Trade, Migration and Inequality in a World without Factor Price Equalisation

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ABSTRACT

The behaviour of trading economies in the absence of factor price equalization is not well understood, although empirical evidence against factor price equalisation is overwhelming. We map regions of diversification and specialization for competitive world economies with different factor endowment partitions. Goods and factor price responses as economies move within and across different regions of specialisation are explored using a series of novel diagrams. The usefulness of endogenising patterns of specialisation is illustrated by considering the impact on inequality of migration flows (such as US-Mexico), the substitutability of trade and migration, and the impact of the entry of a large unskilled labour intensive economy (such as China) on factor prices and factor flows.

1) Introduction

There have been many advances in the theory of international trade in recent years (surveyed for instance in Grossman and Rogoff (1995)), but most trade modelling and policy analysis still operates with fully diversified economies where factor price equalisation holds. This emphasis is problematic as empirical studies such as Davis and Weinstein (2001) and Schott (2003) and Debaere and Demiroglu (2003) suggest incomplete diversification and failure of factor price equalisation is the norm.

We know surprisingly little about the behaviour of trading economies in the absence of factor price equalisation, even for the simplest competitive models. Krugman (1995) in his survey comments that determining what happens outside the factor price equalisation region is a "fairly nasty business"(p1247), Dixit and Norman (1980 p113) that it is “very complicated”, and Deardorff (2001 p143) that we are “surprisingly ignorant”. Standard graduate texts such as Dixit and Norman (1980) and Bhagwati, Srinivasan and Panagariya (1998) err in their discussions of non-factor price equalisation cases. The recent text of Feenstra (2004 p22-5) offers brief comments on the complications involved.

Some work such as Wood (1994), Leamer (1995), Davis (1996) or Oslington (2002) considers specialised economies but imposes a particular pattern of specialisation rather than linking it to underlying endowment, technology, and taste parameters. An important paper which takes up the challenge of linking patterns of specialisation to underlying parameters is Leamer (1987) who considers a three-factor n-good model, showing how the range of products produced in different countries depends on their endowment ratios. While an extremely rich paper its usefulness for the problem considered here is limited by a fixed production coefficients technology, ruling out the changes in factor intensity that flow from the factor price changes which occur outside the factor price equalisation region. Another stand of the literature that endogenises patterns of production and trade is inframarginal economics (for instance Cheng, Sachs and Yang (2000), or Tombazos, Yang and Zhang (2005)) where interactions between technology, economies of scale and transaction costs generate different patterns.

The first aim of the paper is to map the regions of specialisation as for the standard competitive trade model, as no satisfactory account exists in the literature. To make the problem tractable we use Cobb-Douglas tastes and technology, and explore numerically the shapes of the regions of specialisation. For each region of specialisation we will then explore relationships between endowments, factor prices and goods prices for different trading worlds. The second aim is to clarify relationships between trade, migration and inequality outside the factor price region. For we interpret the factors of production as skilled and unskilled labour and consider migration due to factor price differentials. The third aim is to illustrate the usefulness of a world economy model with endogenous patterns of specialisation for debates about the relationship between inequality and migration flows (e.g. US-Mexico), the substitutability of trade and migration, and the impact of the entry of a large unskilled labour intensive economy (e.g. China) on factor prices and migration flows.

The paper is structured as follows. The first aim occupies sections 2 and 3, which are a series of novel diagrams showing regions of specialisation and factor prices in different regions. Sections 4 and 5 introduce the definitions of inequality and migration pressure in a non factor price equalisation world. Section 6, 7, 8, and 9 illustrate the model, meeting the third aim.

2) Integrated Equilibrium Analysis

Our mapping of regions of specialisation builds on the technique of integrated equilibrium analysis developed by Dixit and Norman (1980 pp100-125), who took up Samuelson's (1949 pp194-195) parable of an angel splitting the world factor endowment between countries in different ways[1]. Integrated equilibrium analysis allowed Dixit and Norman to cut through the previous debate on factor price equalisation by reframing it as a question of what joint restrictions on technology, preferences and factor endowments supported factor price equalisation[2]. It has been fruitful in other ways: Deardorff (1994) further clarified the conditions for factor price equalisation; Helpman and Krugman (1985) and Kreickemeier and

[1] Some of the following draws on an unpublished paper on teaching integrated equilibrium analysis Oslington and Towers (2006).

[2] A common approach in the literature is to construct cones of diversification, following McKenzie (1955) and argue that economies with endowments inside the cone will be diversified, while those outside the cone specialised. This is sometimes useful, but cones are drawn for particular goods prices, which are endogenous in a world economy model.

Nelson (2006) have extended it to consider trading worlds with imperfect competition; Davis (1998) called it a truly global approach when deriving some startling results about the consequences for different countries factor markets of factor accumulation in different parts of the world.

The simplest and most widely used model with two countries, two factors and two goods will be used, along with standard assumptions of perfect competition, concave constant returns to scale technology that is the same across the world, and identical homothetic preferences. It will be assumed that equilibrium factor proportions are unique, and degenerate combinations of technology, endowments and tastes which mean a good is produced nowhere in the world will be ruled out.

An equilibrium for a world not divided into countries (or equivalently with free movement of goods and factors between countries) is shown in figure 1[3]. The dimensions of the box are the world endowment of the factors, unskilled labour L and skilled labour K[4]. Equilibrium factor usage vectors for the two products X and Y are shown. X is relatively unskilled labour intensive.

Now consider splitting the world endowment of the factors between countries A and B in the proportions represented by V in figure 2. Since V is within the shaded parallelogram (the area enclosed by the factor usage vectors from figure 1) both countries produce both goods using the same factor proportions as the undivided world. Factor prices and goods prices will be identical to the undivided world. Since preferences are identical and homothetic individuals in the countries will consume the products in the same proportions as the undivided world, so the factor content of consumption in the two countries will be a point on the diagonal of the box such as C. The factor content of trade will thus be the vector VC. This is the factor price equalisation case.

For splits of the endowment outside the shaded parallelogram in figure 2 such replication of the integrated equilibrium is not possible and factor price equalisation breaks down. This has been widely noted in the literature, but there is considerable uncertainty about what exactly happens. Dixit and Norman comment "In order to be able to say what happens outside the factor price equalization region, we need more information concerning technology and demand functions" (p113) and that this can "make matters very complicated" (p113).

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[3] Equilibrium conditions are given in the appendix

[4] Capital can be thought of an intersectorally and internationally mobile third factor.

None of the discussions in the literature of what happens outside the factor price equalisation region are completely accurate. Dixit and Norman's textbook, an excellent and widely used reference, errs in suggesting that there are four regions of specialisation outside the factor price equalisation region[5] (see Dixit and Norman (1980) pp113-114 and especially figure 4.4). As will be shown below there are in fact six regions - they miss the possibility that both countries specialise completely in different goods. Bhagwati, Srinivasan and Panagariya (1998 87-90) repeat the error that there are four regions and miss the regions where both countries specialise. There seems to be no satisfactory account in the literature of what happens outside the factor price equalisation region.

3) What Happens Outside the Factor Price Equalisation Region?

As suggested by Dixit and Norman (1980 p113) the analysis outside the factor price equalisation region is "very complicated" and we will follow their approach of numerical simulation with a particular production technology to map the regions. The case illustrated has Cobb-Douglas production and utility functions, production share of K in X $\alpha = .45$, share of K in Y $\beta = .55$, and consumption share $\sigma^Y = .5$, but we have experimented with a range of parameter values[6].

The six regions of specialisation and diversification are shown in Figure 3[7]. The regions are best explained by tracing how a trading world switches between equilibria as endowments change. Begin with an endowment split in the diversification region marked +.

Give country B more skill and country A correspondingly less, so that we move through the region from + in the direction of the arrow. In country B, factor and goods prices do not change and the output of the labour intensive good X will fall, and Y rise following the Rybczynski

[5] In correspondence on this issue Avinash Dixit mentioned that his colleague Gene Grossman independently realised the error in the Dixit and Norman text (see Grossman (1990), and Grossman and Helpman (1991) p190), as well as a related error in the earlier Helpman and Krugman book. My letter to Avinash Dixit contained an error about the shape of one the regions and I thank him and Gene Grossman for pointing this out. Deardorff (1994 p169) includes a diagram that divides the area outside the factor price equalisation region into six regions, but draws linear boundaries for the special case of fixed production coefficients.

[6] The figures have been generated using *Matlab*, after some initial experimentation with *Mathematica*.

[7] Equilibrium conditions for the different regions are given in the appendix.

Theorem. Eventually the output of X in country B will fall to zero at the boundary of the diversification and specialization regions. Further increases in the endowment of skill in country B will make it impossible for B to fully employ its endowment of both factors producing both products at the integrated equilibrium factor proportions. There is not enough labour to absorb all country B's skill, and to maintain full employment in B production of the labour intensive good X must cease and Y alone be produced in B. The reverse effects will occur in country A, and production of Y in A ceases.

Now the world economy is in the specialization region in figure 3. Continue taking skill from country A and giving it to country B. Responses are now more complex because factor prices and proportions change outside the factor price equalisation region. There will be a Rybczynski-like response at constant factor prices in country A, reducing output of the skill intensive good Y and increasing output of X in country A. However factor prices are not constant, and in country A the return to skill will rise and skill intensity of both goods fall. In country B the output response is straightforward as the additional skill will increase output of the only good produced Y, the return to skill will fall and production become more skill intensive. In A the return to skill rises. The relative supply of good Y falls and the relative world price of good Y rises. This reduces relative demand for good Y, tending to push it out of production. Eventually the combined effects will close down the Y industry in country A.

The world economy is now in the extreme specialisation region where county A produces only X and country B only Y. Continuing to take skill from country A and giving it to B increases output of X in A and increases Y in B. The return to skill rises in A and falls in B. These changes drive down the world price of good Y until eventually it becomes so low that it is profitable to recommence production of X in country B, taking the economy to a specialisation region analogous to the one previously considered.

