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# Effects from trade with heterogeneous workers and minimum wages: numerical exercises

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Index

## 1- Introduction

In spite of the well known benefits from trade, this proposition has been criticised from many angles. One of the views that it is worth whiling to recall at this point is, for example, that in Neary (1982). The model developed there leads to the author to assure that - under special circumstances - the effects of trade may lead to an "immiserising reallocation" showing that national income may fall temporarily during the adjustment process. The introduction of the concept of immiserising reallocation tends to emphasise the likelihood that the effects on the economy may differ from than traditionally expected.

Along this line of concern about the effects of trade when there are market imperfections it seem to be of interest to make clear what are the consequences of the deviation of the traditional approach. The standard trade models, particularly Heckscher-Ohlin, assume that all factors are perfectly mobile and there are not distortions in good and factor markets. However, this is not always the case, and this is the point that have been explored in previous work and will continue in this one.

In fact, in the short run some factors are likely to be fixed or imperfectly mobile - the revision of this literature have been done in the previous work. There also, the case of imperfect mobility of labour has been explored by means of simulation exercises in an application of Leamer's (1980) lost-labour-time models. In this case, skills required in both sectors are identical but the worker faces a friction to the movement, in the form of a period of unemployment before finding a new job. Hence, the resulting unemployment is voluntary and occurs when the workers decide as convenient to leave, taking into account the loss in the form of searching time before being able to get the better job.

The focus of this work is quite similar, and it is in a way a continuation of it, but now considering that the workers to be reallocated are differentiated across sectors, that is, they possess certain skills that make them difficult or impossible to change jobs at the first impact after the shock. One of these possibilities is present in the specific factor model (Jones (1971)), where the specific factor has no alternative use and thus it is trapped in its sector. Two other alternatives will be analysed here. The first one, is a slight variation of the specific factor model incorporating downward rigid wages or the presence of a minimum wage regime. The second one, introduces the features in Mussa (1982) where the workers are not perfect substitutes across sectors, where the differences in productivity (and wages) impose an obstacle to the reallocation.

This work is organised as follows. The section 2 presents a brief summary of the most relevant theoretical aspects to be used in this work. The section 3 describes the models. There are two stages here: firstly, consider a first impact model where no reallocation at all is possible, with flexible and rigid wages alternatively, taking the Heckscher-Ohlin model as a reference framework; secondly, it is presented the description and application of Mussa's (1982) model where the units of labour are imperfect substitutes across sectors. Here also some exercises of simulation are carried out. The final section concludes.

**2- Theoretical overview.**

Consider a small open economy that faces an external shock, for instance in the terms of trade. Under the standard Heckscher-Ohlin (HO) model of trade, where all factors are perfectly mobile, the impact will induce the reallocation of capital and labour according to the best use under the new environment, enabling to reap the full gains from a better reallocation.

However, for example when all the factors are not perfectly mobile this optimal allocation of factors is unlikely to be feasible. Suppose an extreme case where labour is factor specific, that is, there are a different profiles of workers in each sector differing in the skills required. This is in fact a version of Jones' (1971) model with labour instead capital as specific factor (SF model). As the specific factor has no alternative use it is trapped in its sector. Thus, at least in the short run, the firms will have no alternative that reorganise the production process given the substitution possibilities given by the factors (capital and labour) - similar as in the SF model with specific capital.

Consequently, in this case there is a restricted reallocation and hence, lower gains from trade. Note that it is interesting to compare the amount of labour that the expanding sector would need to respond to the shock if workers were homogeneous and the amount of labour specific to that sector available (the sector cannot attract more workers even with higher wages because there not suitable workers available for that job at the moment). This comparison make possible to figure out the restriction imposed by the specificity of labour to the reap of the full gains of trade. Here also there are important distributional effects, and full employment is ensured provide wages are fully flexible.

An intermediate case -in between no movement and immediate reallocation - it is possible to find many cases where there is a sluggish adjustment where factors reallocate gradually. The literature gives many explanations for the imperfect mobility of labour, and they have been already summarised in the previous work. Under certain circumstances, after enough time -in the long run- things will sort out, each factor will be able to find its best allocation assuring the factor return equalisation across sectors leading to the HO results. However, this long term horizon is out of the focus of this work.

But return now to the first impact of the shock when workers are differentiated. Suppose that wages are not fully flexible, for example wages are downward rigid or there is a minimum wage mechanism in the economy. If wages are downward rigid there will be an amount of workers unemployed in the declining sector: workers cannot reallocate immediately due to their specificity, nor it is possible to work for a lower wage (wages cannot go down or to fall below the minimum) in the same job.

