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Trade Labor, Market Rigidities, and Government-Financed Technological Change

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ABSTRACT

Trade, Labor Market Rigidities, and Government-Financed Technological Change*

This paper contributes to the debate on the effects of trade versus technological change on wage differentials. We propose an explanation of the stylized facts which is based on interactions between openness and technological change because of labor market institutions and government intervention. In particular, technology change is induced by rigid wage elements for a developed economy which is trading with less developed countries. With a binding minimum wage and given commodity prices, openness induces the government to subsidize technological innovation in the developed country because production activities in the sector hit by foreign competition would have to close down otherwise. The economy with a binding minimum wage and institutionally induced innovations differs from the flexible economy in the following way:

- The wage differential becomes more compressed the higher the minimum wage. Not only the wage of the unskilled is higher, but also the wage of the skilled is lower.
- The productivity of unskilled workers is higher in the sector intensive in its use.
- Skill intensity within the unskilled-labor intensive sector can rise although the wage of the skilled rises as well.

This perspective may explain why empirical studies have difficulties to find substantial effects of openness on wage differentials although product markets have become increasingly integrated. Moreover, it can explain why the volume of trade between developed and less-developed countries is relatively small. Finally our model yields predictions for developed countries with different labor market institutions that are consistent with empirical evidence.

JEL Classification: F1, F4, J3, O3

Keywords: Trade, government, minimum wage, technology change

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1 Introduction

This paper contributes to the debate on the effects of trade versus technological change on wage differentials. An extensive body of literature has discussed the effects of trade between developed and less developed countries (LDC's). The magnitude and relevance of the effects of openness on wage differentials are still subject to debate (see Johnson and Stafford (1999), Section 5.4, for a recent survey). Factor-content and price studies have difficulties to find substantial effects of trade on wage differentials across decades.[2] Moreover, the volume of trade between developed and less-developed countries is still relatively small in absolute terms (around 2% of GDP for OECD countries, see OECD (1997a)[3]). These two empirical observations are surprising because product markets have become increasingly integrated as trade barriers have been substantially reduced. Average ad-valorem tariffs fell from 40% to 4% since 1947 during eight rounds of GATT trade negotiations. We propose an explanation of these empirical findings which is based on interactions between openness[4] and government-financed technological change because of labor market institutions. In particular, our model points out a specific channel –defensive technology change. Because the size of the technological change is linked to rigid wage elements in the economy, the model can account for differences between the US and continental European countries resulting from differences in labor market institutions.

From a policy perspective it is important to understand the potential interactions between openness, factor prices, labor market institutions and technology changes. Although openness towards trade with less developed countries can have only small effects on the wage differential

[2] For example, Leamer (1998) finds significant effects of trade on wage differentials for the 70s whereas this is not the case for the 80s and 90s.

[3] The small size of the volume of trade extends to using manufacturing GDP instead of total GDP as reference. For the G7 countries the average trade volume with less developed countries is less than 3% of manufacturing GDP in the 90s.

[4] Note that we think about openness as potential for trade, e.g., market access. Actual trade is endogenous and not a good measure for openness as we will point out below.

in our model because of rigid wage elements, the distortion of the production mix in the economy might be considerable. This is potentially propagated dynamically through e¤ects on skill accumulation.[5]

We use a small open economy model with two sectors and two factors, unskilled and skilled labor. Developed countries have a comparative advantage in the production of the skill-intensive good. For ‡exible labor markets standard trade theory tells us that the wage of the skilled rises and the wage of the unskilled workers falls in the developed countries, if the economy opens up. Moreover, the developed country will export the skill-intensive good and import the unskilled-labor intensive good. These results will be modi…ed, if there exists a minimum wage in developed countries (DC's). Since prices are taken as given, the sector intensive in unskilled labor –the sector in which the LDC's have a comparative advantage– will have to close down in the developed countries. This might not be the case, if unskilled-labor-augmenting technological change (ULATC) takes place. With the new technology production of unskilled-labor intensive goods can be continued in the DC's because unskilled workers become more productive.[6] Costly innovations are consistent with pro…t maximization and perfect competition because the costs are borne by the government.[7] In this scenario the e¤ects of openness on the wage di¤erential are dampened compared to the ‡exible-economy case. The minimum wage not only compresses the wage di¤erential "from below", but also "from above" by lowering the wage of the skilled. The institutionally induced ULATC decreases the comparative advantage in the production of the skill-intensive good in the developed countries. This is why openness has smaller e¤ects on wage di¤erentials as well as trade volumes than in a ‡exible economy where no ULATC takes place.

[5] In this paper we take skill supply as exogenous. This is why we consider it a description of the medium run. However, we analyze the e¤ects on skill accumulation in a companion paper (Koeniger (2000)).

[6] In this case technological change is sector and factor speci…c. As we point out below increases in total factor productivity or skilled-labor augmented technological change also allow production to continue.

[7] We motivate below under what conditions it might be optimal for the government to bear the costs of innovation for given distributional preferences.

Our model highlights how labor market institutions induce the government to …nance technology change. It is true that by arbitrarily changing technology and hence making it the residual one can possibly generate every stylized fact. However, we point out a speci…c and arguably also realistic mechanism which determines the character and origin of technology di¤erences. We link the necessity and size of defensive innovations to institutional patterns so that we have a clear understanding why and how much of the innovation is induced. This allows us to check whether the predictions of our model are consistent with empirical evidence for developed countries with di¤erent labor market institutions. Noting that labor markets are relatively more ‡exible in the US than in continental Europe, we observe that empirically the wage di¤erential is indeed higher in the US. Moreover, the proportion of manufacturing trade with less developed countries is higher in the US as our model predicts. Finally, we generate empirical evidence for OECD countries that reveals that in countries with high unit labor costs governments …nance more R&D for industrial development during the period 1981-97.

Furthermore, our model can generate a fall in the relative wage of the unskilled and an increase of the skill-intensity in the unskilled-labor intensive sector. The increase of skill-intensity is often used as an argument against a major role of openness in explaining the rise of the wage di¤erential (see, e.g., Borjas, Freeman, and Katz (1997), p. 43).

In the version of the model presented in this paper the cost of switching technology is ad-hoc, i.e., it is an exogenous cost and does not depend on inputs used for production. This assumption is not essential, however, and can be relaxed. We mention how R&D can be modeled explicitly and how our results would be modi…ed. Moreover, one can also relax the assumption that R&D outcomes are certain. Details of these extensions are provided in a supplement to this paper and are available upon request.

From a policy perspective the government has two possibilities to improve e¢ciency in the second best environment of our model. It either can boost the productivity of the workers adversely a¤ected by opening up the economy while keeping their skill-level constant. This gives them a competitive advantage over their counterparts in the less-developed countries and is the scenario we analyze in this paper. Or it can subsidize skill accumulation to transform unskilled workers into skilled ones, i.e., the factor that is used intensively for the production of the good in which developed countries have a comparative advantage. This scenario will be analyzed in a companion paper in which we endogenize skill accumulation.[8]

Table1: Summary of the comparative statics: Effects of openness compared to autarchy

Cases Variables	flexible	constrained ULATC	Explicit R&D economy-wide	Explicit R&D sector-specific	Explicit R&D excessive
wage of the skilled: w_H	+++	++	++	++	+
effective wage of the unskilled: $w_{L;eff}$	- - -	- -	- -	- -	-
skill intensity unskilled int. sector: h_1	- - -	- -	- -	- -	-
skill intensity in skill int. sector: h_2	- - -	?	?	?	?
unskilled-labor int. production: $F^1(:)$	- -	-	?	-	?
skill intensive production: $F^2(:)$	++	+	?	?	?
trade volume unskilled int. good: X_1	- -	-	?	?	?
trade volume skill intensive good: X_2	++	+	?	?	?

Note: ULATC: unskilled-labor augmented technological progress

Table 1 summarizes the effects we will derive for the most important variables. The cells of the table display the effect of openness on the respective variables for the case considered as compared to the autarchy case. For instance, the first row and first column of Table 1 displays the result that in a flexible economy the wage of skilled workers w_H rises compared to autarchy. The effect is stronger than in the constrained economy which is indicated by the use of + + + instead of ++. In the table $F^i(:)$ denotes production in sector i, h_i is the skill-intensity in sector i and X_i are exports of good i if $X_i > 0$ and imports otherwise. The wage of an efficiency unit of unskilled labor is $w_{L;eff}$.

[8] Both scenarios are only meaningful if unskilled and skilled labor are imperfect substitutes. Perfect substitutability eliminates the problem which we are interested in.

Before we set up our model we now briefly want to summarize the existing literature.

1.1 Existing literature

The effect of trade on countries with binding minimum wages has been analyzed by Krugman (1995) among others. He assumes a big open economy so that the developed countries are able to sustain prices supporting the minimum wage by making the world supply of unskilled labor sufficiently scarce. In our model we consider a small open economy which makes technological change necessary to continue production in the unskilled-labor intensive sector.

The implications of our model for wage differentials and unemployment in the US versus continental Europe are akin to the ones in Davis (1998) who analyzes the effects of various technological changes in a global economy with a binding minimum wage in Europe. In particular, the case of exogenous labor-saving technological change in the unskilled-labor intensive sector in Europe is close to ours. However, in this paper we explain and motivate why such a technological change might happen and analyze the implications for trade between developed and less-developed countries.

Leamer (1999) analyzes the effects of a minimum wage in a small open economy model in which effort is endogenous. One implication of his model is that the increase in effort because of the minimum wage increases the marginal product of capital. Moreover, it decreases the wages of skilled workers and increases their effort. Hence, Leamer's model is able to generate a more compressed wage differential as our model does. However, there is no unemployment in his model. The implications for capital owners are different like the underlying mechanism of the model.

