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3 FDI and outsourcing in a multi-industry framework

The Stolper Samuelson theorem states that some factors benefit from trade at the expense of some other factors. Does that mean that inequality rises due to trade liberalization? We have seen that the answer is complex and depends on the initial wage ratio. However, it is possible to show that with reasonable assumptions about the elasticity of substitution the $2 \times 2 \times 2$ model yields a scenario where inequality is rising in both the developing (Home) and the developed (Foreign) countries. But up to this point of the course we have only been concerned about wage differentials between workers and capital owners. A more realistic distinction between low- and high-skilled workers is still missing in our analysis. We therefore continue by discussing a more recent model that features both high- and low-skilled workers as well as capital. One may argue that this model is too recent to be called canonical but it is still among the most prominent approaches in the entire trade literature. It is tractable and it features both foreign direct investment and offshoring, which allows us to analyze different aspects of international trade in one single model.

Stylized facts about inequality. A first glance at the data suggests that trade rises inequality independently from factor endowments or the level of development. Many studies argue that this development can be rationalized by relative labor demand shifts from low- to high-skill workers. Inequality has been rising throughout the world and improvements in technology and/or more intense outsourcing may be potential explanations for this phenomenon as well as the increase in demand for high-skilled workers. Improvements in production technologies for instance have allowed firms to substitute low-skilled with high-skilled workers. Outsourcing works in the same direction as skill-biased technology change. It allows firms to benefit from a cost saving effect of offshoring. More expensive low-skill production stages can be shifted abroad to countries producing at lower costs. The latter channel is highly relevant in the context of trade between developed and developing countries. Interestingly, we will see that the effect of offshoring on labor demand for high-skilled is identical in both developed and developing countries. The offshored low-skill intensive jobs are mostly jobs that are relatively high-skill intensive in the receiving developing countries. Put differently, jobs that are declared "low-skilled" in Germany may still be relatively "high-skilled" from a developing country perspective.

Thus, one would expect rising wages at the top and stagnant or even declining wages at the bottom of the income distribution in developed and emerging countries that are open to globalization. The stylized facts for Germany presented in Figures 3.9 and 3.10 support this hypothesis. The analysis is conducted for males and females separately. Dustmann, Ludsteck, and Schönberg (2009, QJE) present evidence based on data from the period 1990 - 2004. This period is often referred to as the second "Golden Age of Globalization" characterized by soaring exports and heightened outsourcing activities. Thus, it is not surprising that the depicted evidence on inequality is associated with globalization, although globalization is certainly not the only driving force.

The authors use German worker-level data to trace real wage developments at different percentiles of the income distribution. The low-income group is represented by the 15th percentile, the medium income group is represented by the 50th percentile, and the high-income group is represented by the 85th percentile. First, all workers representing the different percentiles in the different years are sorted within each period. Notice that the workers who represent the different percentiles across the different years may be different. Depending on changes in the income distribution and changes in the workforce competition different workers may be drawn from different percentiles in different periods. Once the workers at the different percentiles are identified in each year, one can use the wage information associated with those particular workers to compare them over time. The question is how does the wage of the worker associated with the respective percentile in one particular year compare to the wage of the respective percentile worker's wage in the period before.[2] Take the median

[2] The data is the universe of German workers subject to social security contributions. Notice that the

income worker as example. Every period there is exactly one worker earning a wage that is equal to the median wage. Comparing this median worker's wage in period t with the median worker's wage in period $t+1$ allows us to derive the evolution of the median income between t and $t+1$. Figure 3.9 reveals an interesting evolution of incomes among the male workers in the sample. The wage rate of the 85th percentile worker is rising over the period. The wage of the worker at the 50th percentile is rising as well but not so fast as at the 85th percentile. Most interestingly, the wage of the 15th percentile workers was stagnant in the first half of the sample period and even declining after 1997. Taken together, we can conclude that inequality was rising during this time. The wage pattern for female workers looks similar but we are not able to replicate declining wage pattern in the low-income group represented by the 15th percentile of the income distribution.