The extreme specialisation region (the region missed in some previous discussions) region has the convex lens shape shown in figure 3[8]. If the production technology was fixed coefficient then the boundaries of the extreme specialisation region would be straight line extensions of the factor usage vectors which enclose the diversification region, as illustrated by Deardorff (1994 p169). However in our more general case factor price changes induce factor intensity changes

[8] An explicit expression for the boundary of the extreme specialisation region has been derived for the general Cobb-Douglas case, but is extremely complex and given in an appendix.

which delay the switch to extreme specialisation described above.

We can map goods prices p^Y and factor prices w^A, w^B, r^A, r^B for all possible endowment splits, as shown in figures 4-8. These fully characterise the responses to endowment changes for the standard model, encompassing the local comparative static responses within regions and responses as we switch between regions[9].

Some responses reverse well known properties of factor price equalisation economies, for instance the correspondence between relative goods price and factor price movements. As we have seen in the specialisation region, reallocating capital from A to B causes the relative world price of the capital intensive good Y to rise and the relative return capital to rise in A and fall in B. In the extreme specialisation region same reallocation of capital causes the price of good Y to fall, but the relative return capital still rises in A and falls in B. Thus reverse results can emerge, and the reversals reverse as we switch between regions.

Stolper–Samuelson "reversals" like this were previously noted by Cheng, Sachs and Yang (2000). It is perhaps unfair to describe these reversals as failures of the Stolper –Samuelson theorem, because country B produces a single good so the usual resource reallocation mechanisms are not operating.

[9] Comparative static responses to endowment changes within each region can be obtained by manipulation of the equilibrium conditions given in the appendix equations (10)-(17) for the specialisation region and (18)-(24) for the extreme specialisation region.

4) Inequality

We now move to the second aim of clarifying relationships between trade, migration and inequality outside the factor price region. To do this we will interpret the factors as unskilled and skilled labour, and the ratio of skilled to unskilled wages r/w will be our measure of inequality[10]. In a society of two individuals with given endowments where one owns all the unskilled labour and the other all the skilled labour, this measure would correspond to the ratio of the incomes of the two individuals, and would also be proportional to the Gini coefficient. This simple measure of inequality ties into recent debates over trade and wage inequality.

Using the factor price solutions from the previous simulations we can find values of inequality for the two countries for different partitions of the world factor endowment. These values are shown in figure 9. The inequality surface for country A labelled r^A/w^A runs from the top left (or West[11]) of figure 9 to the bottom right, and for B from the top right to bottom left. The flat central region that is part of both surfaces indicates the level of inequality in the countries when factor returns are equalised across countries, which is the level of inequality that would prevail in a borderless world.[12] In the West part of figure 9 where country A is relatively well endowed with unskilled labour country A has greater inequality than country B. In the East where country A is relatively well endowed with skilled labour it has less inequality. These differences in inequality come entirely from differences in factor abundance between countries.

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[10] This interpretation suggests $w \le r$, and appropriate choice of units for labour and skill can ensure this. An alternative, not explored in this paper would be a production technology that allowed skilled workers to be substituted for unskilled, but not visa versa, so the skilled wage can never fall below the unskilled.

[11] Directions West and East here and elsewhere in the paper are relative to North at O^B and South at O^A.

[12] In the simulations r/w=1 for the flat region since K=L and the technologies are symmetric Cobb-Douglas.

5) Migration Pressure

We need to specify what drives migration flows, and in the illustrations which follow, migration pressure will come entirely from factor price differentials which reflect differences in factor endowments between countries. When individuals migrate, the endowment partition changes and income is assumed to be spent in the destination country. It is recognised that migration decisions in reality are more complex, and others influences include technological differences between countries[13], networks created by previous migrants, ease of remittances, risk, and locational preferences as discussed by Massey (1990) and the specialist literature on migration.

For our simplified world the sign and magnitude of migration pressure for different between different countries can be read off the inequality surfaces in figure 9. In the factor price equalisation region there is no pressure for labour to move between countries. Outside the factor price equalisation region, in the West of figure 9 where $r^A/w^A > r^B/w^B$ unskilled labour will flow from A to B and skilled labour will flow from B to A, and in the East of figure 9 the reverse flows occur.

[13] Technology and endowments are alternative (and sometimes equivalent) analytical boxes. It can be argued (e.g. Woodland 1982) that technology differences are omitted factors. If we allow technology differences between countries this stretches the logic of integrated equilibrium analysis, and makes the analysis of migration messier because both technological and endowment differences contribute to the factor price differentials that drive migration flows. However we could still consider the effects of migration and trade on inequality in a world with technological differences.

6) Migration and Inequality

The third aim of the paper is to illustrate the usefulness of a world economy model with endogenous patterns of specialisation for some contemporary debates. The relationship between migration and inequality has been an important and contentious policy issue for a long time, as discussed by Lindert and Williamson (2003), Hatton and Williamson (2005) and many others.

Consider an endowment point in the West part of figure 10 where country A is relatively well endowed with unskilled labour. As explained in the previous section, opening up migration of unskilled labour induces migration flows from country A to B, pushing the endowment point for country B up its inequality surface so inequality rises in B, and pulling the endowment point for A down its inequality surface so inequality falls in A. Opening up migration of skilled labour induces the opposite flows, skilled labour moves from B to A, but inequality moves in the same direction, rising in B and falling in A. These movements are indicated by the arrows in figure 10.

Migration and the induced changes to factor prices will continue until the edge of the fpe plane is reached. If we know the starting endowment partition for the world economy and only one factor is mobile we can predict exactly where on the edge of the fpe plane the world will end up, but with two mobile factors a range of possible points on the edge of the fpe plane are possible.

Result 1

Opening up migration of either factor pushes countries towards the factor price equalisation plane, i.e. level of inequality that would prevail in an integrated world economy

Result 2

Opening up migration of either factor reduces inequality in the most unequal country (the labour abundant country) and increases inequality in the other country (the skill abundant country).

These Results mean that if a country like the US is relatively well endowed with skilled labour, relaxing barriers to migration will reduce inequality in Mexico, and increase inequality in the US. The result is consistent with previously derived comparative static effects of exogenous endowment changes (e.g. Woodland 1982, Falvey and Kreickemeier (2005)) for a single country.

However it is more general in endogenising the endowment changes, endogenising world goods prices, and considering effects on different parts of the world simultaneously.

7) Trade and Inequality

Relationships between trade and inequality are also contentious, especially the impact of imports of unskilled labour intensive products on US inequality over the last 20 years (for example Wood (1994) or Bhagwati (2004)). In our model, comparing the free trade inequality surfaces with autarky inequality surfaces gives the effect of opening up trade on inequality in each country.

Autarky inequality surfaces for the two countries in our trading world are shown in figure 11. For endowment partitions on the diagonal of the box each country has the same relative endowments, which are the same as the relative endowments of the borderless world, so autarky factor prices and inequality on the diagonal of the box must be the same as the borderless world. What happens as we move away from the diagonal? If free trade goods price ratios lie between the two countries autarky price ratios, then as we move away from the diagonal autarky P^Y surfaces (not shown in figure 11) must rise and fall in the same directions as the free trade P^Y surfaces rise or fall away from the factor price equalisation plane in Figure 4. Furthermore if autarky factor price ratios move in the same direction as autarky goods price ratios, then autarky inequality surfaces will rise and fall away from the diagonal of the box in the same directions as the free trade inequality surfaces move away from the flat fpe region Figure 9, only be steeper. This implies the two countries flatter free trade inequality surfaces in Figure 9 must lie between the steeper autarky inequality surfaces, which are shown in Figure 11.

When trade is opened up we move from autarky inequality surfaces to the corresponding free trade surfaces, giving:

Result 3

Opening up goods trade reduces inequality in the most unequal country (the labour abundant country) and increases inequality in the other country (the skill abundant country).

8) Trade and Migration and Substitutes

It is well known that for endowment partitions that support factor price equalisation, trade and migration are substitutes in the sense that opening up either trade or migration will equalise factor prices (Mundell 1957 p321 or Wong 1995 p170-1). For world economies with endowment partitions outside the factor price equalisation region free trade is insufficient, but migration will equalise factor prices.

There is another sense in which trade and migration are substitutes, which applies beyond the factor price equalisation region. Comparing Results 2 and 3, opening up either trade or migration of either factor has the same effects on inequality, reducing inequality in the most unequal country and increasing inequality in the other country.

Result 4

Trade and migration are substitutes in the sense that opening up either reduces inequality in the most unequal country (the labour abundant country) and increases inequality in the other country (the skill abundant country). They are "inequality substitutes" for all endowment partitions.

9) Unskilled Labour Growth

The model can also be used to consider the effects on inequality and migration flows of adding a large pool of unskilled labour to the world economy. An example would be the growth of China's unskilled labour endowment, either from demographic forces or from unskilled workers moving into the market economy.

In figure 12, an increase in country A's unskilled labour endowment can be represented by stretching the world economy box away from the country A origin from O^A to $O^{A'}$. This stretching of the box alters the boundaries of the regions, perhaps leaving the endowment point in a different region. For example V in figure 12 previously supported a diversified factor price equalisation equilibrium but is now specialised, and U was previously a specialised equilibrium now diversified.

The inequality surfaces are raised and stretched by the additional unskilled labour, and the new inequality surface is shown in figure 13 lighter hatched, over the old darker surface. In the Western part of figure 13 the new lighter country A and B inequality surfaces lie wholly above the darker old surfaces. In the Eastern part the new A surface is wholly above the old, but the new B surface cuts the old along a line which is shown in figure 14. This line comes from our numerical simulations. Unskilled labour growth in A thus increases inequality in all countries, except in the case where A is skill abundant, when inequality may fall in B. The endowment partitions for which inequality falls in B are shaded in figure 14.

