforts to differentiate must remain within a certain price range and, with a given relative wage rate, within certain limits in the deployment of labour, because they are otherwise unable to sell their products.

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[27] Levinsohn and Feenstra (1990) developed an empirical technique to identify the competition with multi-dimensionally differentiated products and applied it to the US car market. Most of the 136 car models studied had between 2 and 8 competitors.

[28] In order to change the quality of a product and to steer it more towards a different market segment, the producer would need to change its production technology as well.

[29] It should be noted that the average labour productivity is still determined by the technology employed in a country. The producers in a country employ the same technology in the production of a good and differentiate it simply by employing more or less labour.

Consumer demand corresponds to the concept introduced by Dixit and Stiglitz (1977) of the consumers' love of variety. Demand for a good spreads itself between the various versions of the good, provided the price of a product lies within limits acceptable to the consumer. The share of demand for a product is only dependant upon the price of the product and the number of versions of a good[30]. Because demand spreads itself between the home country and abroad according to the size of the country, then a product is sold at home and abroad if is lies within the price limits.

The goods can be thus divided into three groups. The first group consists of those goods of which all versions are produced in the home country because of its technological lead. Even if the foreign country were to use just as much labour it could not attain the required level of quality of the home produced product, because the technology employed there does not allow it. These goods are produced exclusively in the home country and exported from there. The third group of goods is the mirror image of this - they are produced exclusively in the foreign country and are imported from there into the home country.

The second group consists of those goods which are both imported and exported, in other words, for which there is two-way trade in differentiated products or intra-industry trade. In industries in which the home country has only a modest technological lead, a firm in a lesser-developed technological country can improve design and functions of its product with increased deployment of labour to such an extent that it attains the minimum standards demanded by consumers. At the same time, at a given relative wage rate, the product crosses the lower price limit[31]. Because there is demand for a product lying within the price limits both at home and abroad, the firm's product will be exported to the foreign country whilst all other versions will be imported from the foreign country. The more similar the technology level of the two countries in the production of a good, the more the producers from both of the countries will engage in the production of a good, and the greater the level of exchange of differentiated products will be.

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[30] cf. Dixit and Stiglitz (1977) for a comprehensive explanation.

[31] Those firms in the low technology countries which employ less labour are indeed even more price competitive. However, their products are not purchased by consumers because of the lack of design and function.

Figure 6

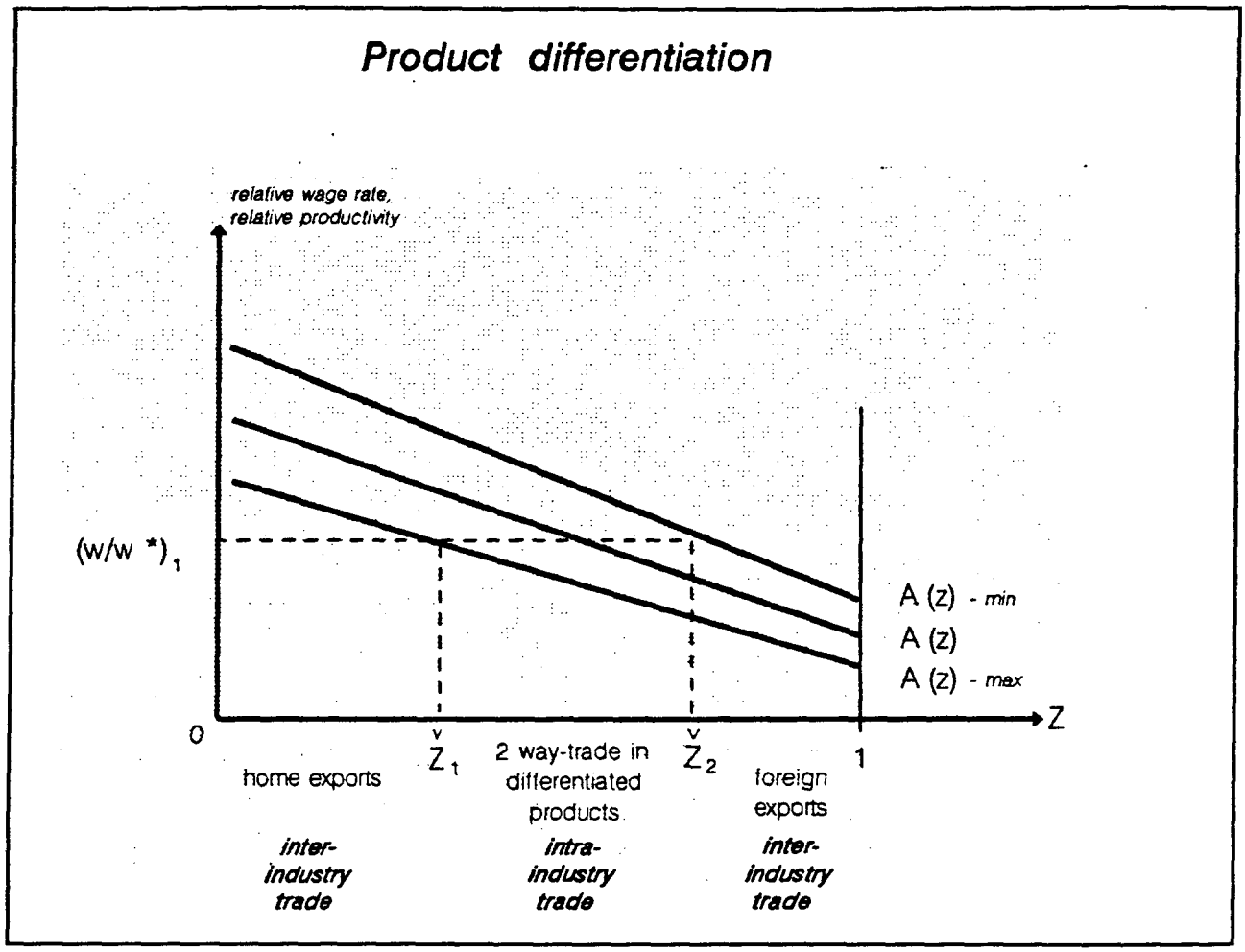

Figure 6 depicts the situation of differentiated products in a graph. Different to before, the A (z) curve now depicts the average productivity differential between the home and foreign country. For the sake of simplicity, it is now assumed that the variation of the unit labour requirement at home and abroad is a fixed percentage for all goods. The curve A (z)-min thus depicts the relationship between the unit labour requirement of the version of the home produced good which deploys the lowest level of labour with the foreign product for which the most labour is deployed, so:

$$\max (a^*_i) / \min (a_i)$$

Conversely, the curve A (z)-max depicts the relationship between the unit labour requirement of the version of the home produced good which deploys the greatest

level of labour with the foreign product for which the least amount of labour is deployed, so:

$$\min (a^*_i) / \max (a_i)$$

With a given wage rate of $(w/w^*)_1$, those goods exclusively produced in the home country and exported from there lie in the range 0 and $\check{z}_1$. Those goods exclusively produced in the foreign country and imported into the home country lie in the range $\check{z}_2$ and 1. Between $\check{z}_1$ and $\check{z}_2$ are those goods which are produced both at home and abroad and are traded in both directions, in other words, goods in intra-industry trade.

5 Conclusion

This paper demonstrates that the Ricardian Model with a continuum of goods is capable of dealing with a wide variety of issues once the model is properly extended. It is by far more powerful than often claimed and allows for an analysis of technical progress, availability goods and differentiated products.

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