Offshoring and skill-biased technological change are able to explain the stylized facts but only if labor-demand shifted from low- to high-skilled workers during the same period of time. The authors present some additional evidence on this issue by computing labor demand shifts based on exactly the same data source. Labor demand shares for different skills by occupations are computed as a ratio between the demand for workers from skill group k and in occupation j over the total demand of labor in skill group j. Those shares are averaged over all occupations and presented as growth rates between different periods in Figure 3.10. Medium- to low-skill ratios, and high- to medium-skill ratios are graphed separately. We find evidence that is consistent with high-skill labor demand shifts which are growing over time. This finding is in line with the hypothesized reasons behind rising inequality. Demand shifted away from medium- to high-skill labor and from low- to medium-skill labor.

The contribution of offshoring can be explained using a simple model that features

analysis does not trace certain workers over time. Each period you group all workers according to their income. The 15th percentile is the one worker with income higher or equal than 15 percent of all workers at the bottom of the income distribution. Thus, the worker at the 15th percentile is not the same in each period. Although the worker who represents the 15th percentile in one period may still be in the sample one year after, her or she may no longer be the worker with income higher or equal than 15 percent of his or her coworkers' wage.

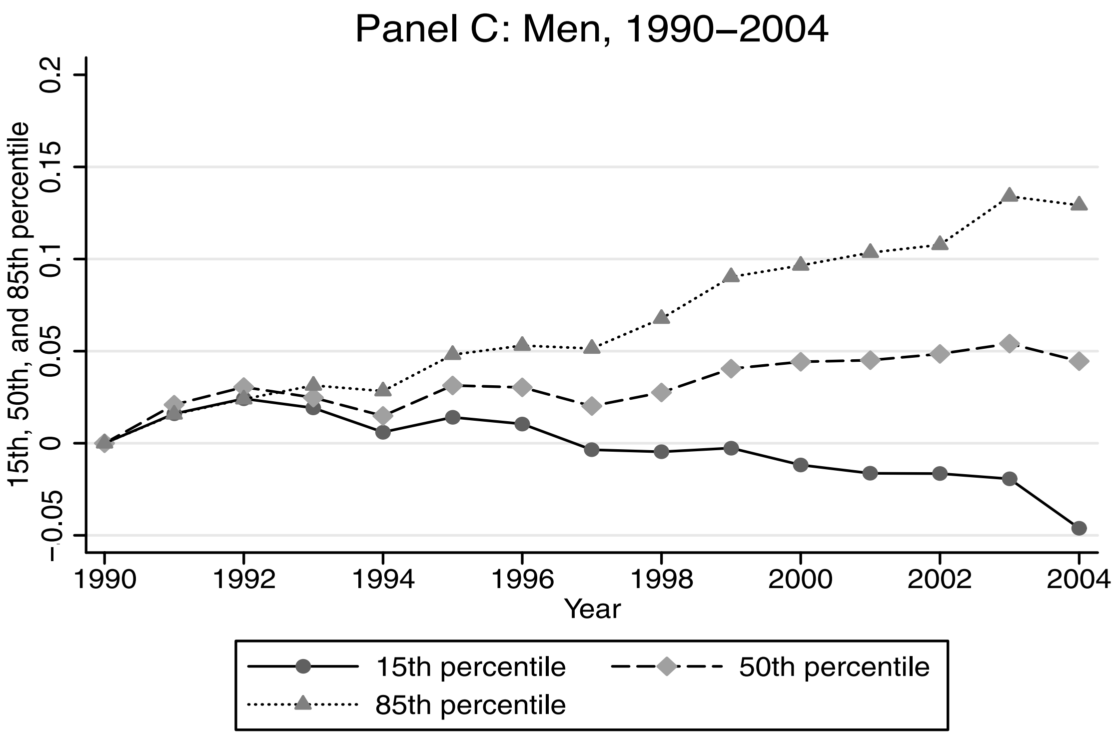

Figure 3.9: Wage inequality among males in Germany
(Source: Dustmann, Ludsteck, and Schönberg (2009, QJE)