So, if country A is skill scarce China then growth of its unskilled workforce increases inequality everywhere, whereas if country A is skill abundant Europe then growth of its unskilled workforce increases inequality in Europe but can reduce inequality in the rest of the world.

Result 5

With free trade but no migration, inequality rises in a country which brings additional unskilled labour to the world economy, but inequality may rise or fall in rest of the world.

An alternative experiment is the effect of unskilled labour growth with completely open borders. With completely free migration countries always end up on the factor price equalisation plane, inequality is the same everywhere in the world, and depends on world endowments. We know that increasing the world endowment of unskilled labour increases world inequality, so:

Result 6

With free migration, growth of the unskilled labour endowment in any country increases inequality in all countries.

With completely open borders, increasing the world endowment of unskilled labour generates migration flows, but to identify these migration it is necessary to isolate migration induced by the additional unskilled labour from migration that would have otherwise have occurred at the original endowment partition. Lets say we begin at V in figure 13 where there was no migration before growth. After growth the endowment point is pushed up the country A west slope, inducing unskilled labour flows from A to B, and skill flows from B to A.

Result 7

Growth of a country's unskilled labour endowment creates migration pressure for the country to shed unskilled labour and attract skilled labour.

10) Conclusions

The paper has provided a full mapping from endowment partitions to patterns of production, goods and factor prices for the simplest competitive trade model. This fills an important gap in the literature, not least because the few existing discussions err.

This mapping of the regions of diversification and specialisation opens the way to consider some important issues in the context of non-factor price equalisation economies. Our two moves of interpreting the factors as skilled and unskilled labour, and assuming migration to be driven by factor price differentials allowed us to generalise existing results about connections between trade, migration and inequality beyond the much analysed factor price equalisation case. Some sharp results were derived – especially the result that opening up either trade or migration reduces inequality in the most unequal country and increases inequality the other country. The mapping also allowed us to consider the inequality and migration impacts of adding unskilled labour to a competitive world economy.

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Appendix – Equilibrium Conditions

For the factor price equalisation region, equilibrium conditions are:

Zero profit for each product produced in each country[14] (X is the numeraire)

$$(1)\quad 1 = c^X(r^A, w^A)$$

$$(2)\quad 1 = c^X(r^B, w^B)$$

$$(3)\quad p^Y = c^Y(r^A, w^A)$$

$$(4)\quad p^Y = c^Y(r^B, w^B)$$

Full employment of each factor in each country ($\overline{L}$ and $\overline{K}$ are world endowments)

$$(5)\quad c^X{}_w(r^A, w^A)\, X^A + c^Y{}_w(r^A, w^A)\, Y^A = L^A$$

$$(6)\quad c^X{}_r(r^A, w^A)\, X^A + c^Y{}_r(r^A, w^A)\, Y^A = K^A$$

$$(7)\quad c^X{}_w(r^B, w^B)\, X^B + c^Y{}_w(r^B, w^B)\, Y^B = L - L^A$$

$$(8)\quad c^X{}_r(r^B, w^B)\, X^B + c^Y{}_r(r^B, w^B)\, Y^B = K - K^A$$

Demand

$$(9)\quad \frac{X^A + X^B}{p^Y Y^A + p^Y Y^B} = \frac{1-\sigma^Y}{\sigma^Y}$$

These conditions yield equilibrium values of p^Y, w^A, w^B, r^A, r^B, X^A, Y^A, X^B and Y^B.

In the region marked specialisation in figure 3, product X is not produced by country B, so that the equilibrium conditions are:

Zero profit for each product produced in each country:

$$(10)\quad 1 = c^X(r^A, w^A)$$

$$(11)\quad p^Y = c^Y(r^A, w^A)$$

$$(12)\quad p^Y = c^Y(r^B, w^B)$$

Full employment of each factor in each country:

$$(13)\quad c^X{}_w(r^A, w^A)\, X^A + c^Y{}_w(r^A, w^A)\, Y^A = L^A$$

$$(14)\quad c^X{}_r(r^A, w^A)\, X^A + c^Y{}_r(r^A, w^A)\, Y^A = K^A$$

$$(15)\quad c^Y{}_w(r^B, w^B)\, Y^B = L - L^A$$

$$(16)\quad c^Y{}_r(r^B, w^B)\, Y^B = K - K^A$$

Demand

[14] These equilibrium conditions are expressed in terms of minimum unit cost functions c(w,r), whose derivatives with respect to the factor prices $c_w(w,r)$ and $c_r(w,r)$ are input-output coefficients - see Woodland (1982).

$$(17) \quad \frac{X^A}{p^Y Y^A + p^Y Y^B} = \frac{1-\sigma^Y}{\sigma^Y}$$

These conditions yield equilibrium values of p^Y, w^A, w^B, r^A, r^B, X^A, Y^A and Y^B.

Equilibrium conditions in the extreme specialisation region are[15]:

Zero profit for each product produced in each country:

$$(18) \quad 1 = c^X(r^A, w^A)$$

$$(19) \quad p^Y = c^Y(r^B, w^B)$$

Full employment of each factor in each country:

$$(20) \quad c^X_w(r^A, w^A)\, X^A = L^A$$

$$(21) \quad c^X_r(r^A, w^A)\, X^A = K^A$$

$$(22) \quad c^Y_w(r^B, w^B)\, Y^B = L - L^A$$

$$(23) \quad c^Y_r(r^B, w^B)\, Y^B = K - K^A$$

Demand

$$(24) \quad \frac{X^A}{p^Y Y^B} = \frac{1-\sigma^Y}{\sigma^Y}$$

These conditions yield equilibrium values of p^Y, w^A,w^B, r^A,r^B, X^A and Y^B.

[15] The boundary of the specialisation and extreme specialisation regions is the locus of L^A K^A obtained from solving (10)-(17) when setting Y^A=0 in (13) and (14). Needless to say it is ugly even for these simple functional forms.

Appendix –Expression for Boundary of Regions

The task is to find the boundary in Figure 3 separating the specialisation region (where country A produces both X and Y while B produces only Y) and the extreme specialisation region (where A produces only X and B produces only Y). The expression for this boundary is obtained by setting $Y^A=0$ in the above equlibrium conditions for the specialisation region. This yeilds an expression for L^A in terms of K^A which is the upper boundary of the lens.

With Cobb-Douglas functions our equations are:

$$1 = \left(\frac{r_A}{\alpha}\right)^{\alpha}\left(\frac{w_A}{1-\alpha}\right)^{1-\alpha} \tag{25}$$

$$P_Y = \left(\frac{r_A}{\beta}\right)^{\beta}\left(\frac{w_A}{1-\beta}\right)^{1-\beta} \tag{26}$$

$$P_Y = \left(\frac{r_B}{\beta}\right)^{\beta}\left(\frac{w_B}{1-\beta}\right)^{1-\beta} \tag{27}$$

$$(1-\beta)P_Y Y_B = (L-L_A)w_B \tag{28}$$

$$\beta P_Y Y_B = (K-K_A)r_B \tag{29}$$

From this system of equation we can find solutions which depend on w_A for the following:

$$r_A = \alpha\left(\frac{1-\alpha}{w_A}\right)^{(1-\alpha)/\alpha}$$

$$r_B = \frac{\beta}{1-\beta}\left(\frac{L-L_A}{K-K_A}\right)w_B$$

$$Y_B = (K-K_A)^{\beta}(L-L_A)^{1-\beta}$$

$$P_Y = \frac{w_B}{1-\beta}\left(\frac{L-L_A}{K-K_A}\right)^{\beta}$$

$$w_B = Q\left(\frac{K-K_A}{L-L_A}\right)^{\beta} w_A^{(\alpha-\beta)/\alpha}$$

where Q is the following collection of parameters

$$Q = \left[\frac{\alpha(1-\beta)}{\beta}\right]^{\beta}(1-\alpha)^{\beta(1-\alpha)/\alpha}$$

Now consider the equations affected by the choice of $Y_A = 0$. We have three equations:

$$(1-\alpha)X_A = L_A w_A \tag{30}$$

$$\alpha X_A = K_A r_A \tag{31}$$

$$X_A = \Delta P_Y Y_B \tag{32}$$

With $\Delta = \sigma/(1-\sigma)$ product X produced in country A can be expressed as

$$X_A = \frac{\Delta}{1-\beta}(L - L_A)w_B$$

By dividing (30) by (31) and using the known expression for r_A we can find that

$$w_A = \left(\frac{K_A}{L_A}\right)^{\alpha}(1-\alpha)$$

Now w_A is known, all the variables can be expressed in terms of parameters for case of $Y_A=0$.

From (30) and using expressions for w_A w_B and X_A we can write an expression for L_A in terms of K_A and the other system parameters:

$$L_A = \frac{L\, f(K_A)}{1 + f(K_A)}$$

where the function is defined as

$$f(K_A) = \Delta^{1/(1-\beta)}\left(\frac{\alpha}{\beta}\right)^{\beta/(1-\beta)}\left(\frac{1-\alpha}{1-\beta}\right)\left(\frac{K-K_A}{K_A}\right)^{\beta/(1-\beta)}$$

So explicitly the boundary is given by

$$L_A = \frac{L\Delta^{1/(1-\beta)}\left(\frac{\alpha}{\beta}\right)^{\beta/(1-\beta)}\left(\frac{1-\alpha}{1-\beta}\right)\left(\frac{K-K_A}{K_A}\right)^{\beta/(1-\beta)}}{1+\Delta^{1/(1-\beta)}\left(\frac{\alpha}{\beta}\right)^{\beta/(1-\beta)}\left(\frac{1-\alpha}{1-\beta}\right)\left(\frac{K-K_A}{K_A}\right)^{\beta/(1-\beta)}} \tag{33}$$

For our typical values of the parameters this expression becomes

$$L_A = \frac{9.564\left(\frac{10-K_A}{K_A}\right)^{1.222}}{1+0.966\left(\frac{10-K_A}{K_A}\right)^{1.222}} \tag{34}$$

Lets define M to be

$$M = \Delta^{1/(1-\beta)}\left(\frac{\alpha}{\beta}\right)^{\beta/(1-\beta)}\left(\frac{1-\alpha}{1-\beta}\right)$$

so that our expression becomes:

$$L_A = \frac{LM\left(\frac{K-K_A}{K_A}\right)^{\beta/(1-\beta)}}{1+M\left(\frac{K-K_A}{K_A}\right)^{\beta/(1-\beta)}} \tag{35}$$

The other boundary of the lens in the northwest part of Figure 3 can be obtained in a similar manner by setting $X^B=0$.