Then, when workers cannot reallocate immediately because they are not prepared to the change it is likely that some unemployment appears. As a permanent inability to change job, this would imply a definitive shrink in the labour endowment of the economy, however this is not a necessary result. Expanding again the temporal horizon, a proper application of time and effort may be effective in conferring to the transient workers the required skills in the expanding sector. Re-training activities and recycling schemes are suppose to show its fruits as times go by. The long-term effects of this activity (re-training or recycling activities) will not be explored in this work.

Finally, to finish off the theoretical framework to be used in the exercises below, suppose now that workers are differentiated -but more gradually- as in Mussa (1982). In this case the units of labour are imperfect substitutes across sectors, which implies an obstacle to reallocation. It can be assumed that the units of labour that each worker owns are not homogeneous measured in efficiency units, hence workers productivity (and wages) differ across sectors, consequently it is costly to change jobs. The imperfect substitutability of labour is modelled by means of an input transformation curve, and the degree of labour mobility is measured by the elasticity of substitution of this transformation function. For the case of an infinite elasticity of substitution between workers (perfect substitutability) this model replicates the SF model.

## 3- Modelling and simulations

The economy-wide effects of a shock will be analysed by means of an application of a static computable general equilibrium trade model under the different alternatives of modelling. The trade model used for this purpose are similar in many respects, following the standard tradition, perfect competition, constant returns to scale and homogeneous products. The variations for each model will be discussed in each case; the complete specification of the models is presented in Appendix 1.

The exercises of comparative static are carried out by simulating a external shock, say a terms of trade shock, for example an increase in the international price of the exportable good (sector A). The whole set of results is presented in the Appendix 2.

In this section two models with be analysed. The Model 1, called the “First impact model” introduces the presence of downward rigid wages in a SF type model with specific labour, causing involuntary unemployment. The Model 2 is an application of that analysed by Mussa (1982) where there is as a loss for moving units of labour imperfectly substitutes across sectors.

The common general settings for both models are as follows. The economy is supposed to consist of two sectors of final goods, using two factors, capital and labour. Factor supplies are considered fixed (exogenous). Both goods are tradable: the exporting sector is labour intensive, and the importing sector is capital intensive. The production functions are Cobb-Douglas, and goods market are perfectly competitive and without distortions. The economy is a price taker one, and the exchange rate is taken as the numeraire. The government is not modelled explicitly, and there is no restrictions to trade. The household’s income is totally spent in both final goods (no savings), and its utility is modelled as a Cobb-Douglas function.

### 3.1 Model 1: First impact model

#### a) The model settings

Recall first, to help in the exposition, the basics in the HO paradigm. In the model, perfect competition firms in the productive sectors ensures goods price equal to unit costs, from the long run zero profit condition, as follows:

$$\pi_i = P_i Q_i - w L_i - r K_i = 0 \qquad \text{i=A,B} \qquad (1)$$

where $\pi_i$ is firm i's profit, $P_i$ the good i's price, $Q_i$ the production function in sector i, $w$ the wage rate, $r$ the capital rental, $L_i$ the labour employment in sector i and $K_i$ the capital employment in sector i. From the first order profit maximisation conditions, workers will be hired up to the point where expression (2) holds; labour will reallocate accordingly, and with perfect mobility eventually wages are equalised across sectors will full employment of labour.

$$w = P_i MP_{Li} \qquad \text{i=A,B} \qquad (2)$$

where $MP_{Li}$ is the marginal productivity of labour in sector i.

Recall now the basics of the SF model with labour as the specific factor (capital perfectly mobile). In this case as labour is specific it has no alternative use, it cannot be reallocated across sectors after a shock. Thus the return of capital is equalised across sectors but the return to labour is a residual from the zero profit condition - consequently, wages differ across sectors. In this case capital is reallocated responding to the changes in the factor return variations, leading to the firms to change the mix of factors in production. As labour is trapped in its original allocation, full employment is ensured provided wages are fully flexible. There are important distributional consequences: the effects on factor return show the workers in the expanding sector favoured with a better wage, those in the contracting sector suffering a wage loss, while capitalists fate lies in between.

Introduce now into the SF model with labour specific the presence of minimum wages. As mentioned before, under perfect competition firms will hire up workers up to the point where the value of the marginal productivity equalise wages, and with perfect mobility of labour workers will reallocate up to the point wages are equalised across sectors. However, the full employment mechanism does not work in presence of minimum wages. Minimum wages may operate in the economy due to institutional regulations, unions activities etc. In this case involuntary unemployment may appear.