The possibility of defensive innovation has already been noted by Wood (1994, 1998).[9] Cardebat and Teiletche (1997) introduce defensive innovation into the calibration of their

[9] Factor-price induced technology change was discovered earlier (see Hicks (1935) and the survey of Thirtle and Ruttan (1987)). Cost-push induced innovation is also used in Bester and Petrakis (1998) who show in a framework of Cournot competition that the wage-productivity ratio is positively related to process innovation. Acemoglu (2000) analyzes factor-price induced technology change in a growth context.

model, but do not explicitly solve for the equilibrium. They model the feedback of trade on technology by assuming that the induced technological progress in a sector is proportional to the ratio of imports or exports of the good produced in that sector over output. This assumption is rather ad-hoc and misses one point made by our model presented below. Trade patterns depend on technology and hence taking actual trade patterns to approximate the trade-induced defensive innovation does not seem to be correct.

Thoenig and Verdier (2000) analyze the e¤ects of di¤erences in property right enforcement on technological change in a model of trade between developed and less developed countries. Better enforcement in developed countries induces skill-biased technological change. Since the trading countries completely specialize, trade-induced technology change implies initial "insourcing" of industries and a decrease of the wage di¤erential in developed countries. However, factor price adjustments potentially o¤set these e¤ects. On the transition path the wage di¤erential can increase whereas trade between countries is quite stable for certain parameter values. As in our model the link between factor price changes and trade volumes is destroyed because of trade-induced technological change.

In the model of Acemoglu and Zilibotti (1999) trade induces endogenous technology changes as well. However, in their model innovations depend on the relative skill supply and relative prices in the developed countries because there is no enforcement of property rights in the LDC's. Hence, trade induces skill-biased technological progress because the relative price of the skill-intensive good rises initially. Thus skilled workers become more productive in the long run.

The model of Burda and Dluhosch (1998) also analyzes interactions between trade and technology. However, the focus of the paper is on intra-industry trade. Moreover, in their framework the institutional settings do not feed back into technological innovation as is the case in our model.

The structure of the paper is as follows. Section 2 presents the basic static model. Section 3 studies the e¤ects of openness and presents some extensions of the model. We point out implications of our results in Section 4. We look at the empirical relevance of our model in Section 5 and conclude in Section 6.

2 The Model

Our analysis is nested in an augmented Heckscher-Ohlin (HO) model which is still the workhorse for the analysis of trade between developed and less-developed countries. The small open economy has two sectors and two factors.[10] Both sectors produce one final good using skilled (H) and unskilled labor (L) as inputs.[11] Without loss of generality let us assume that sector 2 uses a more skill-intensive technology than sector 1. In both sectors the technologies have constant-returns-to-scale (CRS). There is no factor intensity reversal.[12] Producers face the following decision problem:

A producer in sector i can move her production to sector j, $j \neq i$, at no cost,[13] she can close down operations at no cost, and, finally, she can continue producing in sector i.[14] Then she has to choose to produce either with the pre-existing technology or to switch technology at cost S_i. A positive switching cost is realistic and is, of course, necessary because otherwise we cannot generate trade-induced technological changes. Technologies would otherwise be

[10] The arguments we invoke for our proofs are partly based on the Stolper-Samuelson and Rybczynski theorem. As is well-known these do not necessarily hold for the general n factor and m sector case. See Ethier (1984) for details.

[11] It is standard to assume that skilled and unskilled labor are immobile between countries and mobile within countries. For a discussion of migration and adjustment costs resulting from labor reallocation in the context of globalization see Sapir (2000).

[12] Production functions with the same elasticity of substitution between factors in both sectors satisfy this assumption, e.g., Cobb-Douglas or Leontief production functions. Other types of production functions are not excluded as long as we are not in the parameter region in which the factor intensity indeed reverses.

[13] If switching of sectors were costly and lump-sum, nothing crucial would be added to our model. The expansion of the skill-intensive sector would be hampered by these costs and domestic factor returns in the sectors would differ by the cost of moving.

[14] Closing down can be thought of as moving production to a less developed country. Costs of closing down can easily be incorporated, but are not considered since they are not necessary in our model.

renewed at any possible point in time.[15] Switching technology within a sector is costly because of the R&D needed to develop the new technology.

We allow free entry. If production remains in the developed country, free entry implies that the unskilled-labor intensive sector will incur losses after the economy opens up because of the cost of technology change. Hence, it is always optimal to move production to the less-developed countries unless someone is willing to pay these costs. To keep our model simple we will assume that the costs of the technology change S are borne by the government which allows the new technology to be used without payment.[16]

Financing the necessary R&D will be optimal for the government[17], if we presuppose the following program for the government:

$$\min U$$

s.t.

$$w_L \geq w_L^{min}$$

$$T = S + UB .$$

The government minimizes unemployment under the constraint that unskilled workers receive a minimum wage[18] and its budget constraint holds. T is the lump-sum tax for the

[15] There would be a meta-technology whose most profitable sub-technology would be used at any given moment.

[16] Implicitly we assume that there are no technology spill-overs. Spill-overs would feed back into price changes and imply closing down unless further innovations are made.

[17] Note that we assume that skill accumulation is exogenous. An alternative policy with long-run scope would be to subsidize skill accumulation. This is analyzed in our companion paper in which we endogenize skill accumulation.

[18] We assume that there are no feasible transfers t so that the flexible economy equilibrium can be sustained with unskilled workers obtaining $w_L + t = w_L^{min}$. This is, e.g., the case if skill types cannot be observed as in Spector (1999).

population of size one. Unemployed (U) receive benefits B. Hence, the more costly the technology change the higher is the lump-sum tax.

Since the focus of the paper is not on political economy issues, we do not derive the program of the government as resulting from optimization over a general set of objectives and a set of feasible policy instruments. However, it is worth pointing out that the program will be equivalent to maximizing output in the second-best environment, if the costs for R&D subsidies are more than offset by their benefits. These contain the higher present discounted value of output and the smaller presented discounted flow of unemployment benefits resulting from the subsidies. Moreover, minimum wages will be the best way of redistributing income, if lump-sum transfers are not available and distortionary taxation or tariffs result in higher inefficiencies (see Dolado et al. (2000)). For parsimony we keep the assumption of lump-sum taxation, however.

Let us now summarize the most important assumptions:

Assumption 1: CRS technology

Assumption 2: No factor-intensity reversal

Assumption 3: $S_{i;j} = 0$

Assumption 4: $S_i > 0$

Assumption 5: Free entry

Without government subsidies profits of sector i, π_i, are maximized as follows:

$$\max_{I_j;H_i;L_i} \pi_i = \begin{cases} p_i F^i(H_i;L_i) - w_H^{DC} H_i - w_L^{DC} L_i; & \text{if } I_{cont} = 1 \\ p_i F^i(H_i;A_i L_i) - w_H^{DC} H_i - w_L^{DC} A_i L_i - S_i; & \text{if } I_{switch} = 1 \\ p_i F^i(H_i;L_i) - w_H^{LDC} H_i - w_L^{LDC} L_i; & \text{if } I_{close} = 1 \end{cases};$$

where $i = 1;2;$ $j = cont; switch; close$. The production function $F^i(:)$ has constant returns to scale (CRS), is strictly concave and differentiable. ULATC is introduced as the factor A, if technology is switched.[19] As A increases unskilled labor becomes more productive.

[19] We will motivate below why we consider ULATC.

The wages of the skilled and unskilled are w_H and w_L, respectively. The superscripts DC and LDC denote explicitly whether these wages are paid in the developed or less-developed country, respectively.[20] Hence, we understand closing down as moving production to the less-developed country. I_j is an indicator variable which takes the value 1 if production is continued with the current technology, technology is switched or operations are closed down, respectively.[21]

Note that it is never optimal to change technology before the economy opens up because producers always make zero profits. As we will see below, government subsidies of size S_i, however, will allow producers to switch technology without incurring losses once production with the old technology in the open economy has become unprofitable.[22] Hence, they continue production in the developed country instead of moving production to the less-developed country.

For the demand side we assume that households maximize a differentiable strictly-quasiconcave utility function and have homothetic preferences. This excludes any feedbacks from changes in the wage differential on the demand for goods. Furthermore, the two consumption goods are assumed to be imperfect substitutes.

Equilibrium

Proposition 1 An equilibrium exists and is unique for a given technology.

This follows quite easily from the structure of the problem so that we omit an explicit proof for brevity. Note, however, that in autarchy prices are determined by the demand side

[20] They will be different, if there is a binding minimum wage in developed countries whereas wages are flexible in less-developed countries. In the following we omit these superscripts for parsimony. Below, wages can be understood as those paid in the developed country in the respective scenario.

[21] Implicitly we already assume that there exists a unique technology which will be chosen once the producers decide to switch. We will come back to this later.

[22] We neglect observability problems like moral hazard which possibly are important in the real world for the provision of government subsidies. E.g., producers might become unprofitable because of government subsidies.

whereas this is no longer true in the open economy. Then demand determines imports and exports and prices are taken as given.

Institutional Constraints

We assume that there exists a minimum wage w_L^{min} for unskilled labor. This is a realistic feature of all developed countries.[23] Given that unskilled wages paid in LDC's are much lower than in developed countries it is very plausible that the minimum wage becomes binding once the developed country opens up.

Assumption 6: The minimum wage is binding for some p, i.e., 9 p ´ $\frac{p_1}{p_2}$; s:t: $w_L^{min} > w_L(p)$.

After having set up our model we now want to analyze the e¤ects of opening up the constrained economy to trade.

3 The E¤ects of Openness

Before we turn to the analysis of the economy which is constrained by a minimum wage let us brie‡y recall the e¤ects of openness for a ‡exible economy. This is done because we will use the ‡exible economy as a benchmark. Recall that we analyze a developed economy opening up to trade with a less developed country. Hence, we assume that DC's have a comparative advantage in the production of the skill-intensive good.[24] The inauguration of openness will be modeled as a price change so that $p_1^o < p_1^a$ and $p_2^o > p_2^a$ where the superscripts o and a denote openness and autarchy, respectively. The price of the unskilled-labor intensive good falls whereas the one of the skill-intensive good rises in the open economy.

[23] Either developed countries have an explicit minimum wage or an implicit wage ‡oor because of labor market institutions like unions.

[24] This comparative advantage may result from higher schooling costs or credit market imperfections in the LDC's.