Figure 2 – Integrated Equilibrium

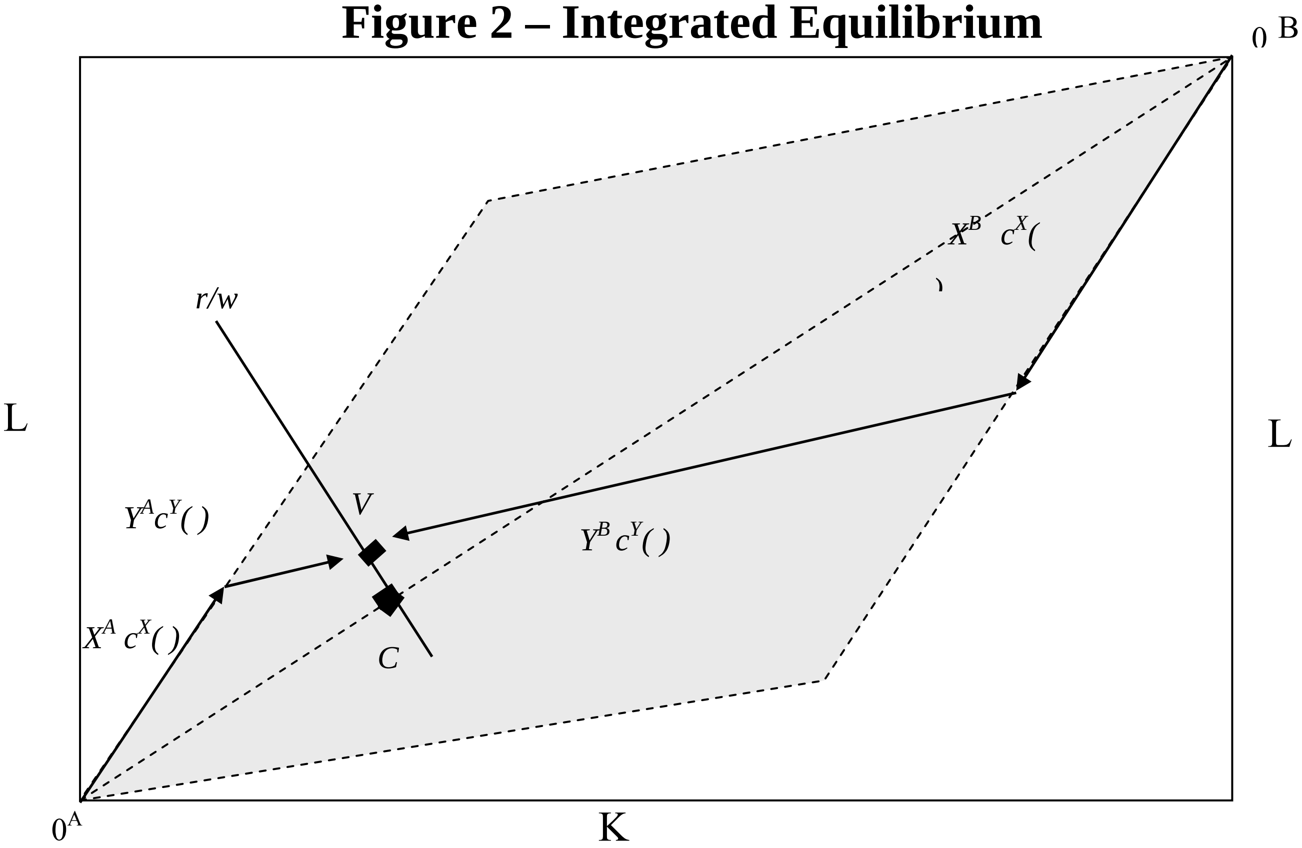


Figure 1 – Borderless World

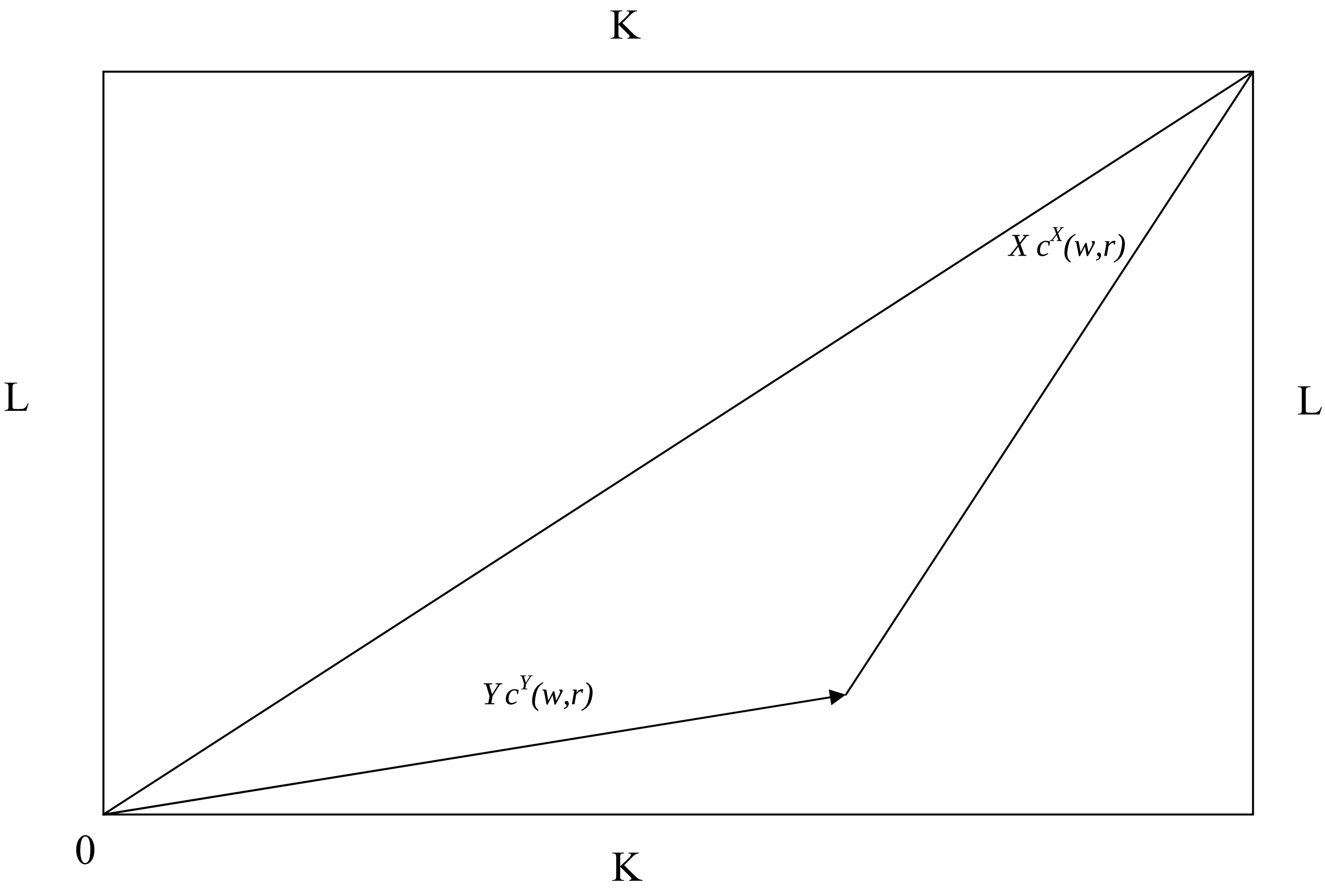
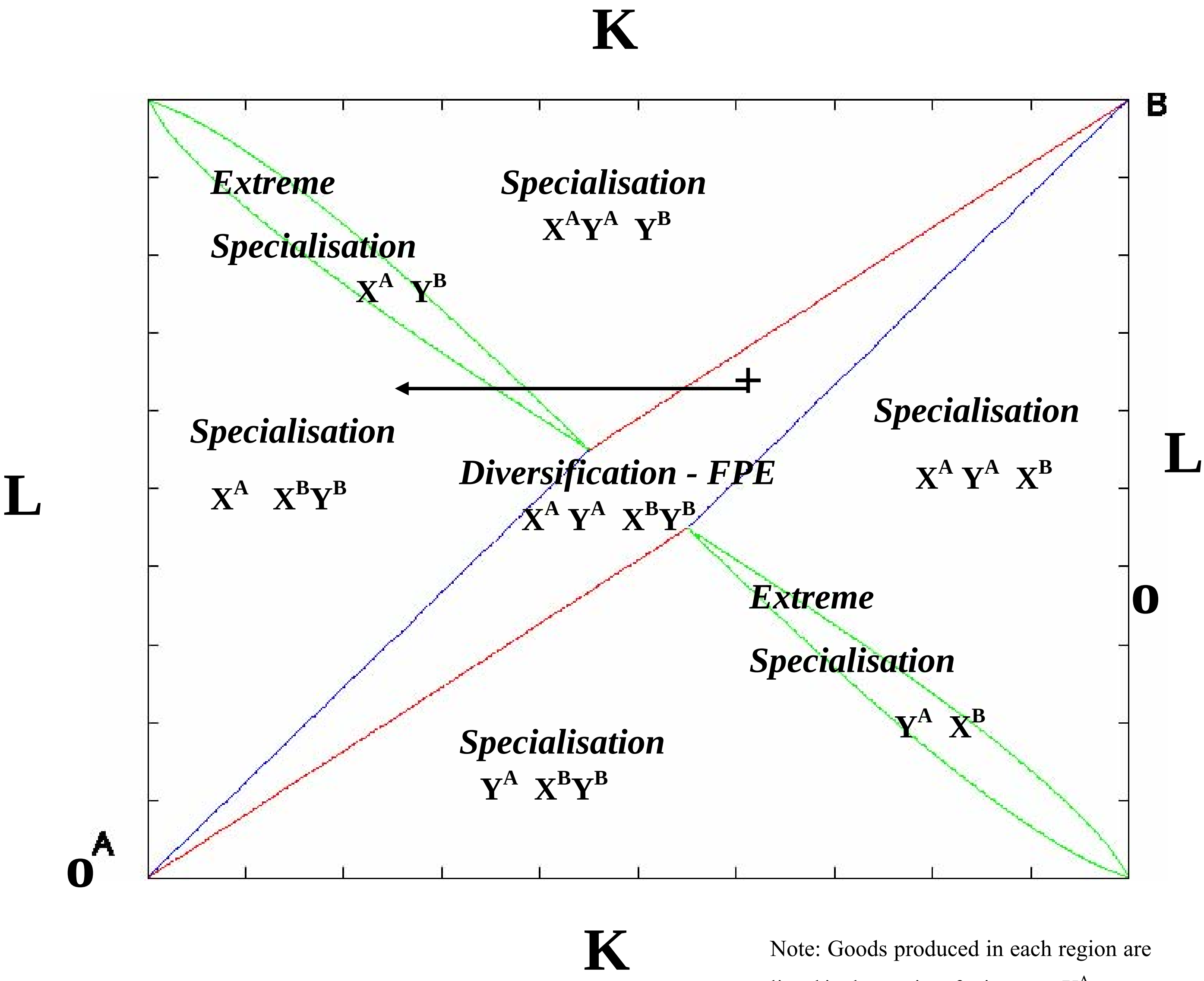
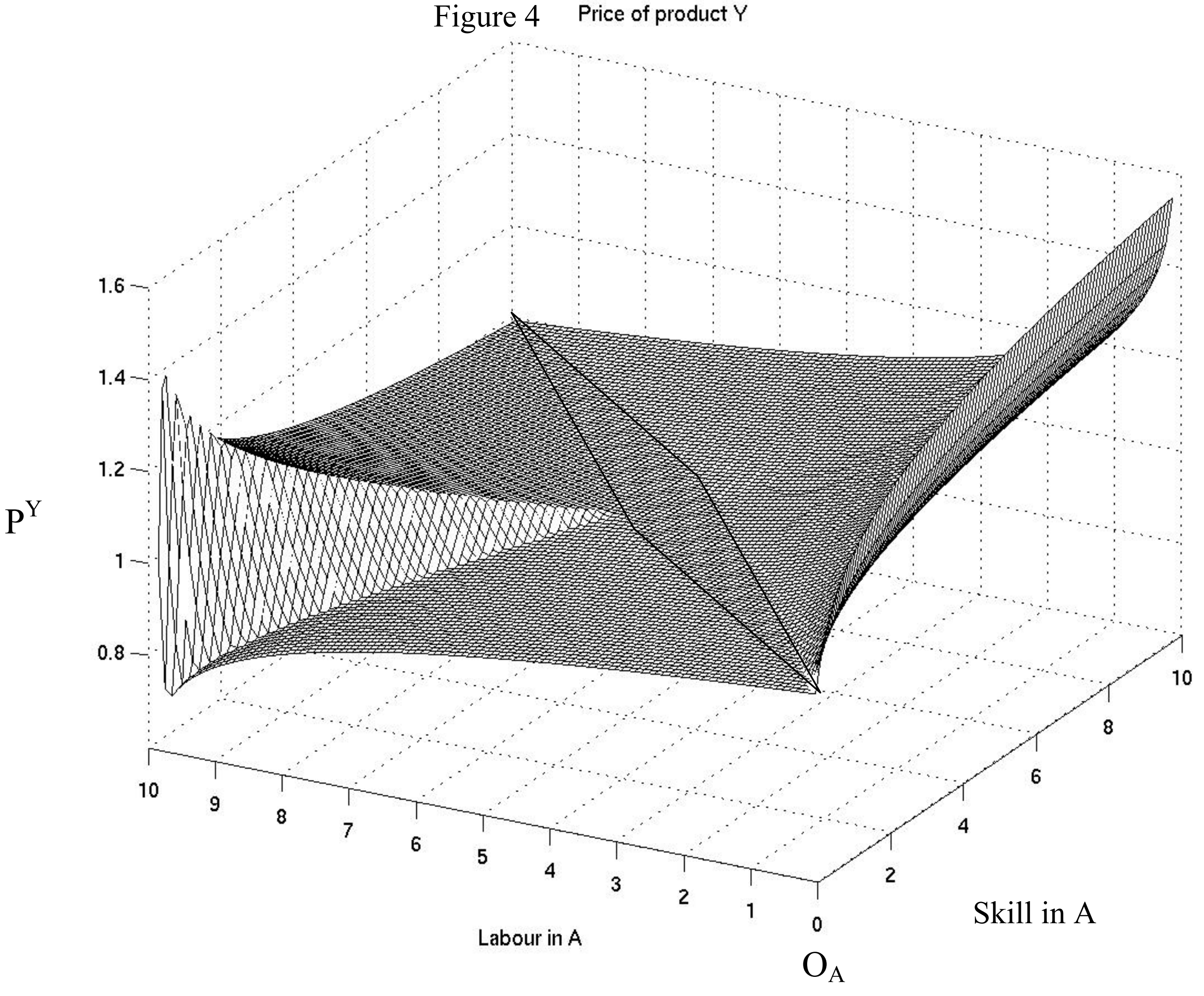


Figure 3 – Regions of Specialisation and Diversification



Note: Goods produced in each region are listed in that region, for instance X^A means good X is produced in country A .

Figure 4



Note: Figure 4 shows the p^Y surface from a perspective that gives the clearest view of the transitions from the specialization to extreme specialization regions in the left portion of the figure, but at the cost of obscuring the symmetric right portion. All the surfaces in Figures 4-8 are symmetric.