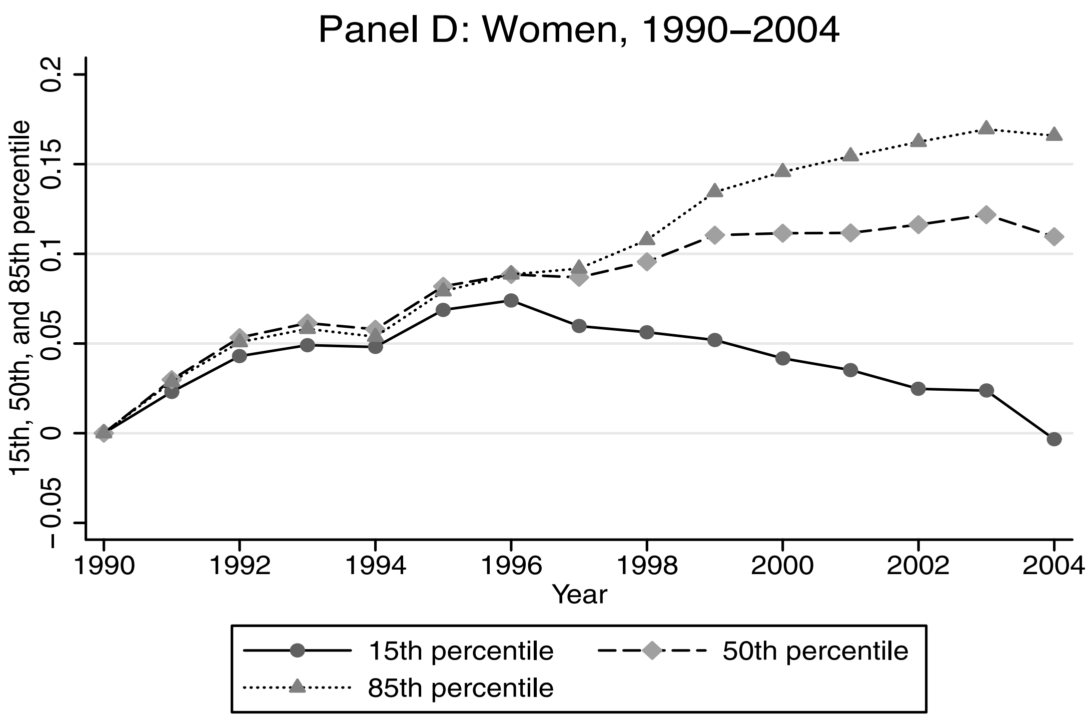

Figure 3.10: Wage inequality among females in Germany
(Source: Dustmann, Ludsteck, and Schönberg (2009, QJE)

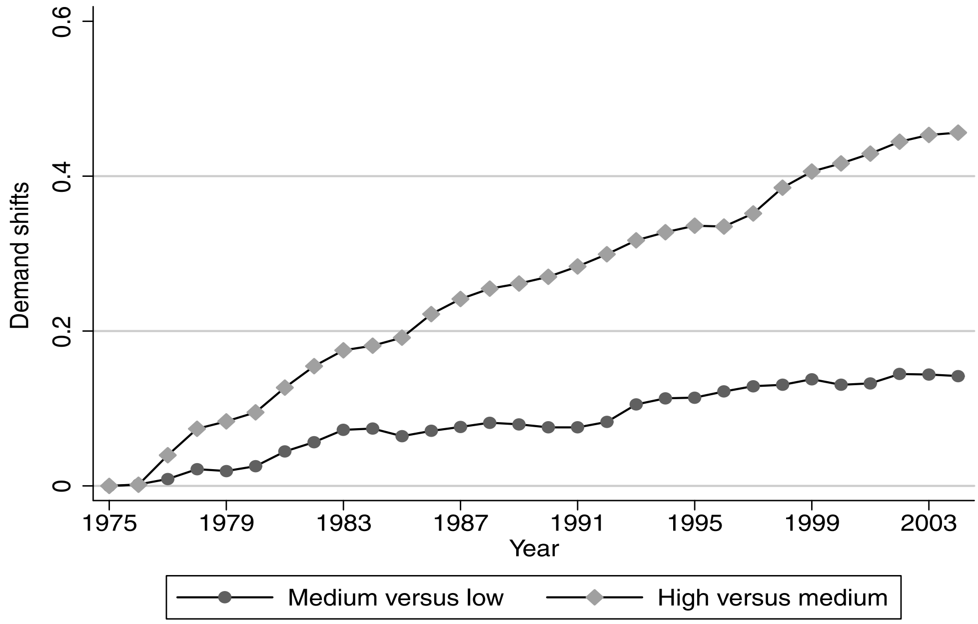

Figure 3.11: Labor demand shifts in Germany
(Source: Dustmann, Ludsteck, and Schönberg (2009, QJE)

both FDI and outsourcing. The model allows us to address potential labor market effects in developed economies that are driven by the emergence of more competitive low-income countries. It also allows us to explain the general equilibrium effects in developing economies' labor markets that are comparable to the effects observed in high-income countries. Quite to the contrary of the Stolper Samuelson theorem, we will see that inequality is rising in both countries due to heightened relative demand for high-skill workers. High-skilled workers benefit in both countries, whereas low-skilled workers' income is declining.