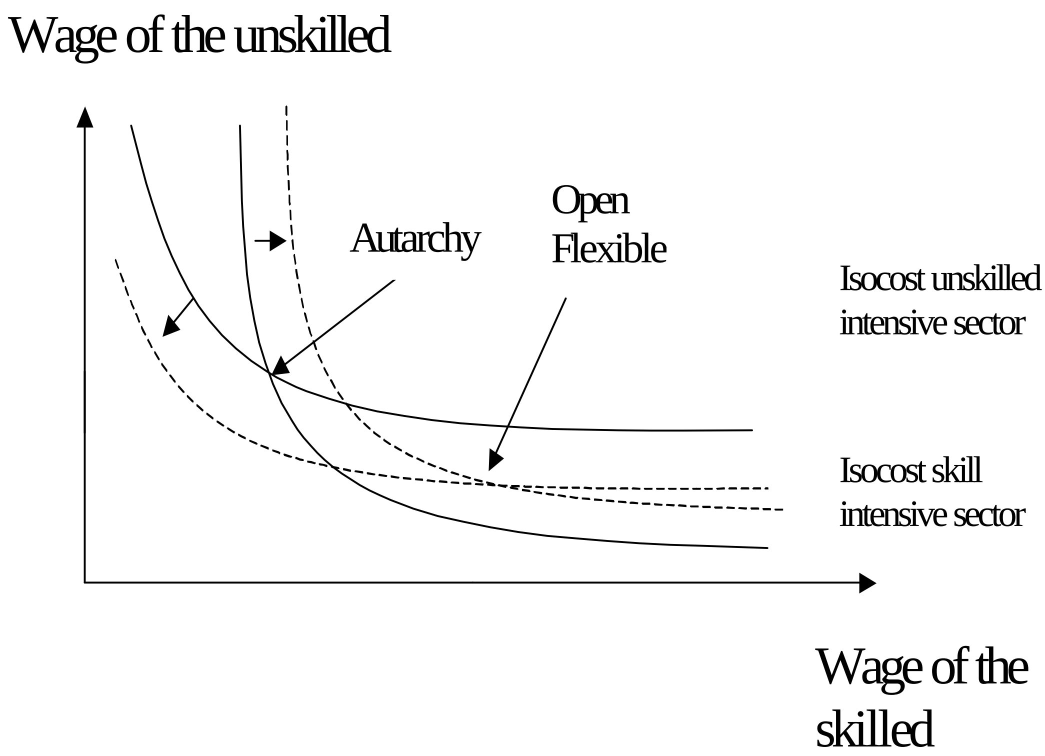

Figure 1: The e¤ects of openness on factor prices in the ‡exible economy

3.1 The Flexible Economy

In a completely ‡exible economy the Stolper-Samuelson theorem applies. Compared to autarchy w_H rises and w_L falls in terms of any of the two commodity prices in the ‡exible economy. The skill-intensity $h_i \equiv \frac{H_i}{L_i}$, $i = 1; 2$, falls in both sectors as a result to the changes in factor prices. The developed country exports the skill-intensive good and imports the unskilled-labor intensive good, as the Heckscher-Ohlin theorem shows. Note that factor prices adjust so that there is full employment in the ‡exible economy. The results are summarized in column 1 of Table 1.

Figure 1 illustrates the e¤ects of openness in a ‡exible economy. Recall that openness increases the price of the skill-intensive good and decreases the price of the unskilled-labor intensive good. This will shift the isocost curve of the skill intensive sector up and the isocost curve of the unskilled-labor intensive sector down. In the new equilibrium wages of the skilled are higher and wages of the unskilled are lower. This is the standard Stolper-Samuelson effect.

Having characterized the effects of openness in a flexible economy we now want to analyze the effects on an economy which is constrained by a minimum wage. It is instructive to first consider the case in which technology remains constant before we turn to the case in which technology adjusts.

3.2 The Constrained Economy with Constant Technology

Let us assume for simplicity that $w_L^a = w_L^{min}$,[25] i.e., the autarchy wage equals the minimum wage. Hence, the minimum wage immediately becomes binding in the open economy.

Proposition 2 Openness with binding minimum wages and constant technology has the following effects:

a) w_H rises, but less than in the flexible economy.

b) h_2 falls but less than in the flexible economy.

c) some unskilled workers become unemployed, i.e., $U_L > 0$.

d) the unskilled-labor intensive sector has to close down.

Proof: see Appendix.

Instead of presenting algebraic arguments which are provided in the Appendix we want to give a graphical illustration.

Figure 2 plots the isocost curves for the unskilled-labor and skill-intensive sector. With a constant technology and a binding minimum wage the equilibrium of the flexible economy is no longer feasible. The unskilled-labor intensive sector has to close down and the new equilibrium is determined where the isocost curve of the skill-intensive sector intersects with the minimum wage schedule. It is immediately apparent that w_H is smaller in this equilibrium.

[25] This is done to emphasize the crucial forces at work in our model. The results can easily be adapted to the case $w_L^a > w_L^{min}$. Then one would observe standard Stolper-Samuelson effects until $w_L^o = w_L^{min}$ holds which then have to be added to the results we report.

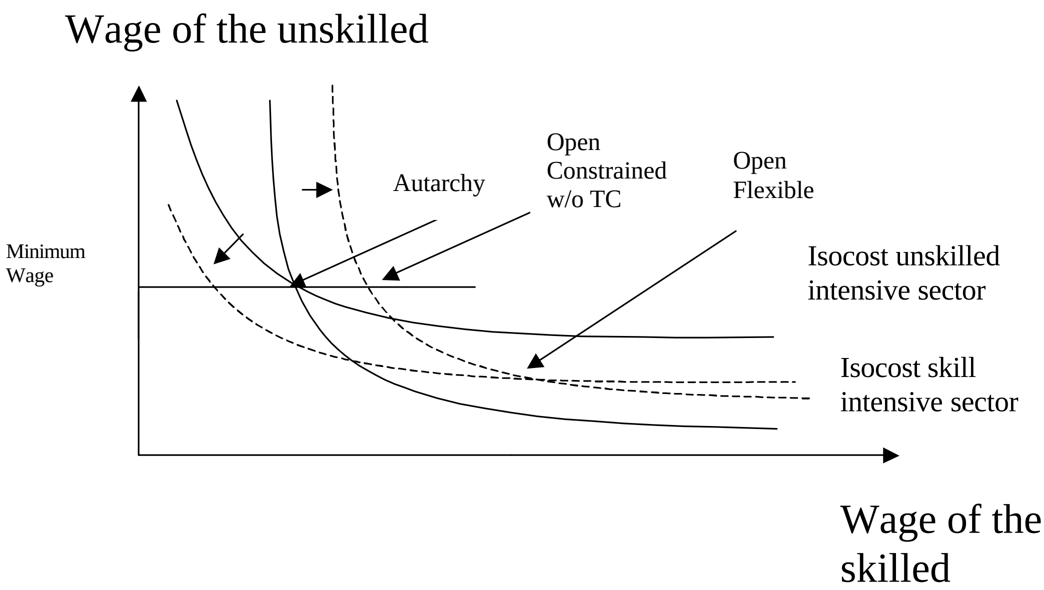

Figure 2: The e¤ects of openness in the constrained economy with constant technology

The slope of the isocost curve of the skill-intensive sector is steeper in the constrained economy than in the ‡exible one. This illustrates that the skill-intensity, h_2, is relatively higher. Unemployment occurs because unskilled workers are not able to bid down the minimum wage in order to become employed.

Whether the economy exports more skill-intensive goods than in the ‡exible-economy case is unclear. Domestic demand is smaller for both goods in the constrained economy because demand is assumed to be homothetic and total output is lower in the constrained than in the ‡exible economy. Production of the skill-intensive good can be higher or lower in the constrained than in the ‡exible economy depending on whether the e¤ect of complete specialization or smaller total output dominates.

Having analyzed the constrained economy with a constant technology we now investigate how ULATC modi…es the results of proposition 2.

3.3 The Constrained Economy with ULATC

Before we analyze the constrained economy with technological change, we want to discuss the type of technological progress which is induced by a binding minimum wage.

3.3.1 The Nature of Technology Change We want to investigate what kind of technology change would allow the unskilled-labor intensive sector to remain in business in the developed country. We examine the technology change necessary to continue production at zero pro…ts. This implicitly assumes that there exists a continuum of technologies so that A can be chosen exactly to o¤set the losses resulting from the binding minimum wage. One can relax this assumption. The implications are contained in the supplement to this paper which is available on request.

As long as skilled and unskilled labor are not perfect substitutes in the production for the unskilled-labor intensive good any kind of technological progress in the unskilled-labor intensive sector –be it increases in total factor productivity or productivity of skilled or unskilled workers– will alleviate the cost pressure introduced by the minimum wage. What kind of technological change will be chosen, then depends on the relative cost of this technology change.

In our analysis below we will focus on ULATC. However, the main results are robust to the nature of the technology change. We will point out the differences in Section 3.3.3.

Proposition 3 Unskilled-labor augmenting technological progress allows the unskilled-labor intensive sector to continue production.

Proof: see Appendix.

The intuition is simple. If ULATC enhances the productivity of unskilled workers enough, it will be profitable to pay them the minimum wage. We now want to give a parametric example for the Cobb-Douglas case before we analyze the equilibrium where such a technology change happens.

Example: Cobb-Douglas production function

To be more explicit consider the Cobb-Douglas case $F(H; AL) = H^{\alpha}(AL)^{1-\alpha}$. With a binding minimum wage we need $w_L^{min} = \frac{\partial F(\cdot)}{\partial L}$ to break even. Hence

$$w_L^{min} = H^{\alpha} A^{1-\alpha} L^{-\alpha}$$

$\iff$

$$A = \left[\frac{w_L^{min}}{h^{\alpha}}\right]^{\frac{1}{1-\alpha}}, \tag{1}$$

where $h \equiv \frac{H}{L}$.