Figure 5 - Surface for r^A

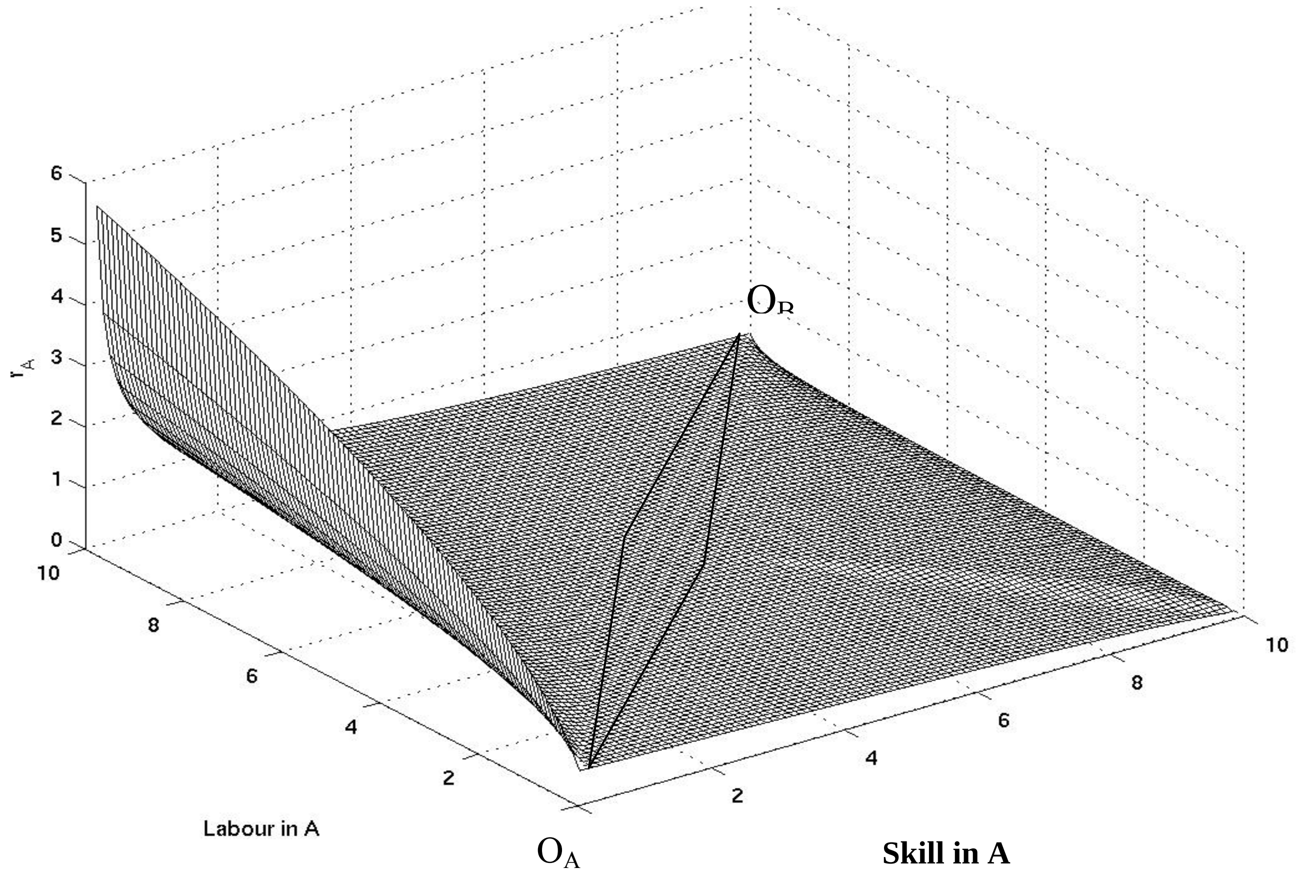


Figure 6 - Surface for r^B

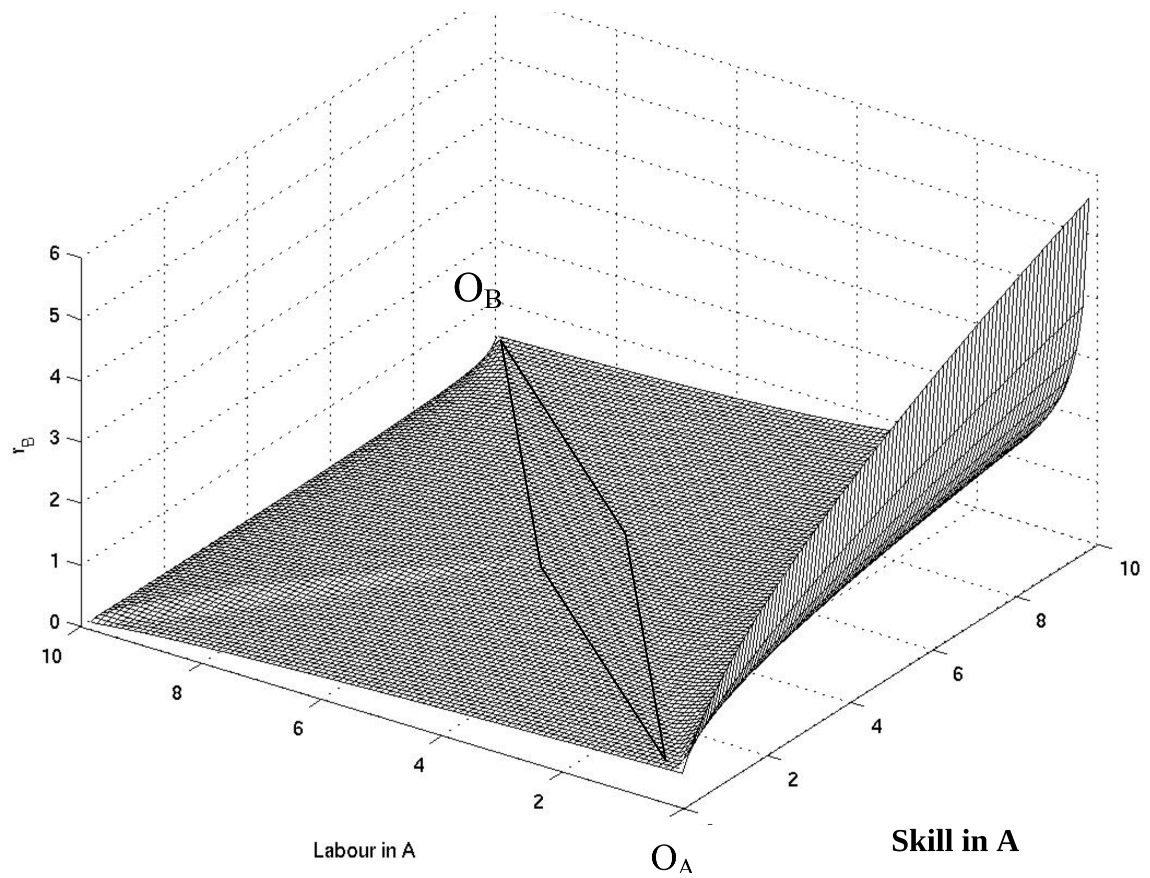


Figure 7 - Surface for w^A

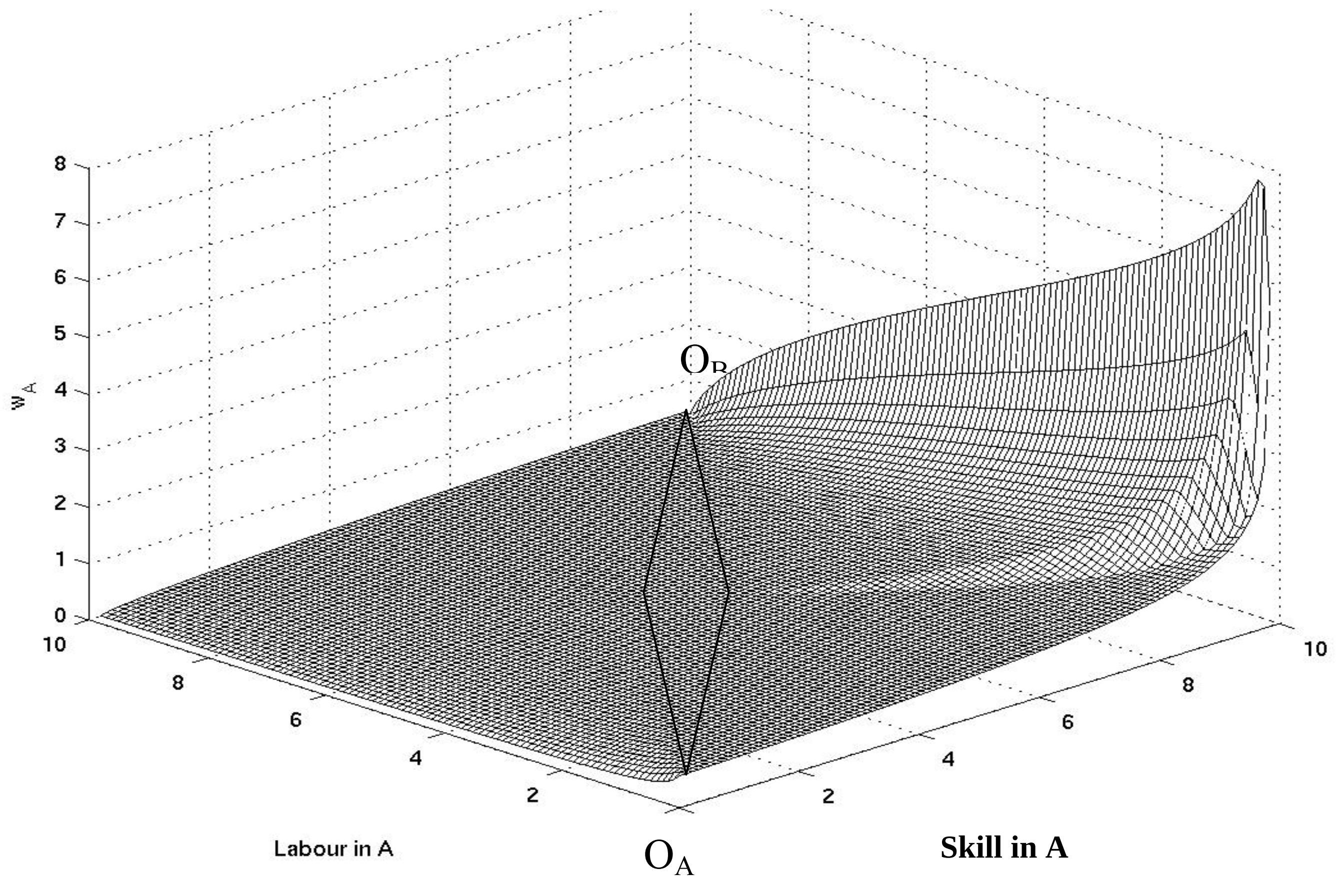


Figure 8 - Surface for w^B