**b) Simulation results**

This section presents results of the same exercise in each of the settings described in this section. Each time it will be assumed a favourable shock in the terms of trade taking the form of an increase in the international price of the exportable good. The reason of the selection of this particular experiment is to analyse the effects of the reallocations of differentiated labour under different settings in the most favourable scenario for the economy under study.

The following tables show the different effects of a moderate increase of the international price of the exportable good (sector A), say 10%, under different frameworks on labour allocation (Table 1), wages (Table 2) and output (Table 3), where the HO model is taken as the reference framework. The whole set of results is presented in the Appendix 2.

The table 1 compares the allocation of labour under the different settings (HO, SF, SF with minimum wages). As it shows, with perfect mobility of labour the economy would have increased the employment in Sector A about a 37% (subtracted from the other sector). As it is quite obvious, with labour sector specific no immediate reallocation is possible, and the effects are completely reflected on factor returns (see Table 2, middle).

Note that, under a minimum wage regime operating the shock (even being favourable to the economy) may make this minimum floor to be effective in the contracting sector, consequently leading to unemployment. In this case this could be seen as the very first impact of the shock - in the very short run. The effect of the presence of minimum wages would have been more pronounced if instead a favourable shock the opposite scenario were supposed, and in this case unemployment would have been generalised to the whole economy.

Table 1: Labour allocation under different models

| HO model | INITIAL | Allocation | % |
|---|---|---|---|
| LA | 900 | 1232.84 | 36.98 |
| LB | 400 | 67.16 | -83.21 |
| SF model | | | |
| LA | 900 | 900 | 0.00 |
| LB | 400 | 400 | 0.00 |
| SF min. w. | | | |
| LA | 900 | 900 | 0.00 |
| LB | 400 | 359.35 | -10.16 |

The table 2 shows also other interesting facts. Note that in spite of the unemployment caused in the sector B by the minimum wage, those still working are better off under this regime than without it (see table 2, second and third panel). Another distributional effect may be noted: as it is well known from the traditional trade theory it is possible to identify gainers and losers from trade - in the short and in the long run (Mussa, 1974, Mayer 1974) - by the effects on the return to factors associated to its owners, but in the very short run (first impact) we can identify a new category: the unemployed (receiving no return at all).

Table 2: Wages comparison for different models

| HO model | INITIAL | Wage | % |
|---|---|---|---|
| w | 1 | 1.21 | 21.00 |
| SF model | | | |
| wA | 1 | 1.12 | 12.29 |
| wB | 1 | 0.97 | -3.28 |
| SF min.w | | | |
| wA | 1 | 1.14 | 13.55 |
| wB | 1 | 1 | 0.00 |

The table 3 shows the effects of the shock on the economic structure under the different settings. The most important part of the table is at the very bottom, where the computation of the GDP at current prices is computed. The results are as expected, specially in the comparison between the HO and the SF model. However, the fall in the GDP caused by the presence of the minimum wage regime it is a -not surprising but- remarkable result. Then, as a final comment from this table it is possible to assure that it is highly likely that when workers cannot reallocate immediately because they do not posses the required qualifications for the new job, the presence of a regime of minimum wages generates unemployment as a first impact from the shock, affecting national output negatively.

Table 3: Output comparison for different models

| HO model | INITIAL | Output | % |
|---|---|---|---|
| QA | 1200 | 1808.16 | 50.68 |
| QB | 800 | 162.54 | -79.68 |
| SF model | | | |
| QA | 1200 | 1225.03 | 2.09 |
| QB | 800 | 773.74 | -3.28 |
| SF min. w. | | | |
| QA | 1200 | 1238.74 | 3.23 |
| QB | 800 | 718.70 | -10.16 |
| | HO | SF | SF m.w |
| GDP | 2151.51 | 2121.27 | 2081.31 |

### 3.2 Model 2: Mussa's model application

This second model follows the lines developed in Mussa (1982), where the capital is specific and labour is imperfectly mobile across sectors. Imperfect mobility of labour comes from the fact that labour units are imperfect substitutes across sectors, modelling the set of possible allocations as a convex (upwards) input transformation curve; the degree of labour mobility is measured by the elasticity of substitution of this transformation function.