Note that the ULATC necessary to keep a sector in business depends positively on the minimum wage. This is intuitive because a higher minimum wage, if binding, makes it necessary to increase the productivity of unskilled workers more. For a given minimum wage, a higher ratio of skilled to unskilled workers used in production reduces the size of necessary ULATC. This is because with Cobb-Douglas technology unskilled labor becomes

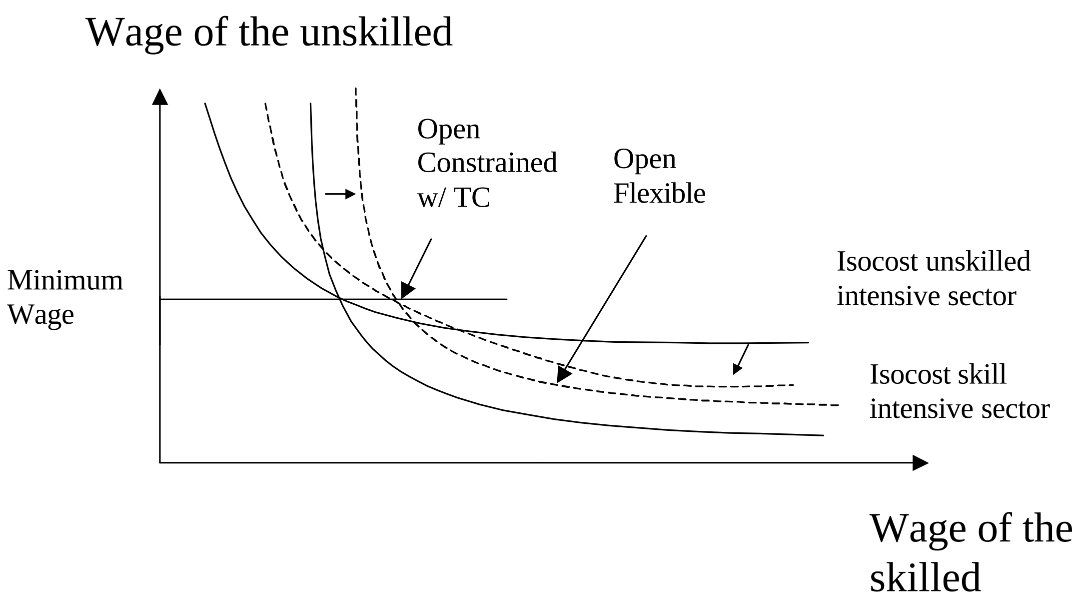

Figure 3: The e¤ects of openness in the constrained economy with endogenous technological change

more productive the more high-skilled workers are employed. Moreover, CRS to both factors implies that $F^i(:)$ has DRS in L.

The technological skill-intensity ® has an ambiguous e¤ect on the necessary ULATC. On the one hand, it in‡uences the e¤ect of the skilled-unskilled ratio on unskilled-labor productivity, on the other hand it a¤ects the direct e¤ect of A on the productivity of the unskilled in the opposite direction.

Now let us investigate how the e¤ects of openness for the constrained economy are modi…ed if we allow for ULATC.

3.3.2 The E¤ects of Openness

We will compare our results with the benchmark of the ‡exible economy. The results are summarized in the second column of Table 1.

Again we give a graphical illustration of the main results of the proposition. First we display the e¤ects of openness on the wage di¤erential for the constrained economy with ULATC in Figure 3. Second we want to illustrate in Figure 4 that the constrained economy trades less with the LDC's .

Proposition 4 With unskilled-labor technological progress openness has the following e¤ects:

a) w_H rises, but less than in the ‡exible economy.

b) h_2 falls, but less than in the ‡exible economy, and the e¤ect on h_1 is ambiguous.

c) the developed country exports the skill-intensive and imports the unskilled-labor intensive good. $F^2(:)$ is smaller and $F^1(:)$ is bigger than in the ‡exible economy so that exports and imports are smaller compared with the ‡exible economy.

d) there is unemployment of the unskilled (U_L).

e) every e¢ciency unit A_1L_1 receives a wage higher than an unskilled worker in the ‡exible economy if both factors are employed by the unskilled-labor intensive sector.

Proof: see Appendix.

Figure 3 is pretty much the same as Figure 2. The crucial di¤erence is that in the constrained economy with technology change both sectors produce in the open economy

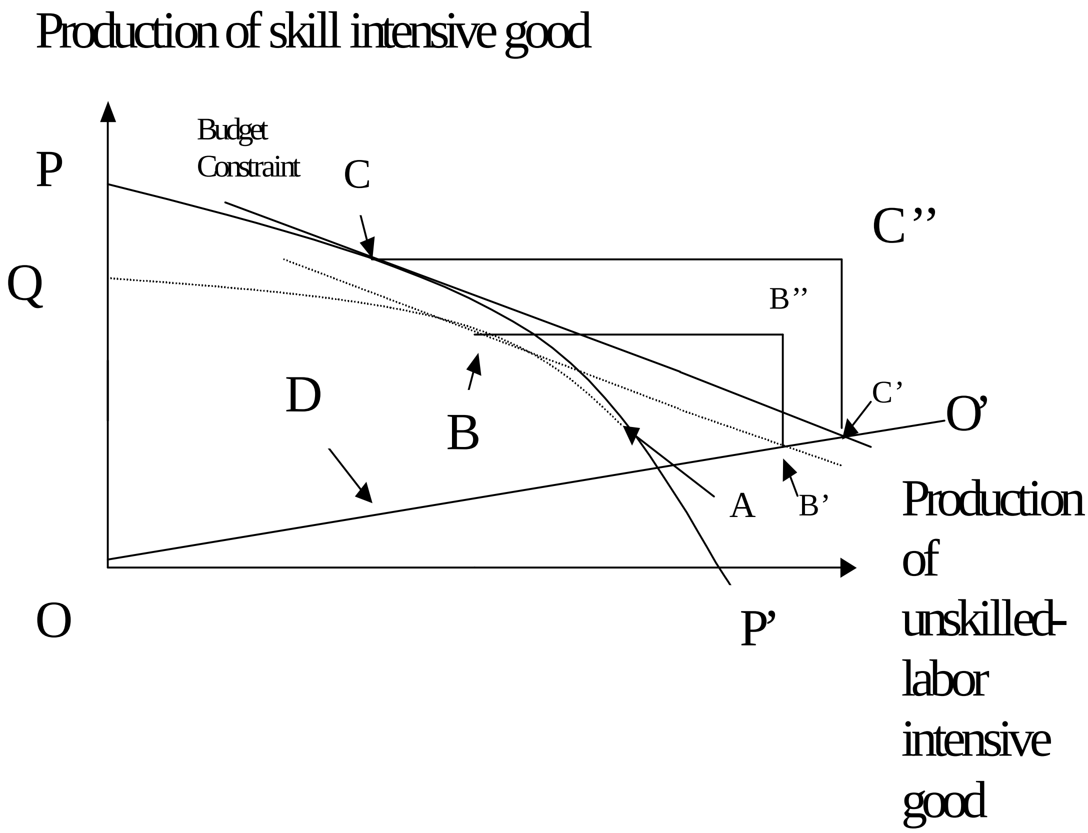

Figure 4: The effects of openness on trade volumes in the constrained economy with ULATC and in the flexible economy

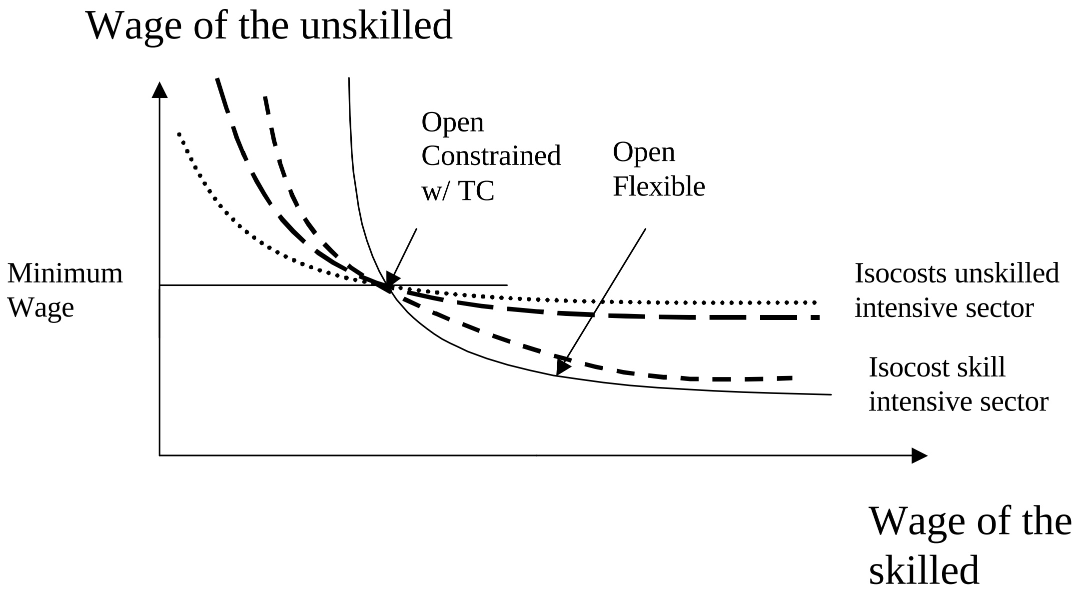

Figure 5: Di¤erent types of technological change

equilibrium. ULATC will tilt the isocost curve of the unskilled-labor intensive sector upwards so that the wage of the unskilled equals the minimum wage. Hence, the isocost curve of the unskilled-labor intensive sector intersects with the isocost curve of the skill-intensive sector exactly where it is feasible to pay the minimum wage. Because of the upward tilt of the isocost curve of the unskilled-labor intensive sector it is unclear whether its skill-intensity rises or falls compared to autarchy. Let us now illustrate the e¤ects on trade volumes.