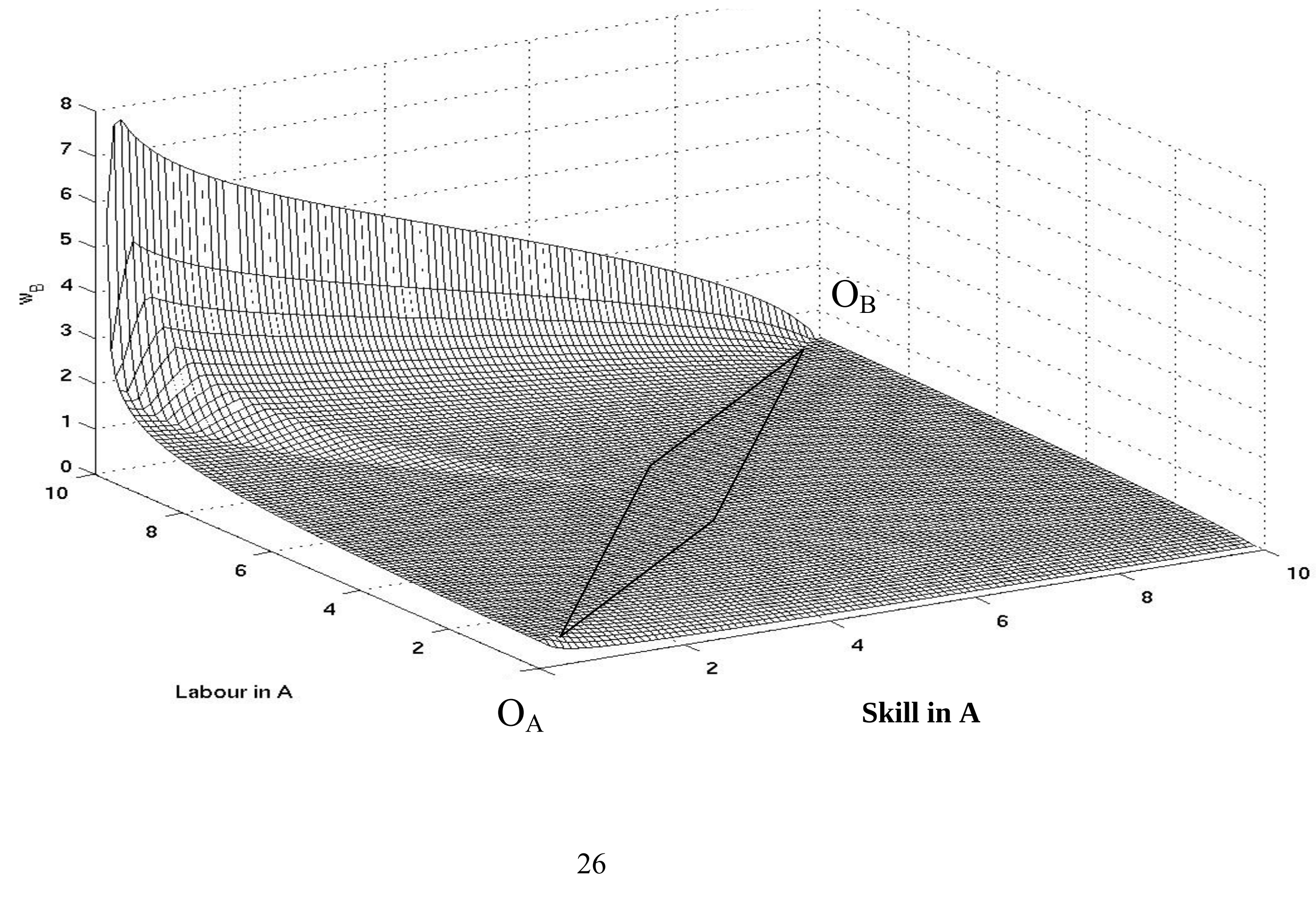


Figure 9 – Free Trade Inequality Surfaces

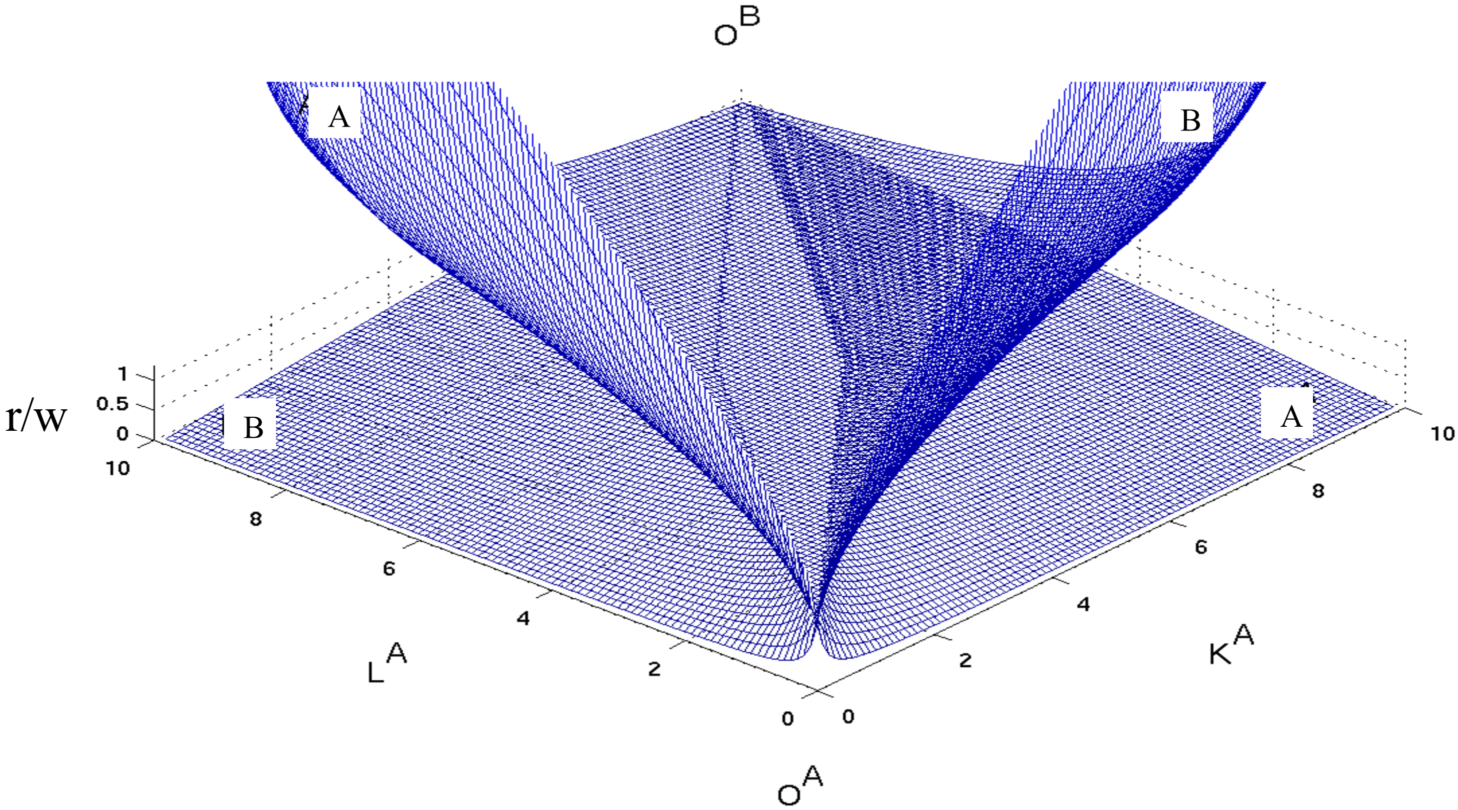


Figure 10 –Effect of Migration Flows on Inequality

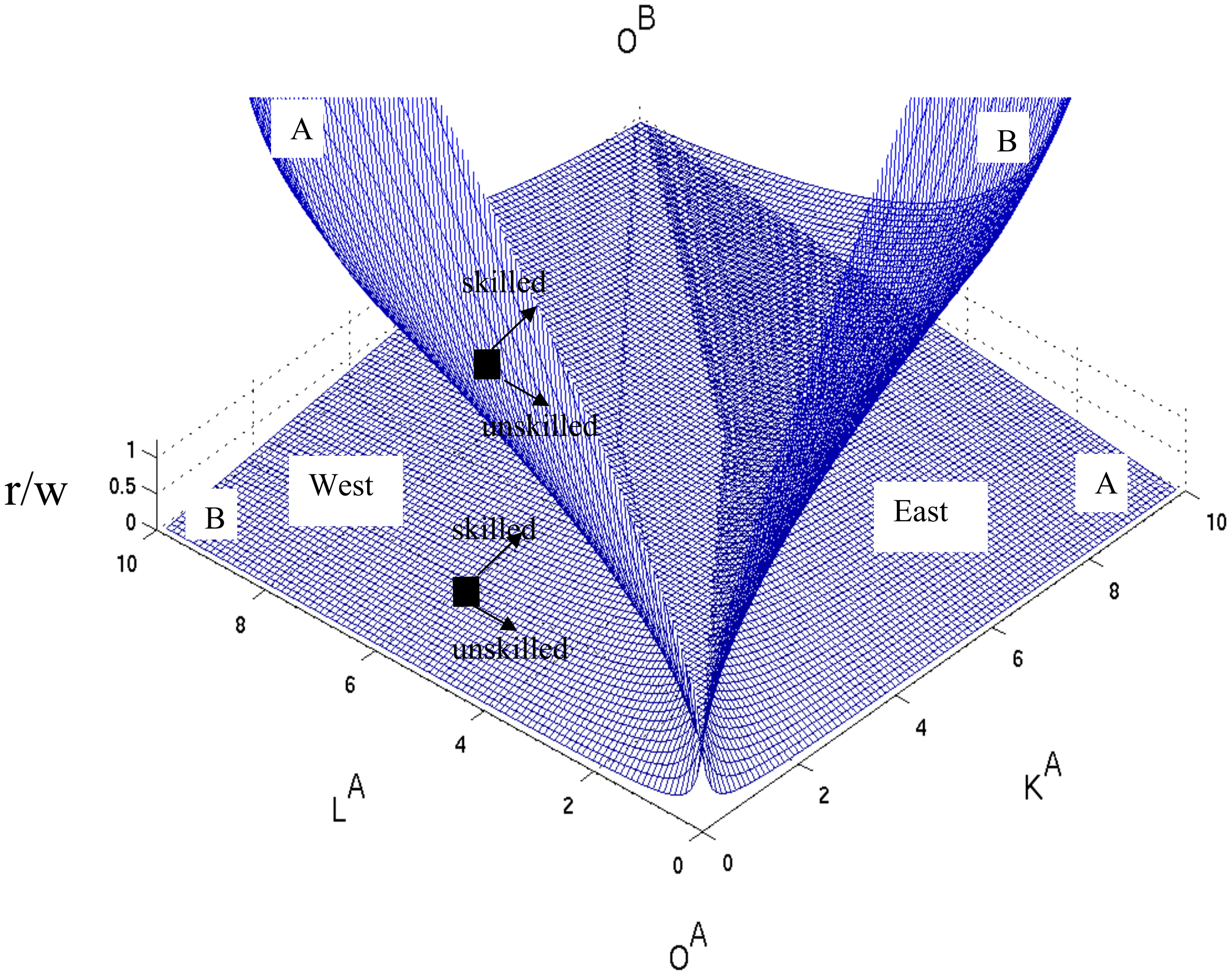


Figure 11 – Autarky Inequality Surfaces