3.1 The Feenstra and Hanson model

Production takes place in a continuum of industries that rely on inputs of factors capital, high-skilled workers, and low-skill workers. Having more than two industries is key to bringing the model to the data in a more convincing way. However, the idea of a continuum of industries implies that the number of industries is infinite. Put differently, individual industries are not identifiable. Thus, we have to compute the mass of industries instead of the number of industries. A mass of industries aggregates the continuum bounded by two thresholds that fulfil certain criteria. It allows us to quantify certain outcome variables for the economy. Factor markets are competitive so that wages of high-skilled, low-skilled, and capital owners are equal across industries.

We will find that each country specializes in a certain range of industries according to the comparative cost advantage determined by production costs. Countries will be active in industries that produce more cost-efficiently compared to the the same industry in Foreign. A key difference with standard trade models discussed above is the idea of trade in intermediate goods rather than trade in final goods. The whole range of intermediate goods produced within the individual industries is required to assemble the final good. The intermediates themselves are produced using labor and capital inputs in the continuum of industries. Imported intermediate goods are in fact goods that were outsourced by the importing country when the economy moves from autarky to free trade. The traded good cannot be consumed directly without going through another assembly process that must take place in each economy separately. Intermediates that are produced in one country are combined with the intermediate goods that are purchased from the rest of the world through outsourcing in order to obtain the final consumption goods. Under autarky, there is no possibility to offshore such that the whole continuum of intermediates must be produced and assembled within the respective country. For sake of simplicity, we will focus on the two-country scenario where a developed North and an undeveloped South coexist. Equilibria for autarky and free trade (offshoring) will be determined separately in order evaluate inequality under both scenarios. Moreover, we will allow for FDI in the free trade scenario. Cross country capital flows trigger changes in production costs through their impact on capital rentals. Thus, changes in capital rentals trigger a shift in the comparative advantage across different industries, which has an effect on inequality.

How does outsourcing affect labor demand shifts from low- to high-skilled workers?

We will see that the developed country has a comparative cost advantage in more high-skill intensive industries. Low-skill intensive industries are shifted to the developing country. Starting from the free trade equilibrium, one may ask how changes in the cost of offshoring (i.e. through FDI or lower offshoring costs) affect labor demand for high-skilled relative low-skilled workers. The developed North offshores additional industries to the developing South. The resources that were freed up by offshoring are reallocated to the remaining industries. From the perspective of the North, the offshored industries that shift to the South are low-skill intensive. As a result, the North loses some of the more low-skill intensive industries. From the receiving country's perspective (South) those industries are the more high-skilled intensive industries. Thus, we can conclude that offshoring stimulates a labor demand shift from relatively low- to relatively high-skilled industries in both the developed and the developing country.

The model discussed in this chapter is taken from Feenstra and Hanson (1995). The continuum of industries are ordered according to their relative high-skill intensity in ascending order using index z that identifies one particular industry within the whole continuum. Production in industry z takes place according to the Hicks neutral production function

$$x(z) = A\left[\min\left\{\frac{L(z)}{a_L(z)}, \frac{H(z)}{a_H(z)}\right\}\right]^{\theta} K^{1-\theta} \quad , \quad z \in [0,1] \tag{3.41}$$