## a) The model

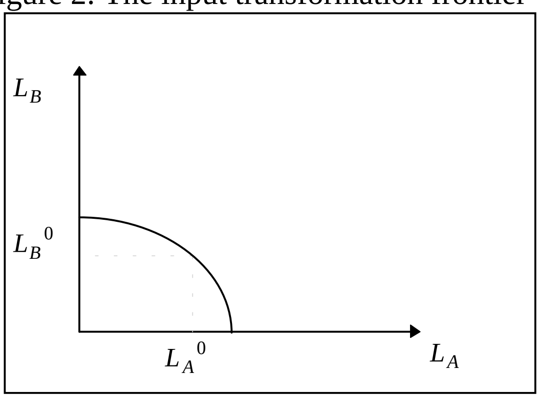
In the expression (2) before, it was stated that under perfect competition workers will be hired so as to equalise the value of marginal productivity and the wage rate. In this model workers are mobile but not homogeneous, that is, workers productivity (and wages) varies across sectors. Then, according to expression (3) firms will hire up workers up to the point where:

$$w_i = P_i MP_{Li} \qquad i = A, B \qquad (3)$$

The units of labour that each worker owns differ in efficiency, then it will be easy for those with higher efficiency to move first, that is, he/she will be more easily absorbed by the other sector. To determinate the allocation of labour in this case, a more explicit treatment of the input transformation function is required. The input transformation function can be represented in the $L_A$ , $L_B$ plane as shown in the figure 2, expressing conveniently $L_B$ as a function of $L_A$ as $L_B = H(L_A)$, with $H' < 0$, $H'' < 0$.

The shape of the input transformation frontier shows that workers are imperfect substitutes across sectors, and it is expressing the fact that the amount of labour that each worker owns is measured in different units, say in efficiency units. Note that, for homogeneous workers the figure 2 would show a straight line where the with infinite elasticity of substitution between labour units.

Figure 2: The input transformation frontier




The marginal input transformation rate ($MITR$) can be defined, for discrete changes and adding a minus to make the measure positive, as in the expression (4):

$$MITR = -\frac{\Delta L_B}{\Delta L_A} \qquad (4)$$

This expression shows that the $MITR$ measures the amount of (physical) units of labour that must leave the sector B in order to increase the employment in sector A in one (effective) unit (analogously in the reverse case). For infinitesimal changes the $MITR$ shows (minus) the slope of the input transformation curve at any point. Hence, a worker moving across sectors along the input transformation curve, should take into account the rate at which his/her units of labour in one sector are transformed before reaching its final destination.

Using the expression (4) the elasticity of substitution, $\sigma$, between $L_A$ y $L_B$ can be expressed as follows:

$$\sigma = \frac{\Delta(L_B / L_A) / (L_B / L_A)}{\Delta MIRT \; / \; MIRT} \qquad (5)$$

The expression (5), $\sigma$ indicates how the allocation varies as long as the slope of the function varies, and it is a measure of the curvature of the input transformation frontier. Then, when small changes in the slope causes major changes in the allocation it is revealing a flat frontier (high $\sigma$). Thus, the elasticity of substitution can be used as a measure of the degree of labour mobility.

According to what have been said, the worker's decisions to move across sectors - for instance from the contracting sector (say sector B) to the expanding one (say sector A) - will be based on the expression (6), assuming that the workers have all the relevant information at the moment of making the decision:

$$P_B \; MP_{LB} \;\; MITR \leq P_A \; MP_{LA} \qquad (6)$$

The expression (6) makes clear the fact that *the worker will move if and only if the return to leaving (physical) units of labour from sector B in order to increase employment in sector A in one unit is less than the return of the one (efficiency) unit reaching the expanding sector of destination*. Analogously as before, when the equality holds the worker is indifferent to move, which places the limits to the wage gap across sectors. To sum up, the worker will be willing to move whenever the loss suffered due to the presence of a transformation function of labour is outbalanced by a higher enough wage in the other sector.

A centrally decided allocation of labour is developed in Mussa (1982, pgs.126-128). The optimisation program of suppliers of labour is to maximise total labour income given the wages paid in each sector and subject to the constraint of the input transformation function. The optimal solution to this program requires that the wage rate ratio to be equal to minus the slope of the input transformation function. The solution exactly corresponds to the development presented above, considering the expression (3) together with (6) hold as an equality.

**b) Simulation results**

In this section the exercises presented are similar to the previous ones, analysing the effects of a favourable external shock, in the form of an increase in the international price of the exportable good. In this case, the simulations are carried out for different level of shocks and under different alternatives of degree of imperfect mobility of labour.

Analogously as before, consider under which conditions workers are willing to move in this model. To this purpose the table 4 will help. To its construction the starting point is consider an arbitrary allocation of labour (in this case the benchmark one) and then analyse the moving decision of the marginal worker (i.e. that one with the highest efficiency in terms of the alternative allocation). The table 4 presents the computation of the expression (6) placing both terms in the left hand side of the inequality, for alternative $\sigma$ and prices.