Figure 4 illustrates the result that trade volumes are smaller in the constrained than in the ‡exible economy. The curve connecting the points P and P^{0} is the autarchy production possibility frontier (PPF). In the constrained economy with ULATC this frontier will change to become the curve connecting Q and P^{0}. The line between O and O^{0} connects the demand bundles for di¤erent income levels in the open economy. It is straight because we assumed homotheticity. It crosses the PPF below the autarchy equilibrium A because of the price-e¤ect on demand under the assumption that both goods are normal. The other straight line is the budget constraint which has the slope $-\frac{p_1}{p_2}$. In the autarchy equilibrium A production equals demand, where we assume as above that $w_L^a = w_L^{min}$. This is why the new PPF changes its slope exactly in point A. If $\frac{p_1}{p_2}$ is above the autarchy level there will be no ULATC and the two PPF's coincide. If $\frac{p_1}{p_2}$ is below the autarchy level then production of the skill-intensive good 2 is smaller than in the flexible economy and hence the new PPF lies below the autarchy curve. Furthermore, the budget constraint shifts down because there is unemployment in the open constrained economy. Thus, the equilibrium production point in the constrained economy is B, the bundle of goods demanded is illustrated by point B'. The corresponding points for the flexible economy are C and C'. The amount of exports and imports in the constrained economy is smaller than in the flexible economy as is made explicit by comparing the trade triangles $CC'C''$ and $BB'B''$.[26] Exports and imports per GDP can fall if the increase in unemployment is small enough which depends on the production technology. Note that the goods consumed by the private sector can actually be anywhere on the demand line between O and B', e.g., in D, depending on the cost of ULATC.

Let us now briefly give the intuition for results d) and e) in the previous proposition. The reason for the existence of unemployment is that ULATC is sector specific, i.e., the increase in productivity for the unskilled only occurs in the unskilled-labor intensive sector whereas no technology change occurs in the skill-intensive sector to alleviate the cost pressure of the minimum wage. The result that the unskilled wage per efficiency unit falls less than in the flexible economy is rather mechanical and follows from the fact that the skilled wage is smaller in the constrained than in the flexible economy. Again the distortion of the production mix is at the root of this phenomenon.

Having derived the main results of this paper we now want to mention the modifications

[26] Observe that in the flexible and in the constrained open economy there is balanced trade. In terms of Figure 4, the trade triangles $CC'C''$ and $BB'B''$ imply that $\frac{X_2}{|X_1|} = \frac{p_1}{p_2}$, i.e., the ratio of exports to imports equals the slope of the budget constraint. Thus $p_2 X_2 = p_1 |X_1|$.

for other types of technological progress.

3.3.3 Other types of technology change

As mentioned above total factor productivity (TFP) improvements or skilled-labor augmenting technological change (SLATC) would also alleviate the cost pressure of the minimum wage.[27]

In Figure 5 we plot three di¤erent isocost curves for the unskilled-labor intensive sector which di¤er with respect to the technological progress. Ranked according to their slope, the isocost curve after ULATC is the steepest followed by increases in TFP[28] and SLATC. As can be seen all three types of technological progress potentially render production in the unskilled-labor intensive sector feasible. However, compared to ULATC both increases in TFP and SLATC result in smaller distortions of the production mix.[29] This is because these types of technological progress make more skilled labor available which allows the skill-intensive sector to expand relatively more in the open economy. Hence, there will be less unemployment. This is reinforced by the fact that increases in TFP and SLATC make less unskilled workers idle per production unit in the unskilled-labor intensive sector for given productivity increases. Clearly, also the skill-intensity in the unskilled-labor intensive sector depends on the type of technological progress. The skill-intensity will be highest with ULATC and lowest with SLATC.

Before we highlight some implications of our model we want to mention some extensions.

3.4 Extensions

1. It is possible to model the R&D-sector explicitly as employing skilled labor for research. Then R&D is needed most in the developed country when it is more expensive. Before

[27] In the Cobb-Douglas case it can easily be veri…ed that the productivity of unskilled in the unskilled-labor intensive sector increases most for TFP improvements and least for SLATC.

[28] Increases in TFP shift the isocost curve parallely compared with the isocost curve without technology change so that the skill-intensity remains constant.

[29] Hence, there is trade-o¤ between di¤erent technology changes concerning productivity increases of the unskilled and distortions of the production mix.

opening up the economy no innovations are done since they are costly, prices adjust so that markets clear, and price changes are unexpected. Once the economy is open and minimum wages are binding, innovations are necessary for the sector intensive in unskilled labor to remain in business. Because the wages of the skilled are higher in the open economy R&D is more costly. Nonetheless R&D will be undertaken unless the cost of closing down is smaller than the cost of R&D activity. Production in the economy will fall even more than in the version of the model we presented above because skilled labor is diverted from production. Furthermore, trade patterns will be dampened additionally.

2. Another extension is to model innovations as uncertain or discrete. This will induce more innovation than necessary to remain in business if R&D is undertaken. It is possible that initial trade patterns induced by the price change are o¤set by "excessive" ULATC. In this scenario initial trade patterns induced by the relative price change after opening up the economy can be completely o¤set.

The results of these extensions are summarized in the last three columns of Table 1. In the third column we summarize the case where the skilled labor necessary for R&D is supplied by the whole economy. In the fourth column the skilled labor has to be supplied by the unskilled-labor-intensive sector itself. In the …fth column we look how uncertain R&D outcomes might a¤ect our results. Details are given in a supplement of this paper which is available upon request.

4 Implications

After presenting extensions of our basic model let us point out two interesting implications. First we want to state explicitly the consequences of a higher minimum wage in the scenario where ULATC happens. Second we mention the implications for factor-content studies.

4.1 The Effects of a Higher Minimum Wage

We apply our simple model to study its implications in different institutional settings. We reduce this exercise to varying the level of the minimum wage. We call the case with the lower, but still binding minimum wage the US and the case with the higher minimum wage continental Europe (EU). We assume everything else to be equal in the two countries. Given these assumptions we are able to observe:

Remark 5 If $w_L^{min;US} < w_L^{min;EU}$, then $w_H^{US} \geq w_H^{EU}$; $U_L^{US} \leq U_L^{EU}$, $h_i^{EU} \geq h_i^{US}$, $[\frac{\partial F^1(.)}{\partial (A_1 L_1)}]^{EU} \geq [\frac{\partial F^1(.)}{\partial (A_1 L_1)}]^{US}$, and $|X_i^{US}| \geq |X_i^{EU}|$; $i = 1; 2$.

Proof: Follows immediately from proposition 4.

These predictions of our model seem to be at least roughly in line with casual empirical observation. E.g., Sapir (2000) provides evidence that 45% of US manufacturing trade in 1998 is with non-industrialized countries compared with 20% in the European Union. We will discuss the empirical relevance more in Section 5.

4.2 Implications for Factor-Content Studies

Our model has the following interesting implications for factor-content studies.[30]

Remark 6 Factor-content studies will be inaccurate, if trade induces technology changes:

The more important is unskilled-labor intensive technological change (ULATC), the smaller is the size of the effects of openness on factor prices. Moreover, factor-content studies are especially misleading if ULATC absorbs skilled labor as an input or ULATC is excessive.

This follows immediately from Proposition 4. The basic insight that endogenous technology change makes the thought experiment of factor content studies impossible is already noted by Panagariya (2000), p. 112 f.

[30] Factor-content studies have been criticized especially by Leamer (2000). In our case they are problematic because of trade-induced technology changes.

ULATC lowers the effects of openness on the wage differential and reduces trade. Hence, the link between factor prices and trade patterns which is key for factor-content studies is blurred by ULATC. Trade-induced technology change makes it impossible to construct the necessary counterfactual so that factor-content studies are no longer meaningful. Once we model ULATC as R&D employing skilled labor as an input and/or R&D can be excessive trade patterns change and in the case of excessive R&D also wage differentials. Thus the link between trade patterns and factor prices is blurred even more. See the supplement of our paper for details.

Explicitly modelling the defensive technological change improves our understanding of why factor-content studies might fail. The costlier the necessary technological change in the sense that R&D employs a lot of skilled workers, and the more ULATC takes place, the less accurate are factor-content studies. However, it seems a very difficult, if not impossible, task to disentangle trade-induced technology changes from autonomous ones.

Moreover, factor-content sudies focus only on the effects of trade on wage differentials whereas our model points out that other effects of openness might be more important such as the distortion of the production side and effects on productivity. Furthermore, it becomes clear once factor-content studies are performed they should use the factor-proportions used in the LDC's as proposed by Wood (1994) because DC's will use less unskilled labor in the sector intensive in its use than the LDC's, if ULATC takes place.

Having pointed out some interesting empirical implications it is now time to look at the empirical relevance of our model before we conclude.

5 Empirical Relevance

Let us mention some empirical studies which shed light on the relevance of the mechanism pointed out by this paper. For brevity reasons we only report studies which are insightful for the crucial mechanism in our paper. For a more extensive review of the literature see Johnson and Stafford (1999), Slaughter (1998) and Wood (1998). Note that we still report studies which try to assess the impact of openness by actual trade. The results of these studies have to be interpreted with care. Furthermore, we take as given that the degree of openness increased in OECD countries especially since the 70s. See, e.g., OECD (1997) for an exposition.[31]

First we want to give an example for the gap between minimum wages in developed countries and wages of the unskilled in developing countries. Second we present evidence on R&D expenditure and productivity. Third we want to investigate whether sectors hit by import competition indeed receive state subsidies in countries with a binding minimum wage. Fourth we present some suggestive evidence which supports the bigger role of government subsidies for R&D in countries with higher labor costs.

Minimum Wages

Nominal minimum wages per hour in the US were approximately[32] $1.6 in 1973 and increased to $5.15 in 1997 (see Neumark and Wascher (1992) and OECD (1998)). The hourly wages for unskilled labor in LDC's are definitely smaller. Average wages in Poland, for example, were approximately $3 in 1997, converted using purchasing power parity, and thus substantially lower than the US minimum wage.[33] The difference is likely to be even more pronounced for other LDC's and if one takes the average wage of unskilled workers only. In as far as trade is concerned what matters is how productive workers in LDC's are for the wage they are paid. Since it is likely that they are less productive than in DC's the gap between wages per efficiency unit is presumably smaller. As long as autarchy productivity differences do not completely explain the wage gap our argument remains valid, however.[34]

[31] Average ad-valorem tariffs fell from 40% to 4% during the eight rounds of GATT negotiations.