We assume that the range of industries in each country is bounded by 0 at the lower bound and 1 at the upper bound. Notice that this is the maximum range of industries that can exist. All industries must be active under autarky but some may be offshored under free trade. The mass of one individual industry is zero so we rely on the mass of a range of industries. The total mass of industries can be computed through the integral at the lower and upper bounds of all industries. However, this exercise is trivial as the mass is exactly equal to unity. Let the variables $L(z)$ and $H(z)$ denote inputs of high- and low-skill labor in industry z. We say that production in industry z

follows a Leontief production function nested in a Cobb Douglas production function. Low- and high-skilled workers are teamed according to the input coefficients a_L and a_H, which determine the input requirement for one good in industry z. The relationship is fixed which explains why we call this part of the production function Leontief: high- and low-skilled workers cannot be substituted by each other. Notice that these coefficients do not stem from any cost minimization problem. They are given exogenously without any further micro foundation. The labor-aggregate is combined with capital in a Cobb Douglas production function. θ determines the Cobb Douglas output elasticity. Thus, the model allows for some degree of substitution between labor and capital leaving the input relationship between low- and high-skilled workers fixed. One may also think about substitution between capital and a labor aggregate. The latter aggregates high- and low-skilled workers. Finally, K denotes the input of capital in industry z.

We are able to solve the cost minimization problem using the standard solution method the production function is Leontief in nature. Both types of workers can be treated as combined aggregates so that we optimize production for labor (low- and high-skilled bundled together according to the fixed relationship determined by a_L and a_H) and capital. The cost minimization problem can be solved as demonstrated for the standard Cobb Douglas case with two input factors, the labor bundle and capital. The solution yields the unit-cost function (3.41)

$$c(w,q,r,z) = B[wa_L(z) + qa_H(z)]^{\theta} r^{1-\theta} \tag{3.42}$$

Later in this chapter we will demonstrate how the endogenous factor prices can be determined. Once all output x in all industries z is known, the number of final goods can be determined by the production function

$$\ln Y = \int_0^1 \alpha(z) \ln x(z) dz \quad . \tag{3.43}$$

Final goods are assembled according to another Cobb Douglas production function without incurring any additional costs. The production function in the assembly process is different as we have to deal with a continuum of industries. Each industry enters the assembling process with a Cobb Douglas share α that sums to unity over all industries.

The comparative cost advantage. Conditional on wages and capital rentals in Home and Foreign we are able to characterize the unit cost functions in both countries. The graphical representation of both functions is shown in Figure 3.12. The slope of both cost curves is an important determinant of comparative advantage. Recalling that industries in both countries are ordered according to their high-skill intensity we find that industries closer to the lower bound are the least skill-intensive industries. This result applies for Home and Foreign. However, the steeper slope tells us that the skill-intensity in Home is increasing faster than the skill-intensity in Foreign.

From the graph we can see that the undeveloped foreign country has a comparative advantage in all industries to the left of z^* due to lower unit costs in these particular industries. The developed home country has a comparative advantage in all industries to the right of z^*. Industry z^* is the one industry where both countries produce with identical costs so that neither country has a comparative advantage. We pay attention to any particular industry but rather focus on the range of industries between 0 to z^* in Foreign and z^* to 1 in Home.

What are the necessary conditions that secure a stable equilibrium? The assumption $q/w < q^*/w^*$ must hold. The high- to low-skilled workers' wage ratio must be higher in Home than in Foreign. This assumption is realistic for a North/South country setting.

We can apply Sheppard's lemma in order to solve for the demand for high- and low-skilled workers in industry z as

$$l_l = \frac{\partial c}{\partial w} \quad , \quad l_h = \frac{\partial c}{\partial q} \tag{3.44}$$