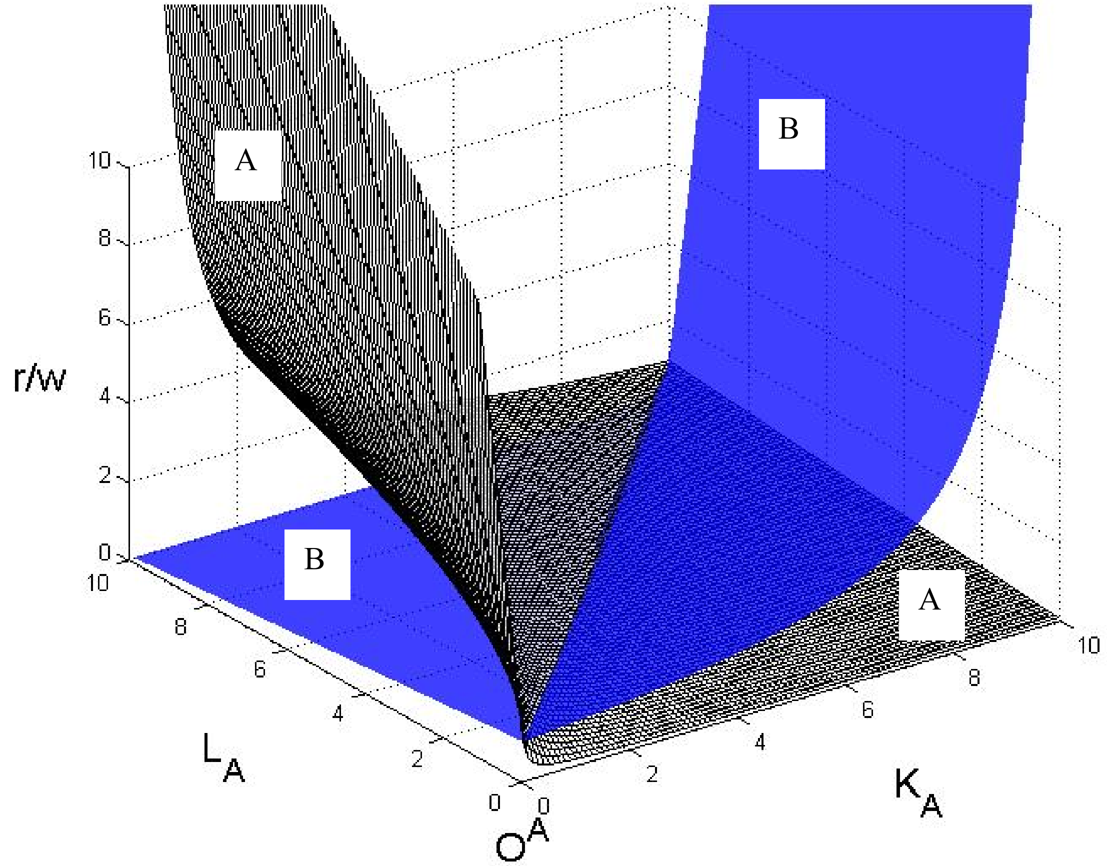


Figure 12 – Labour Endowment Expansion

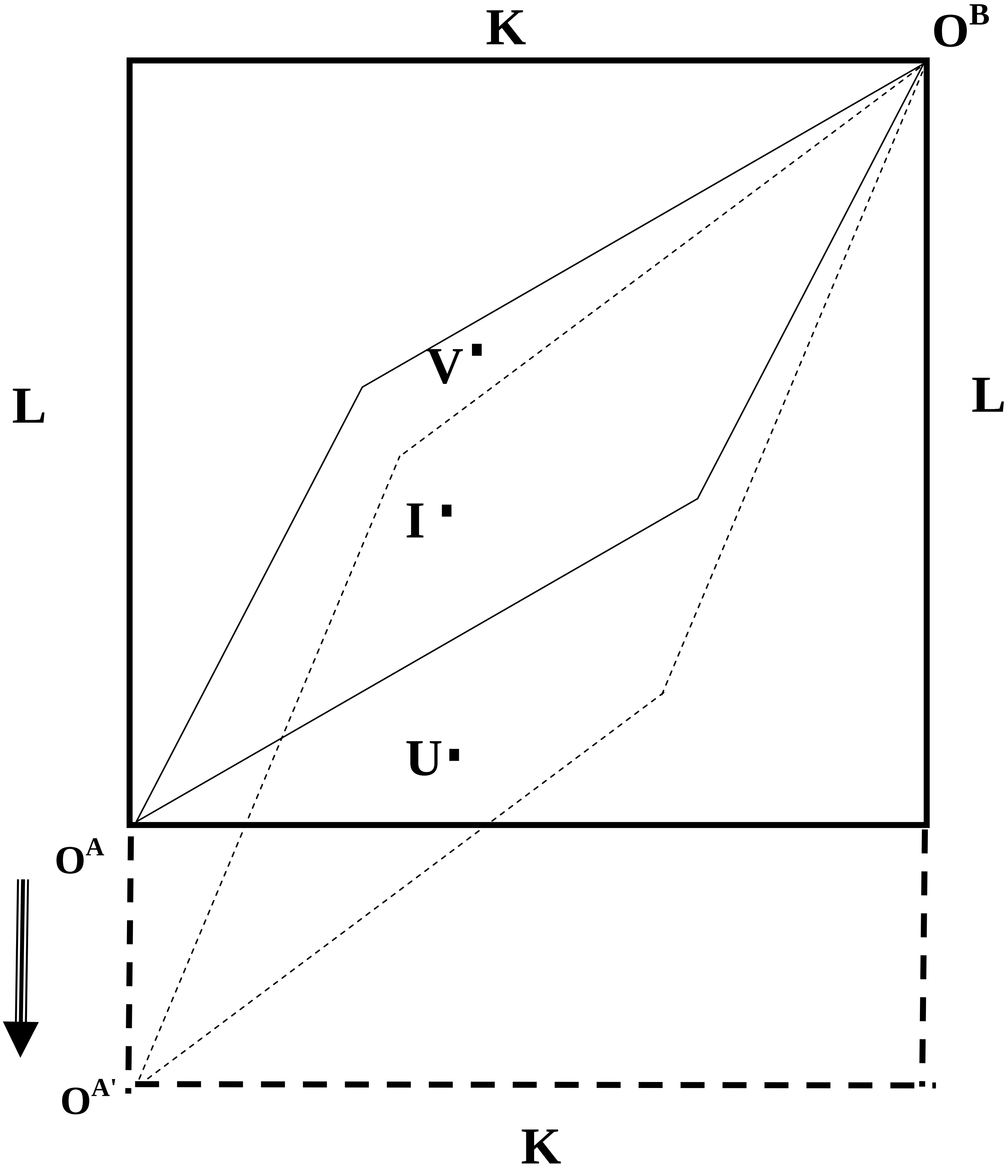


Figure 13 –Effect of Labour Endowment Expansion on Inequality

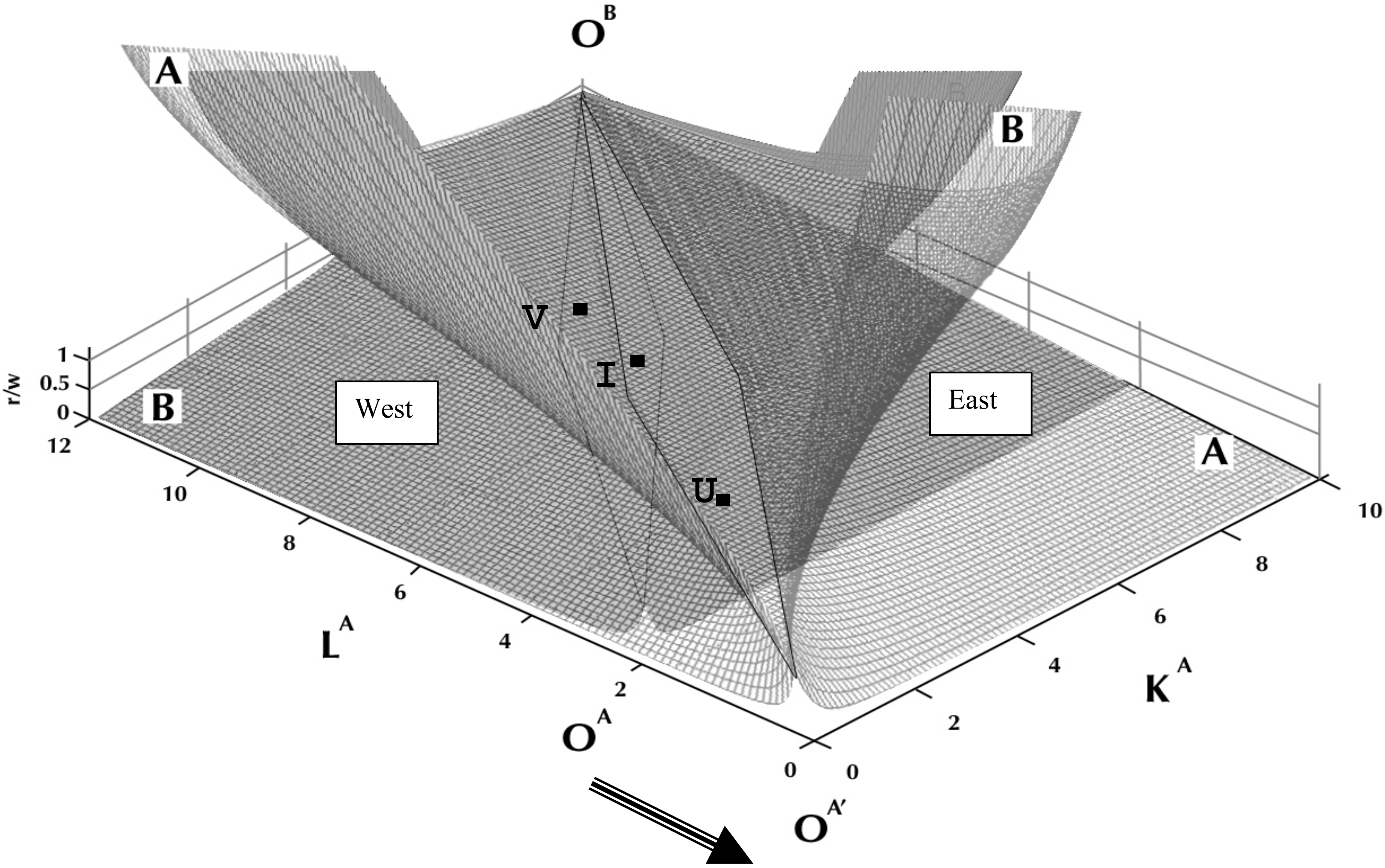


Figure 14 – Where do the Surfaces Cross?