[32] We report the federal minimum. Minimum wages in single states can diverge from the reported value. Nonetheless, our point remains the same qualitatively.

[33] Just multiplying the wages of the LDC's by the exchange rate would result in even lower wages in terms of dollars.

[34] In the steady state of completely open economies our model predicts that productivity differences do indeed fully explain the wage gap.

Data from the OECD Statistical Compendium on unit labor costs reveal that productivity differences are unable to fully explain the wage gap, e.g., between Poland and EU countries or the US. Hence, minimum wages in developed countries are likely to become binding when these countries open up more.

Openness, Productivity and R&D

Our model implies that productivity growth is relatively higher in unskilled-labor intensive industries. This effect should be stronger the more open the developed country. Studies of Sachs and Shatz (1994), Lawrence and Slaughter (1993), Fitzenberger (1997), Cortes and Jean (1997), Hine and Wright (1998) provide evidence which is consistent with this hypothesis for the US, France, Germany and the UK. However, the evidence is far from complete since there are endogeneity problems which prevent causal interpretations. Moreover, Fitzenberger finds that TFP growth was substantial in high-skilled industries as well. Using an industry panel of 13 OECD countries since 1970 Griffith et al. (2000) find that import penetration explains very little of TFP growth. They conclude that trade does not seem to play a big role. Actual trade might not, but openness and potential trade might very well explain increases in TFP. Our model points out that we might actually observe less imports in countries which have higher productivity growth.[35]

Our model implies as well that innovations and productivity growth will be more essential if the cost of labor is high. Flaig and Stadler (1994), Nabseth (1994) and Doms, Donne, and Troske (1997) find supportive evidence for the US, Germany and Sweden.

Our model implies that R&D or productivity growth can be positively correlated with the skill-intensity in unskilled-labor intensive sector, if the effects of ULATC outweigh the

[35] This is an example where it becomes difficult to interpret evidence which uses imports as a proxy of openness or foreign competition. On the one hand openness will induce more imports and also a higher productivity of unskilled workers compared to autarchy. On the other hand if one compares two open economies, higher import penetration will imply a less binding minimum wage in our model –we are closer to the flexible economy case– and hence a smaller productivity increase.

effects of changes in commodity prices. Machin and van Reenen (1998) report a positive correlation between R&D and a higher skill-intensity in the manufacturing sector for OECD countries. Neven and Wyplosz (1996) provide evidence of defensive restructuring in unskilled-labor intensive industries for France, Germany, Italy and the UK. This includes downsizing as well as the use of a higher skill-intensity in these sectors.

Moreover, in our model the increase of the skill-intensity in the unskilled-labor intensive sector should be positively correlated with unemployment. Scarpetta et al. (2000) find evidence for skill-biased employment adjustments in the manufacturing sector in OECD countries since the 70s which are accompanied by net employment losses in continental Europe. Since GDP per hours worked in the manufacturing sector increased relatively more in these countries since the 70s, the productivity of unskilled workers has indeed increased more in these countries as well.

State Subsidies for Unskilled-Labor Intensive Sectors

We modeled the government as bearing the cost for ULATC. Hence, we should observe that unskilled-labor intensive sectors get state subsidies in countries with a binding minimum wage. Case studies for the shipbuilding and the automobile sector reveal that these sectors have received a considerable amount of subsidies in Europe and the US since the 70s (see Lavdas and Mendrinou (1999)).[36] For example, the EU assigned 3.5 billion ECU to the shipbuilding industry in the period 1990-95. Moreover, explicit objectives are aid for rescue and restructuring, R&D and investment aid for innovation to improve competitiveness.[37] Relatively high labor costs compared to trading partners and social considerations as unemployment are explicitly mentioned in the discussion of subsidies by the Commission (see

[36] For an earlier example of the discussion of subsidies versus abandonation of import-competing industries see Denton et al. (1975) and Corden and Fels (1976).

[37] It is likely that the subsidies are indeed used for these purposes because their use is monitored. Reports are submitted to the European Commission every half year (see, e.g., European Commission (1995, 1999) for the textile and shipbuilding industry).

European Commission (1995)). Finally, Clements et al. (1998) find that conditional on various controls the size of the manufacturing sector's share –the sector of tradable goods which is biggest in size in developed countries– is positively correlated with the ratio of government subsidies to GDP for a sample of 40 countries in the period 1975-92.[38]

Having presented some evidence which is consistent with the simple story of our model we now provide some empirical evidence on the relationship between government subsidies for R&D, unit-labor costs and productivity which is key in our model.

5.1 Government Subsidies for R&D, Unit-Labor Costs and Productivity

In our model governments in developed countries subsidize R&D in sectors which are hit by import competition from less developed countries. The implied productivity increase allows the sector intensive in unskilled labor to remain in business. We want to provide some empirical support for this hypothesis.

We find evidence which is consistent with the story that openness induced governments in countries with high labor costs to subsidize R&D in industries hit by foreign competition in order to increase their competitiveness.[39]

The structure of our empirical analysis is as follows. We first present the hypotheses. We then discuss the data and its shortcomings before we provide some suggestive evidence for the hypotheses.

5.1.1 Hypotheses

We are interested to find evidence on the following hypotheses:

1. Government subsidies for R&D are higher in developed countries with higher institutionally induced wage floors.

2. Government subsidies for R&D enhance productivity.

[38] Unfortunately, however, they do not disaggregate the manufacturing sector into skilled and unskilled-labor intensive production.

[39] Without openness and potential trade there is no need to subsidize these sectors to prevent them from closing down. Recall that in a small open economy prices are taken as given whereas in a closed economy prices are determined by supply and demand.

5.1.2 Data We use annual data for OECD countries in the period 1981-97.[40] Ideally, we would like to have a country panel for unskilled-labor intensive industries which produce tradeables. However, data availability only allows an analysis for the whole manufacturing sector. Clearly, this sector includes high-technology industries which are likely to be relatively skill-intensive. Thus, di¤erent industry structure across countries poses a serious problem. Econometrically, we will try to account for country speci…c factors by performing a …xed-e¤ect estimation.

We use the following variables:

1. Government outlays and budget appropriations for industrial development[41]

2. Unit Labor Cost in the manufacturing sector[42]

We only have data on employment and unit labor cost for all workers, i.e., the data does not allow for a decomposition between skilled and unskilled workers. Composition e¤ects might matter if countries use di¤erent technologies or because of a di¤erent industry structure. Again country …xed e¤ects should alleviate this problem.

Unit labor costs are de…ned as wages over productivity. Hence, our model would imply no correlation between this measure and government subsidies to R&D in steady state. Higher wage costs have to be neutralized by productivity increases for the unskilled-labor intensive sector to remain in business. However, during the time period we analyze (1981-97) OECD countries opened up further to trade with less developed countries (see, e.g., OECD (1997)). As long as these increases in openness are at least partly unexpected we can expect to …nd out-of-steady-state correlations. In particular, we should …nd a positive correlation between unit-labor costs and government subsidies to R&D as long as increases in productivity have

[40] The OECD only provides data for government outlays for R&D in this period. All data is taken from the OECD Statistical Compendium.

[41] This excludes expenditure on agriculture, forestry and …shing, energy, transport and telecommunications, prevention of pollution, health, university funds, general advancement of knowledge, civil space, defence.

[42] We prefer unit labor costs as measure over minimum wages because it captures any kind of institutionally induced wage ‡oor.

not materialized.

3. Value Added per employee in the manufacturing sector

We use value added per employee as labor productivity measure. Ideally we would use value added per employee hours worked to account for different institutional structures of the labor market. However, the sample size would become too small.

Maximum working hours and hiring and firing regulations do affect labor productivity per employee. Moreover, the proportion of full- and part-time workers varies considerably across countries. However, one would expect the labor productivity increases per hour worked to be even more positively correlated with government subsidies to R&D. This is because in countries with high government subsidies to R&D as, e.g., the Netherlands a substantial part of the population only works part–time and working hours per full-time job tend to be smaller.

4. Total factor productivity (TFP) growth in the manufacturing sector

TFP is defined as residuum after taking changes of inputs into account.[43] It is worth pointing out that mechanically we should not expect any correlation between TFP growth and government subsidies to R&D if these subsidies take the form of remunerated factors. As a residuum the TFP measure is cleaned from these by definition. However, if government subsidies induce productivity increases of a non-remunerated kind we should find a positive correlation.

5. Labor productivity (LP) growth in the manufacturing sector

We expect labor productivity to increase after government subsidies to R&D independent of whether the technological change is embodied or disembodied.

Let us now present some suggestive evidence.

5.1.3 Suggestive Evidence

We summarize the results of our fixed-effect estimations in Table 1.

[43] See Scarpetta et al. (2000) for the methodology used for the construction of this variable.

Table 2: Results of Fixed-E¤ect Estimations

Dep. Var	Regressor	Coe¤.	P-Value	R2	Nobs	Year-Dum.
Ln(Gov. R&D)	Ln(Unit-Labor Cost)	.22	.10	.24	205	Yes
Ln(Gov. R&D)	Labor Productivity	.21	.04	.22	150	Yes
TFP-Growth	Ln(Gov. R&D)	.006	.54	.37	129	Yes
LP-Growth	Ln(Gov. R&D)	.14	.05	.59	140	Yes

Note: The number of observations varies because of data availability.

Government R&D and Unit Labor Cost To account for country speci…c e¤ects we perform a …xed e¤ect estimation[44] controlling for aggregate shocks with time dummies. As reported in the …rst row of Table 1 the elasticity of unit labor costs is .22 which is signi…cant on a 10% level.[45] Endogeneity is a potential problem. However, it will additionally bias our estimate downward[46] because government R&D should reduce unit labor costs. Hence, we are able to interpret our estimate as a lower bound.