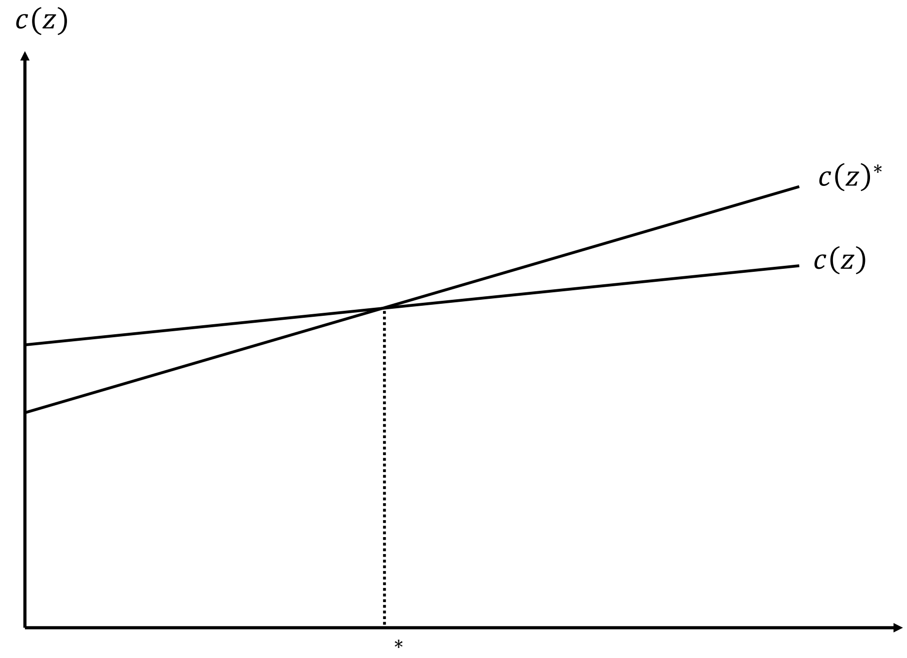

Figure 3.12: The comparative cost advantage

Total demand for low- and total demand for high-skilled workers can be computed by integrating industry-level labor demand over the whole continuum of active industries. The solutions can be found in the numerator and denominator of Home's relative demand function

$$D(z^*) = \frac{\int_{z^*}^{1} \frac{\partial c}{\partial q} x(z) dz}{\int_{z^*}^{1} \frac{\partial c}{\partial w} x(z) dz} \tag{3.45}$$

Total demand for highly skilled workers in industry z is $\frac{\partial c}{\partial q} x(z) dz$. Shepard's Lemma gives us the optimal labor demand associated with producing one unit of the good as $\frac{\partial c}{\partial q}$ due to the specific setup of the cost minimization problem, which was solved under the constraint that one unit of the good can be produced. Total labor demand in industry z is thus unit labor demand times the total output in industry z. However, labor demand in one industry is meaningless in the continuous case. We aggregate by integrating over all active industries using the integral from the lower to the upper bound of industries where the respective country has a comparative advantage. Notice that the lower bound in Home is fixed to 0 and the upper bound in Foreign is fixed to 1. The cutoff z^* is the variable bound of active industries in both countries.

Labor market clearing. We are now able to solve the labor market clearing condition in relative terms. Notice that endowments are exogenously given and remain constant throughout the analysis. In principle we only need to solve two equilibrium conditions with two unknowns. The wage of high-skilled workers must be such that total labor demand for high-skilled workers is equal to the exogenously given labor supply of high-skilled workers, H. The wage of the low-skilled workers must be such that total labor demand for low-skilled workers is equal to the exogenously given labor supply of low-skilled workers, L. It is easier to reduce the problem to one equation and one unknown by expressing everything in relative terms. Relative demand for low-skilled workers (related to high-skilled labor demand) must be equal to the relative supply of low-skilled workers (related to high-skilled labor supply). To what extent does labor demand depend on wages of high- and low-skilled? We assume a Leontief production function so that the input relation is fixed. From Sheppard's Lemma we know that the demand for labor depends on wages. However, wages still affect labor demand through substitution between worker types and capital inputs. The labor bundle becomes more expensive if q or/and w are rising so that demand for both high- and low-skilled workers becomes lower. The input proportion between low- and high-skilled is independent of changes in either wage rate. This can be easily verified using the first derivatives of the unit cost function.

A graphical solution for z^* and q/w can be found in Figure 3.13. The relative labor supply is constant.[3] Relative demand is a downward sloping function. The higher the high-skilled wage relative to the low-skilled wage, the higher is the relative demand for low-skilled workers in the economy. How can this result comply to the assumption of a proportional input relation between high- and low-skilled within one industry? The answer is complex and described in the proof to Lemma 1 b) discussed in the Appendix of Feenstra and Hanson (1995). This course does not go into further detail.

A downward sloping labor demand curve with constant relative labor supply yields

[3] This is different from the original version of the model where relative labor supply is a positive function of the relative wage of high- and low-skilled workers. Increasing high-skilled wages induce positive education decisions of low-skilled workers which increase the relative labor supply of high-skilled.