The workers in the sector of lower wages will have to decide whether to remain or change sector, and to make up their minds they must be aware of the imperfect mobility. Thus, the decision of movement will be based on expression (6), assuming that they have all the relevant information at that moment. As can be deducted from the text above, only when the resulting value is negative the worker is willing to move.

The table shows that the degrees of labour mobility - regulated by $\sigma$ - is a crucial parameter at the moment of taking the decision to move. When the mobility is high (higher values of $\sigma$) the workers in the sector B are willing to move even for low increases in prices (and wages) in sector A. However, when the degree of factor mobility is very low (low $\sigma$) it is required a very high increase in prices (say, 350%) to make worth whiling the movement. Thus, not any shock will induce workers to move.

Table 4: Worker decisions on movement (see text for explanations), for different prices and $\sigma$.

| $\sigma$ | $P_A$=1.1 | $P_A$=1.2 | $P_A$=1.3 | $P_A$=1.4 | $P_A$=1.5 | $P_A$=1.6 | $P_A$=3.5 |
|---|---|---|---|---|---|---|---|
| -10 | -0.46 | -0.76 | -0.91 | -1.06 | -1.21 | -1.36 | -4.21 |
| -5 | -0.41 | -0.71 | -0.86 | -1.01 | -1.16 | -1.31 | -4.16 |
| -2 | -0.28 | -0.58 | -0.73 | -0.88 | -1.03 | -1.18 | -4.03 |
| -0.5 | 0.75 | 0.45 | 0.30 | 0.15 | 0.00 | -0.15 | -3.00 |
| -0.25 | 3.56 | 3.26 | 3.11 | 2.96 | 2.81 | 2.66 | -0.19 |

A second step in the analysis will be to compare the effects of an increase in prices for different degrees of labour mobility in the economy. The case of an increase in prices of 60% was selected. As expected, the degree of labour mobility affects positively national output, as can be seen at the very end of the Appendix 2 (GDP computation at current prices).

Table 5: Effects on factor returns of a rise in the price of good A on factor returns (in percentage)

| | $\sigma$ = -10 | $\sigma$ = -2 | $\sigma$ = -0.5 |
|---|---|---|---|
| $w_A$ | 46.66 | 53.11 | 59.77 |
| $w_B$ | 81.15 | 31.04 | 1.03 |
| $r_A$ | 107.77 | 82.60 | 60.70 |
| $r_B$ | -44.80 | -23.69 | -1.02 |

Note: $w_A$ , $w_B$ , $r_A$ , $r_B$ are the factor returns

The complete set of results is presented in the Appendix 2, and to this stage, it will be recalled only the effect of this shock on factor returns. This is presented in the table 5, for alternative $\sigma$, expressed in percentage. This table shows that as labour is imperfectly mobile while capital is specific, always the wages rates are inside the range determined by the changes in the capital return (SF type result, or more generally Hill and Mendez's (1983) type results).

**5- Final comments**

The central point of this work is to investigate the general equilibrium effects from a shock in an economy where labour workers are differentiated, by means of simulations using a static CGE model of trade. To this purpose two alternative models are analysed.

In the previous work the effects of external shocks on economies with imperfectly mobile labour has been worked out by an application of Leamer's (1980) lost-labour-time model. In this case, labour units are homogeneous - the skills required in both sectors are identical - but there is a friction to the movement that cause transitory unemployment. There, the imperfect mobility is modelled as a loss of units of labour during the transfer across sectors, an "iceberg" type movement, due to searching time etc.

In this work the focus has been on models with differentiated workers. Firstly, a version of Jones's (1971) model but with labour instead capital is used, including the presence of downward rigid wages or of a minimum wage mechanism. Secondly, an application of Mussa's (1982) model is worked out, where labour employed in each industry are considered imperfect substitutes.

The first model emphasises the first impact from the shock: when wages are downward rigid it is likely that unemployment appear. The reason may be as simple: workers cannot reallocate immediately due to their specificity, nor it is possible to work for a lower wage - due to the minimum floor - in the same job. The standard trade theory identify gainers and losers from trade associated to the effect on factor returns (in the short and long run), but in the very short run (first impact) we can identify a new category of losers: the jobless. This first impact effect should not be overlooked; however, good economics and best politics can persuade us that a little bit of patient can pay.

The second model suppose a more gradual differentiation between units of labour. Workers are imperfect substitutes across sectors, making imperfect the mobility across sectors. The set of possible allocations is modelled as an input transformation curve; the degree of labour mobility is measured by the elasticity of substitution of this transformation function.