Government R&D and Productivity The …xed e¤ect estimates are reported in the second row of Table 1. The elasticity of government R&D with respect to labor productivity is .21 which is signi…cantly positive at the 5%-level. The sign of the correlation might seem counter-intuitive at …rst sight because in our model more productive sectors should receive less

[44] The use of the …xed e¤ect estimator is standard for country panels. However, the Hausman test does not reject consistency of the random e¤ect estimator. The point estimate is :21 and nearly the same as with the …xed e¤ect estimation.

[45] The positive sign is robust once we control for openness using production-weighted average ad-valorem tari¤s as a measure which is reported in OECD (1997b). Because of limited data availabilty these results were obtained performing a simple regression of decade averages for the 80s and 90s for OECD countries inserting a dummy for the respective decade. For tari¤s data of 1988 and 1993/96 were used for the 80s and 90s, respectively. Interestingly, average tari¤s are signi…cantly positively correlated with government subsidies. Hence, tari¤s and subsidies seem to be complementary policy instruments.

[46] This presupposes that the errors of the two equations are not negatively correlated.

subsidies.[47] However, the sign of the correlation seems to indicate a considerable endogeneity bias because high government outlays for R&D are likely to enhance productivity.[48] To investigate this a little further we regress TFP growth and LP growth in the manufacturing sector on government R&D outlays, respectively. As can be seen from the third row in Table 1 there does not seem to be a significant correlation between TFP growth and government outlays for R&D whereas there is positive significant correlation for LP growth (row four).

Scarpetta et al. (2000) provide evidence of substantial upskilling within industries of the manufacturing sector where this is accompanied by employment losses for the unskilled in many continental European countries. Thus, it seems that part of the positive correlation is resulting from compositional skill changes of the labor force. Hence, it is likely that the correlation between value added per unskilled worker and government subsidies to R&D would be even more positive. This suggests that government subsidies to R&D are associated with labor augmenting technological progress rather than disembodied TFP growth.[49] Note that the evidence is consistent with capital deepening, i.e., embodied technology change. As noted above TFP is mechanically uncorrelated with government subsidies to R&D in this case.

5.1.4 Summary We present some suggestive evidence on the correlations between government subsidies to R&D for industrial development and unit labor cost and productivity, respectively. From our model we know that these correlations cannot be interpreted as causal effects because of endogeneity and reverse causation. However, once the estimates turn out to be significant and effects have opposite signs we can interpret the estimates as lower bounds.

From this perspective we find that governments in countries with high unit labor costs

[47] Outside our model one could rationalize this correlation by arguing that governments only give subsidies to industries with better prospects, i.e., the more productive ones. However, anecdotal evidence for the textile and shipbuilding industry casts doubt on this explanation (see above).

[48] For value added per employee-hour we do not find significant correlations, however. This is likely to result from the small sample size which yields imprecise estimates.

[49] Note that the evidence is consistent with capital deepening, i.e., embodied technology change. As noted above TFP is mechanically uncorrelated with government subsidies to R&D.

subsidize R&D for industrial development more than countries with low unit labor costs. The subsidies for R&D seem to induce productivity growth for labor, but the results are also consistent with capital deepening.

Our results suggest that the mechanisms pointed out in our model seem to play a role empirically. However, better data is necessary to be more confident about the results. In particular, a decomposition of aggregate labor into skilled and unskilled-labor intensive industries is desirable. Finally, data with a long time series dimension seem to be necessary to disentangle the different causal effects between the variables.

Let us now conclude.

6 Conclusion and policy implications

Our model offers the following conclusions:

- Technological change in the sector adversely hit by openness reduces the amount of trade and the effect of openness on wage differentials and thus helps to explain why empirical studies have difficulties to find substantial effects of trade on wage differentials; and why the volume of trade between developed and less developed countries is small in absolute terms.

- Openness of an economy with minimum wages can induce productivity increases of unskilled workers because of defensive technological progress.

- Binding minimum wages can lower the wage of the skilled compared to the flexible economy.

- Binding minimum wages distort production and make countries produce relatively more in unskilled-labor-intensive industries. They lower the comparative advantage in the production of the skill-intensive good.

- Openness can increase the skill intensity in the unskilled-labor intensive sector even though the wage of the skilled rises as well because of unskilled-labor augmenting technological change. The skill-intensity in the skill-intensive sector falls.

- Our model implies that the factor content of actual trade cannot be used to assess the effect of openness on wage differentials. This is because the relationship between factor prices and factor contents in traded goods is blurred. Moreover, as argued by Wood (1994), once they are performed factor content studies should use the skill-intensities of the exporting sectors in the LDC's because the ones in the developed countries are altered by technological change.

The main mechanisms of our model also apply for a big open economy where the employment adjustment necessary to support the prevailing minimum wage under the pre-trade prices in the developed country leads to complete specialization in production. This is not unreasonable if one thinks about the vast differences of developed countries' minimum wages and the actual wages for the unskilled in developing countries.[50]

The main results are robust with respect to the use of embodied or disembodied technological change in the model. It is possible to model capital as a third factor of production and let capital-unskilled-labor substitution take the role of an increase in A.[51] The main results of the paper extend to this case and details are spelled out in the supplement to this paper. Empirically, both embodied and disembodied technology change seem to matter for the observed productivity increases of unskilled workers. Scarpetta et al. (2000) report that on the aggregate level the capital-labor ratio is higher in continental Europe than in the US. The increase of the capital-labor ratio in some continental European countries in the 90s is more driven by employment reductions than increased investment, however. Anecdotal evidence for the automobile industry in the US and Europe (Bhaskar (1988)) suggests that besides capital deepening there were substantial other process innovations which increased the productivity of unskilled workers during the 80s. One example is the "door-off" assembly technique pioneered by Rover which allows unskilled workers to access the interior of cars more easily and makes it possible to store tools closer to the assembly line. Another example is the increased use of teamwork and use of workers for different purposes in the production

[50] For more details on big-open economy HO models see Krugman (1995) and Brecher (1974).

[51] The importance of capital-labor substitution in continental Europe has been pointed out by Blanchard (1998).

process to increase the ‡exibility of workforce. Since this requires more skills of workers, this implies an increase in the skill-intensity in the production process, i.e., unskilled-labor saving technological change. Hence, both embodied and disembodied technical change seem to matter.

So far we did not explicitly point out who bears the cost of the distortion introduced by minimum wages. Under autarchy, prices adjust and whether there is full employment or not depends on the amount of output produced and the implied factor demands under the prices compatible with the minimum wage. The cost of higher prices is borne by the consumers and by producers where the share of the cost borne by each of them depends on the elasticities of demand and supply. Once the economy opens up, a binding minimum wage induces unskilled unemployment and cost for producers –or "capital owners" if one explicitly models capital as a third factor– who face the decision of leaving the country or investing into innovative activity at some cost.[52] If the government pays for the innovative activity it depends on the tax structure of the economy who bears the burden of the minimum wage. We then should observe that countries with higher minimum wages provide higher state subsidies for …rms exposed to import competition.[53]

Moreover, skilled workers earn a lower wage in the constrained than in the ‡exible economy. Hence, the employed unskilled workers bene…t from the institutional arrangement of minimum wages and everyone else looses. The lower return to capital in countries with higher minimum wages is consistent with arbitrage on capital markets, if the price changes induced by opening up the economy were unexpected at the time the capital was invested. This would imply that the expected return to capital was the same across countries before the price shock occurred. If future adverse price shocks are anticipated no additional capital will be invested unless a higher rate of return makes up for the expected costs implied by the minimum wage.

[52] The notion of sunk cost of capital investment is akin to the concept of speci…city of Caballero and Hammour (1998).

[53] This presupposes that it is always possible for the government to …nance these higher subsidies with taxes. However, this becomes more di¢cult as economies open up and the factors of production become more mobile.

Consequently, the amount of capital investment in countries with high minimum wages will be smaller –there can even be disinvestment– than in countries with low minimum wages if it is expected that the economies open up further.

Note that the importance of the e¤ects indicated by our model for a given economy depends on the size of the part of the economy which is actually a¤ected by the foreign competition. Furthermore, there exist also government subsidies to high-tech sectors. As long as these do not compensate for the change of comparative advantage introduced by the subsidies to the unskilled-labor intensive sector our point remains valid. Finally, we neglect feedbacks on skill-accumulation which may further exarcerbate the adverse output e¤ects of minimum wages. This extension is explicitly analyzed in a companion paper.

Policy implications

Protectionist policies are in general not a sensible solution.[54] The root of unskilled unemployment is not trade as such, but the second-best environment with minimum wages. Once a society regards a minimum wage ‡oor as important it should think about alleviating the incidence on the unskilled, e.g., by o¤ering alternative forms of employment in the non-tradeable service sector. Moreover, capital owners have to be compensated for their extra cost so that the developed countries attract further capital investment.

There are two main policy options. Financial support of R&D activities to keep as much of the production in the country as possible only mitigates the incidence of unemployment for unskilled workers in the short to medium run. It will distort the economy's production mix towards the unskilled-labor intensive sector and hence decrease the comparative advantage of the developed country.