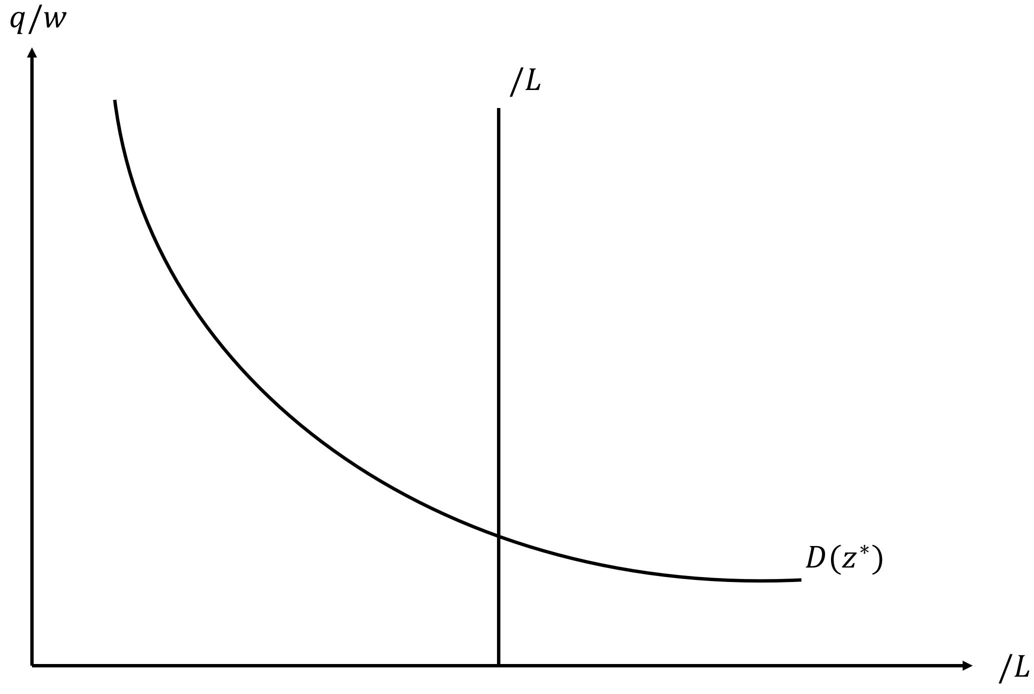

Figure 3.13: Labor market clearing

a unique solution for q/w at the intersection between the relative labor supply and demand curves.

To fully characterize the equilibrium we have to solve the capital rental using Shepard's Lemma and the property

$$\frac{wL + qH}{\theta}(1 - \theta) = rK \tag{3.46}$$

that stems from the assumption of a Cobb Douglas production function over the labor aggregate and capital. Notice that K is fixed in the short-run without allowing for foreign direct investment (FDI). Knowing the total labor costs and the total supply of capital in the Cobb Douglas case implies that the capital cost share in total production costs is proportional to the Cobb Douglas elasticity of substitution, $1 - \theta$. A share θ of total production costs is spent on capital and a share θ on the labor bundle.

3.2 Capital market liberalization, offshoring and wage inequality

What happens if a government decides to liberalize the capital market? Home investors will have an incentive to invest abroad providing the Foreign interest rate is higher than that in Home.

Capital flows into the country in the form of FDI until the rates of return are equalized, that is, $r = r^*$. The domestic capital stock decreases due to FDI with the result that the capital rental rate increases. Capital becomes relatively more scarce, which is reflected in higher capital rental rates. The opposite happens in the FDI receiving country, where the capital rental rate is declining in order to restore capital market equilibrium: increased capital supply must be met by higher capital demand induced through lower capital rental rates.

The aforementioned adjustment process of capital rental rates in Home and Foreign shift the unit-cost schedules, $c(z)$ and $c^*(z)$, up or down. The direction of the shift within each country depends on whether the change in r is positive or negative. Thus, the two cost schedules shift in opposite directions. Suppose that wages and the cutoff remain fixed. Firms in each industry have to pay a higher interest rate for capital deployed in the production process. As a consequence, the equilibrium cutoff must change, followed by increased offshoring in the form of additional industries being shifted abroad. These industries survive the initial move from autarky to free trade but they are no longer competitive due to the change in capital rental rates. The country where capital flows out due to FDI looses its comparative cost advantage in some of the industries located close to the former cutoff. These industries are not able to compete with the FDI receiving country that benefits from lower capital rentals. The cutoff shifts to the point $z^{*'}$ at the right of the initial cutoff z^*. All industries between the initial cutoff and the new cutoff lose their comparative cost advantage to Foreign. Remember that the entire continuum of industries ranging from zero to one is needed to produce one unit of the final output good. The shift in industries implies a surge in offshoring of home industries to the foreign economy.