Some exercises of simulation were performed, in the form of a favourable terms of trade shock. As expected, the national output and welfare -even facing a favourable shock - depends on the flexibility to reallocate the factors of production. Unemployment in the Model 1 and the differential in productivity for the transferring units in the Model 2, implies that the economy is unable to fully reap the expected welfare gains.

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# APPENDIX 1

## *1 Basic model:*

(1) $C_A = \theta \frac{Y}{P_A}$

(2) $C_B = (1-\theta)\frac{Y}{P_B}$

(3) $P_A = w\, l_A + r\, k_A$

(4) $P_B = w\, l_B + r\, k_B$

(5) $C_A = Q_A - E$

(6) $C_B = Q_B + M$

(7) $k_A = \frac{1}{H_A}(\frac{w}{r}\frac{\alpha}{1-\alpha})^{1-\alpha}$

(8) $K_A = k_A\, Q_A$

(9) $l_A = \frac{1}{H_A}(\frac{r}{w}\frac{1-\alpha}{\alpha})^{\alpha}$

(10) $L_A = l_A\, Q_A$

(11) $k_B = \frac{1}{H_B}(\frac{w}{r}\frac{\beta}{1-\beta})^{1-\beta}$

(12) $K_B = k_B\, Q_B$

(13) $l_B = \frac{1}{H_B}(\frac{r}{w}\frac{1-\beta}{\beta})^{\beta}$

(14) $L_B = l_B\, Q_B$

(15) $K_A + K_B = K$

(16) $L_A + L_B = L$

(17) $Y = w\, L + rK$

(18) $P_A = P_A^W F$

(19) $P_B = P_B^W F$

(20) $P_A^W E - P_B^W M = 0$

a) In the HO model the endogenous variables are $C_A$, $C_B$ consumption, $Y$ income, $Q_A$, $Q_B$ output, $P_A, P_B$ domestic prices, $L_A$, $L_B$ labour allocation, $K_A$, $K_B$ capital allocation $w$ labour return, $r$ capital return, $E$ exports, $M$ imports, $l_A$ , $l_B$ unit labour demand, $k_A$ , $k_B$ unit capital demand, $F$ the foreign exchange rate,

b) In the SF model with labour as a specific factor the endogenous variables are $C_A$, $C_B$ consumption, $Y$ income, $Q_A$, $Q_B$ output, $P_A, P_B$ domestic prices, $K_A$, $K_B$ capital allocation, $w_A, w_B$ labour return, $r$ capital return, $E$ exports, $M$ imports, $l_A$ , $l_B$ unit labour demand, $k_A$ , $k_B$ unit capital demand, $F$ the foreign exchange rate; eliminating equation (16) and re-writing adequately equation (17).

c) In the SF model with minimum wages the endogenous variables are $C_A$, $C_B$ consumption, $Y$ income, $Q_A$, $Q_B$ output, $P_A, P_B$ domestic prices, $L_B$ sector B employment, $w_A$, labour return in sector A, $r$, capital return, $E$ exports, $M$ imports, $l_A$ , $l_B$ unit labour demand, $k_A$ , $k_B$ unit capital demand, $F$ the foreign exchange rate; eliminating equation (16) and re-writing adequately equation (17), $\overline{w}$ is the minimum wage that prevails (it is effective) in the contracting sector.

The exogenous variables are $P_A^W$ , $P_B^W$ the international prices, $H_A, H_B$ are the scale parameters in the Cobb Douglas function, and $\alpha$, $\beta$ the share of capital in total income in sectors A and B respectively.

***2 Mussa's model application:***

The input transformation curve is assumed to be a CET (Constant Elasticity of Transformation) function, with the required properties for the function $L_B = H(L_A)$, that is $H' < 0$, $H'' < 0$. The functional form of this curve is shown in the expression (A1):

$$Z = D\,(\delta\, L_A^{\phi} + (1-\delta)\, L_B^{\phi})^{\frac{1}{\phi}} \qquad \text{(A1)}$$

where $\sigma = \dfrac{1}{1-\phi}$ , $\phi > 1$, $\sigma$ the elasticity of substitution between $L_A$ y $L_B$, $Z$ is the "composite" amount of labour in the economy taken as exogenous, and $D$ a scale parameter (used for convenience to calibrate the CET function to the values in the benchmark data set).