A more promising option are education subsidies which we analyze in more detail in our companion paper. This policy is especially desirable because the lower wage of the skilled in

[54] Dixit and Norman (1980, 1986) prove that tari¤s should not be used in an economy with lump-sum or distortionary commodity taxes. However, Spector (1999) shows that income redistribution may not be enough to make everybody better o¤ in an open economy once the type of workers cannot be observed.

the constrained economy can have adverse long-run growth effects because of smaller skill-accumulation. A higher supply of skills also alleviates the distortion in the production sector and allows more production of the skill-intensive good. This is crucial in the sense that unskilled-labor intensive sectors mostly generate low (employment) growth. However, the effects of this policy are long run, i.e., unemployment decreases only very slowly initially. Moreover, it is possible that not all unemployment can be eliminated by subsidies to skill accumulation if the marginal cost of education increases too much. Furthermore, many low-skill intensive services are not sustainable at continental European minimum wage levels. Then it is necessary to choose between either unemployed unskilled workers or such workers employed at less than the minimum wage.[55]

7 Appendix

7.1 Proofs

Proof of Proposition 2

Let us start with the skill-intensive sector two. Since $p_2^o > p_2^a$, ceteris paribus it is possible to produce at least the amount that was produced before the economy opens up. Because of the binding minimum wage, however, production in the second sector will not expand as much as in the flexible economy unless the unskilled-labor intensive sector closes down. More formally

[55] Freeman (1994) argues that labor standards do not have to be given up because of foreign competition. Should a country have a preference for labor standards then these can be financed via currency devaluation or via taxes. Currency devaluation seems to be a short-run solution only because retaliation is likely. Taxation of capital is also not possible in the long-run because capital tends to be mobile enough to avoid taxation. Additional taxes on skilled or unskilled labor to finance labor standards or to redistribute income are the only viable long-run possibilty. This may incur a high cost as a result of the distortions introduced, especially for skill accumulation.

$$p_2 F^2(\cdot) - w_H H_2 - w_L L_2 = 0$$

implies that[56]

$$\hat{p}_2 = \theta_{H,2}\,\hat{w}_H + \theta_{L,2}\,\hat{w}_L\,;$$

where we divide by $F^2(\cdot)$. $\theta_{i,2}$, $i = H, L$, is the respective factor proportion of skilled and unskilled labor in sector 2 and a circumflex denotes a proportional change, $\hat{x} \equiv \frac{dx}{x}$. Note that $\hat{p}_2$ is given exogenously so that it does not differ in the constrained and flexible economy. Recall that in the flexible economy $\hat{w}_H > \hat{p}_2 > 0 > \hat{w}_L$. Because the minimum wage immediately becomes binding as the constrained economy opens up, $\hat{w}_L = 0$ in the constrained economy. Hence, $\hat{p}_2 = \theta_{H,2}\,\hat{w}_H$. This implies that $\hat{w}_H = \frac{\hat{p}_2}{\theta_{H,2}}$ in the constrained economy which is smaller than in the flexible economy case where $\hat{w}_H = \frac{\hat{p}_2}{\theta_{H,2}} - \frac{\theta_{L,2}}{\theta_{H,2}}\hat{w}_L$. The fact that w_L is higher and w_H is lower in the constrained than in the flexible economy makes the skilled sector produce at a higher skill-intensity h_2. This implies that not all unskilled workers who are released by the unskilled-labor intensive sector after the economy opens up are employed by the skill-intensive sector. Note that for every unit of production transferred from the unskilled-labor intensive sector to the skill-intensive sector there is an excess supply of unskilled workers and an excess demand for skilled workers. As factor prices are not allowed to adjust in the constrained economy, factor markets do not clear. Unskilled workers cannot bid down the wage to become employed. Hence in the constrained economy $U_L > 0$ where U_L is the number of unemployed unskilled workers in the economy.

Let us now analyze what happens to sector one. With the same reasoning as above we can derive $\hat{p}_1 = \theta_{H,1}\,\hat{w}_H$. This equation is clearly violated because $\hat{w}_H > 0$, $\hat{p}_1 < 0$, and $\theta_{H,1} \geq 0$. This implies that

$$p_1^o F^1(\cdot) - w_H^o H_1 - w_L^{min} L_1 < 0\,:$$

[56] The sum of the derivatives of factor proportions is zero because of cost minimization.

The unskilled-intensive sector closes down because it is no longer profitable to produce. ¥

Proof of Proposition 3

From proposition 2 we know that $w_L(p^o) < w_L^{min}$. The unskilled-labor intensive sector either closes down or switches technology whereas the skill-intensive sector always remains in business without the need for innovation. Trivially, there will be no ULATC if the unskilled-labor intensive sector closes down. Because of assumption 4', we know that there exists a parameter region in which technological progress is optimal. We know that profit maximization and the previous proposition imply:

$$p_1^o F^1(:) - w_H^o H_1^o - w_L^{min} L_1^o < 0 \tag{2}$$

$$p_2^o F^2(:) - w_H^o H_2^o - w_L^{min} L_2^o = 0 : \tag{3}$$

However, unskilled-labor augmenting technological progress allows production to continue where $A_1^o > A_1^a \equiv 1$ and $A_1^o L_1^{adj} = L_1^o$. $L_1^{adj} - L_1^o$ is the amount of unskilled labor saved because of the superior technology. The amount of technological progress is given by $A_1^o = \frac{L_1^o}{L_1^{adj}}$: L_1^{adj} is determined by

$$pF^1(H_1^o; A_1^o L_1^{adj}) - w_H^o H_1^o - w_L^{min} L_1^{adj} = 0:$$

¥

Proof of Proposition 4

Recall that we assumed for simplicity that $w_L^a(p) = w_L^{min}$. As before, opening up of the economy results in the following price changes: $p_1^o < p_1^a$ and $p_2^o > p_2^a$: These price changes then trigger changes in factor prices and factor allocation.

From proposition 2 we already know what happens to factor prices and h_2. ULATC modifies the results of proposition 2 for h_1, U_L and the production in the two sectors. ULATC makes unskilled workers productive enough to ensure that it is worth paying them the minimum wage.

For given prices this will make U_L unskilled workers unemployed. To see this let us construct the following hypothetical flexible economy. Suppose an economy like in proposition 2 without ULATC. We know that for the unskilled-labor intensive sector to remain in business we would need to pay unskilled workers $w_L^* < w_L^{min}$ in this very sector. If this were possible, everyone in the economy would be employed. This would be an equilibrium because unskilled workers would not be able to bid down the wages of the unskilled in the skill-intensive sector. However, since w_L^{min} has to be paid in the unskilled-labor intensive sector as well, ULATC is necessary to make workers productive enough. This will make U_L workers idle who are not able to bid down the minimum wage in any of the two sectors. The intuition is that ULATC is sector specific, i.e., the increase in productivity for the unskilled only occurs in the unskilled-labor intensive sector whereas no technology change occurs in the skill-intensive sector to alleviate the cost pressure of the minimum wage.

The effect of openness on h_1 is ambiguous because on the one hand ULATC raises $\frac{H_1}{L_1}$ whereas $\frac{H_1}{A_1 L_1}$, i.e., the skill-intensity in efficiency units, is equal to the skilled-unskilled ratio before ULATC. On the other hand the rise of w_H relative to w_L induces a decrease in h_1. Whether h_1 rises or falls depends on the size of the price effect relative to the effect of technological change. However, economy-wide h rises because the production share of the skill-intensive sector increases.[57]

In the constrained economy the wage of unskilled workers is higher than in the flexible economy. The same also holds for their wage in efficiency units. This is because the wage of the skilled is lower in the constrained economy than in the flexible one and technology changes. Formally, we know from proposition 2 that $\hat{p}_1 = \theta_{H;1}\hat{w}_H + \theta_{L;1}\hat{w}_L$. After technological change

[57] It is possible to build models without any ULATC which yield an increase in h_i along with an increase in the wage differential. However, these seem to be rather special and extreme cases. For an example the reader is referred to the supplement to this paper.

this becomes $\hat{p}_1 = \mu_{H;1}\hat{w}_H + \mu_{L;1}\hat{w}_{L;eff}$, where $\hat{w}_{L;eff}$ is the change of the efficiency wage per unit of A_1L_1. Because $\mu_{i;1} \geq 0$, $i = H; L$, and $\hat{p}_1$ is the same in the constrained and flexible economy, $\left|\hat{w}_{L;eff}\right|$ must be smaller or equal (strictly smaller if $\mu_i > 0$) in the constrained than in the flexible economy if $\hat{w}_H$ is smaller. That means that in the constrained economy $w_{L;eff}$ falls less for every efficiency unit.

Recall that in the constrained economy the wage per unskilled worker in sector one remains constant at the minimum wage level once the economy opens up. But the ULATC makes it possible to pay a lower $w_{L;eff}$ per efficiency unit and hence alleviates the pressure of the binding minimum wage. Notice that there is one special case in which the wage per efficiency unit is the same in the constrained and the flexible economy. This is so if the skill-intensive sector uses the technology $F^2(H_2) = H_2$, i.e., it does not use unskilled labor. Then the skilled wage will rise as much in the constrained open economy as in the flexible open economy which also implies that the same wage will be paid per efficiency unit of unskilled labor in the unskilled-labor intensive sector. Moreover, trade patterns in the flexible and constrained economy will be identical. In general, however, the constrained economy produces less of the skill-intensive good and more of the unskilled-labor intensive good than the flexible economy. Hence, exports and imports are both smaller in the constrained economy.[58] This is not only resulting from the smaller size of output in the constrained economy, but also because of a relatively smaller output share of the skill-intensive sector. ■

Glossary of Symbols and Abbreviations

a) symbols

A: factor augmenting unskilled labor

a: superscript for autarchy

α: technology parameter in the Cobb-Douglas production function

B: unemployment benefits

[58] Note that demand will also change in the open economy compared to autarchy because of the price changes. However, as long as none of the two goods is Giffen this will not affect the result.

$F^i(:)$: production function of good i

$f^{\,i}(:)$: intensive form of production function of good i

H_i: amount of skilled labor used in sector i

h_i: skill-intensity in sector i de…ned as $\frac{H_i}{L_i}$

I_j: indicator variable taking the value one for action j and zero otherwise

L_i: unskilled labor used in sector i

o: superscript for the open economy

p_i: price in sector i

p: relative price in terms of good two

¼$_i$: pro…t in sector i

S_i: cost of switching technology in sector i

$S_{i;j}$: cost of switching production from sector i to j

μ_i: share of factor i

t: transfers

T: lump-sum tax

$U(:)$: instantaneous utility function

w_L: wage for unskilled workers

$w_{L;eff}$: wage per e¢ciency unit of unskilled workers

w_L^{min}: minimum wage

w_H: wage for skilled workers

X_i: ex- or imports of good i

b) abbreviations

CRS: constant returns to scale

DC: developed country

DRS: decreasing returns to scale

EU: continental Europe

H-O: Heckscher-Ohlin

LDC: less developed country

OECD: Organization for Economic Cooperation and Development

PPF: production possibility frontier

R&D: research and development

SLATC: skill-labor augmented technology change

TFP: total factor productivity

ULATC: unskilled-labor augmented technology change

US: United States of America

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