From the expression (A1) it can be deducted an analytical form for the function $L_B = H(L_A)$, shown in the expression (A2):

$$L_B = \left[ \frac{(Z/D)^{\phi} - \delta L_A^{\phi}}{1-\delta} \right]^{\frac{1}{\phi}} \qquad \text{(A2)}$$

The $MITR$ shows (minus) the slope of the input transformation curve, and in the case under study an analytical expression can be derived for this ratio, adding a minus to the derivative of $L_B = H(L_A)$, which takes the form:

$$MITR = \frac{\delta}{1-\delta} \left[ \frac{(Z/D)^{\phi} - \delta L_A^{\phi}}{1-\delta} \right]^{\frac{1-\phi}{\phi}} L_A^{\phi-1} \qquad \text{(A3)}$$

The system of equations is similar to the basic model, maintaining equations from (1) to (14) and (18) to (20), suppressing (15) and changing equations (16) to (17) for:

(16') $w_A = w_B \dfrac{\delta}{1-\delta} \left[ \dfrac{(Z/D)^{\phi} - \delta L_A^{\phi}}{1-\delta} \right]^{\frac{1-\phi}{\phi}} L_A^{\phi-1}$

(17') $L_B = \left[ \dfrac{(Z/D)^{\phi} - \delta L_A^{\phi}}{1-\delta} \right]^{\frac{1}{\phi}}$

totalling 20 endogenous equations and 20 unknowns: $C_A$, $C_B$ consumption, $Y$ income, $Q_A$, $Q_B$ output, $P_A, P_B$ domestic prices, $L_A$, $L_B$ labour allocation, $w_A, w_B$ labour return, $r_A$, $r_B$ capital return, $E$ exports, $M$ imports, $l_A$, $l_B$ unit labour demand, $k_A$, $k_B$ unit capital demand, $F$ the foreign exchange rate.

The equations (16') and (17') include the parameters from the CET input transformation function, where $\sigma = \dfrac{1}{1-\phi}$, $\phi \rangle 1$, $Z$ is the "composite" amount of labour in the economy taken as exogenous, and $D$ is a scale parameter used to calibrate the CET function to the values in the benchmark data set.

# APPENDIX 2

BENCHMARK

| | Household | Sector A | Sector B | External | |
|---|---|---|---|---|---|
| Sector A | -1000 | 1200 | 0 | -200 | 0 |
| Sector B | -1000 | 0 | 800 | 200 | 0 |
| Capital | 700 | -300 | -400 | | 0 |
| Labor | 1300 | -900 | -400 | | 0 |
| | 0 | 0 | 0 | 0 | 0 |

## 1 -<u>Basic models</u>: Results after the terms of trade shock

### a) Heckscher-Ohlin

| | solution | % change |
|---|---|---|
| $C_A$ | 977.9602 | -2.20 |
| $C_B$ | 1075.756 | 7.58 |
| $Q_A$ | 1808.159 | 50.68 |
| $Q_B$ | 162.5372 | -79.68 |
| $P_A$ | 1.1 | 10.00 |
| $P_B$ | 1 | 0.00 |
| $K_A$ | 601.665 | 100.56 |
| $K_B$ | 98.335 | -75.42 |
| $L_A$ | 1232.836 | 36.98 |
| $L_B$ | 67.16413 | -83.21 |
| w | 1.21 | 21.00 |
| r | 0.826446 | -17.36 |
| Y | 2151.512 | 7.58 |
| $k_A$ | 0.33275 | 33.10 |
| $k_B$ | 0.605 | 21.00 |
| $l_A$ | 0.681818 | -9.09 |
| $l_B$ | 0.413223 | -17.36 |
| E | 830.1991 | 315.10 |
| I | 913.219 | 356.61 |
| F | 1 | 0.00 |

Note: $C_A$, $C_B$ represent consumption, $Q_A$, $Q_B$ production, $P_A$, $P_B$ domestic prices, $L_A$, $L_B$ labour allocation, $K_A$, $K_B$ capital allocation, w, r the factor returns, $k_A$, $k_B$, $l_A$ , $l_B$, the unit requirement of factors, E, I, F foreign trade and exchange rate

**b) Labour as a specific factor**

| | solution | % change |
|---|---|---|
| $C_A$ | 964.2173 | -3.58 |
| $C_B$ | 1060.639 | 6.06 |
| $Q_A$ | 1225.032 | 2.09 |
| $Q_B$ | 773.7424 | -3.28 |
| $P_A$ | 1.1 | 10.00 |
| $P_B$ | 1 | 0.00 |
| $K_A$ | 325.8267 | 8.61 |
| $K_B$ | 374.1733 | -6.46 |
| $w_A$ | 1.122946 | 12.29 |
| $w_B$ | 0.967178 | -3.28 |
| r | 1.033936 | 3.39 |
| Y | 2121.278 | 6.06 |
| $k_A$ | 0.265974 | 6.39 |
| $k_B$ | 0.483589 | -3.28 |
| $l_A$ | 0.734674 | -2.04 |
| $l_B$ | 0.516968 | 3.39 |
| E | 260.8152 | 30.41 |
| I | 286.8967 | 43.45 |
| F | 1 | 0 |

Note: $C_A$, $C_B$ represent consumption, $Q_A$, $Q_B$ production, $P_A$, $P_B$ domestic prices, $K_A$, $K_B$ capital allocation, $w_A$, $w_B$, r the factor returns, $k_A$, $k_B$, $l_A$ , $l_B$, the unit requirement of factors, E, I, F foreign trade and exchange rate

**c) Labour as a specific factor with minimum wages**

| | solution | % change |
|---|---|---|
| $C_A$ | 946.0477 | -5.40 |
| $C_B$ | 1040.652 | 4.07 |
| $Q_A$ | 1238.736 | 3.23 |
| $Q_B$ | 718.6951 | -10.16 |
| $P_A$ | 1.1 | 10.00 |
| $P_B$ | 1 | 0.00 |
| $K_A$ | 340.6524 | 13.55 |
| $K_B$ | 359.3476 | -10.16 |
| $w_A$ | 1.135508 | 13.55 |
| r | 1 | 0.00 |
| Y | 2081.305 | 4.07 |
| $k_A$ | 0.275 | 10.00 |
| $k_B$ | 0.5 | 0.00 |
| $l_A$ | 0.726547 | -3.13 |
| $l_B$ | 0.5 | 0.00 |
| E | 292.6885 | 46.34 |
| I | 321.9573 | 60.98 |
| F | 1 | 0.00 |
| $L_B$ | 359.3476 | -10.16 |

Note: $C_A$, $C_B$ represent consumption, $Q_A$, $Q_B$ production, $P_A$, $P_B$ domestic prices, $K_A$, $K_B$ capital allocation, $w_A$, r the factor returns, $k_A$, $k_B$, $l_A$ , $l_B$, the unit requirement of factors, $L_B$ is the amount of workers that remain working in the sector, E, I, F foreign trade and exchange rate.

**2 - Mussa's model application:** General equilibrium effects from a selected shock in prices (increase in $P_A$ = 60%)

| | Benchmark | $\sigma$ = -10 | $\sigma$ = -2 | $\sigma$ = -0.5 |
|---|---|---|---|---|
| $C_A$ | 1000 | 917.15 | 875.52 | 850.08 |
| $C_B$ | 1000 | 1467.44 | 1400.84 | 1360.13 |
| $Q_A$ | 1200 | 1558.29 | 1369.48 | 1205.28 |
| $Q_B$ | 800 | 441.62 | 610.51 | 791.82 |
| $P_A$ | 1 | 1.60 | 1.60 | 1.60 |
| $P_B$ | 1 | 1 | 1 | 1 |
| $L_A$ | 600 | 850.04 | 715.57 | 603.52 |
| $L_B$ | 400 | 121.89 | 232.95 | 391.86 |
| $w_A$ | 1.5 | 2.20 | 2.30 | 2.40 |
| $w_B$ | 1 | 1.81 | 1.31 | 1.01 |
| $r_A$ | 1 | 2.08 | 1.83 | 1.61 |
| $r_B$ | 1 | 0.55 | 0.76 | 0.99 |
| Y | 2000 | 2934.87 | 2801.68 | 2720.27 |
| $k_A$ | 0.25 | 0.19 | 0.22 | 0.25 |
| $k_B$ | 0.5 | 0.91 | 0.66 | 0.51 |
| $l_A$ | 0.5 | 0.55 | 0.52 | 0.50 |
| $l_B$ | 0.5 | 0.28 | 0.38 | 0.49 |
| E | 200 | 641.14 | 493.95 | 355.19 |
| I | 200 | 1025.82 | 790.33 | 568.31 |
| F | 1 | 1 | 1 | 1 |

Note: $C_A$, $C_B$ represent consumption, $Q_A$, $Q_B$ production, $P_A$, $P_B$ domestic prices, $L_A$, $L_B$ labour allocation, $w_A$, $w_B$, $r_A$, $r_B$ the factor returns, $k_A$, $k_B$, $l_A$ , $l_B$, the unit requirement of factors, E, I, F foreign trade and exchange rate

| | $\sigma$ = -10 | $\sigma$ = -2 | $\sigma$ = -0.5 |
|---|---|---|---|
| GDP | 2934.26 | 2801.67 | 2720.26 |