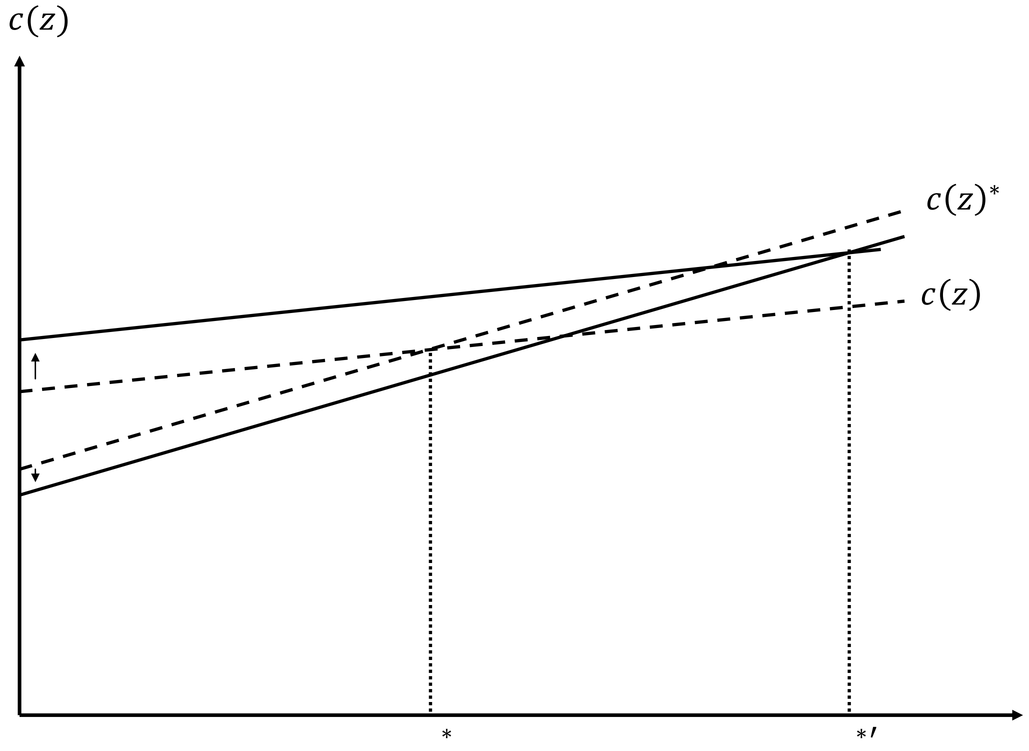

Figure 3.14: The effects of FDI on the comparative cost advantage

How do the domestic and the foreign labor markets react to this shock? We are able to analyze the effects of FDI and offshoring within the same graph that we were using beforehand to solve the labor market clearing condition. Relative labor supply remains fixed at its initial level H/L but the relative labor demand curve shifts to the right due to the change in the cutoff z^*. This change implies a reduction of the range of active industries in Home. Only the most high-skill intensive industries can survive in Home and the higher relative demand for high-skilled workers must be met by a higher relative wage q/w to stimulate low-skill labor demand. This counteracting effect on relative demand is necessary to restore equilibrium. Notice that the total supply of high-skilled and the total supply of low-skilled remains constant. Although the input relation in one industry is fixed by the assumption of a Leontief production function, changes in the relative wage rate affect the slope of the cost curve and therefore total demand for different skills over the continuum of active industries. Given the assumption that high-skilled wages are higher than the low-skilled wages in both countries ($q/w > 1$ in both Home and Foreign), we are able to conclude that inequality rises in Home.

What happens in the foreign country? Offshoring in this model increases high-skill labor demand in both countries. The developing country becomes competitive in industries that are more high-skill intensive from the developing country perspective. Thus, the relative demand for high-skilled labor increases as well. Following the same reasoning we can conclude that the relative wage of high-skilled must increase in the developing country as well. Inequality increases in both countries.

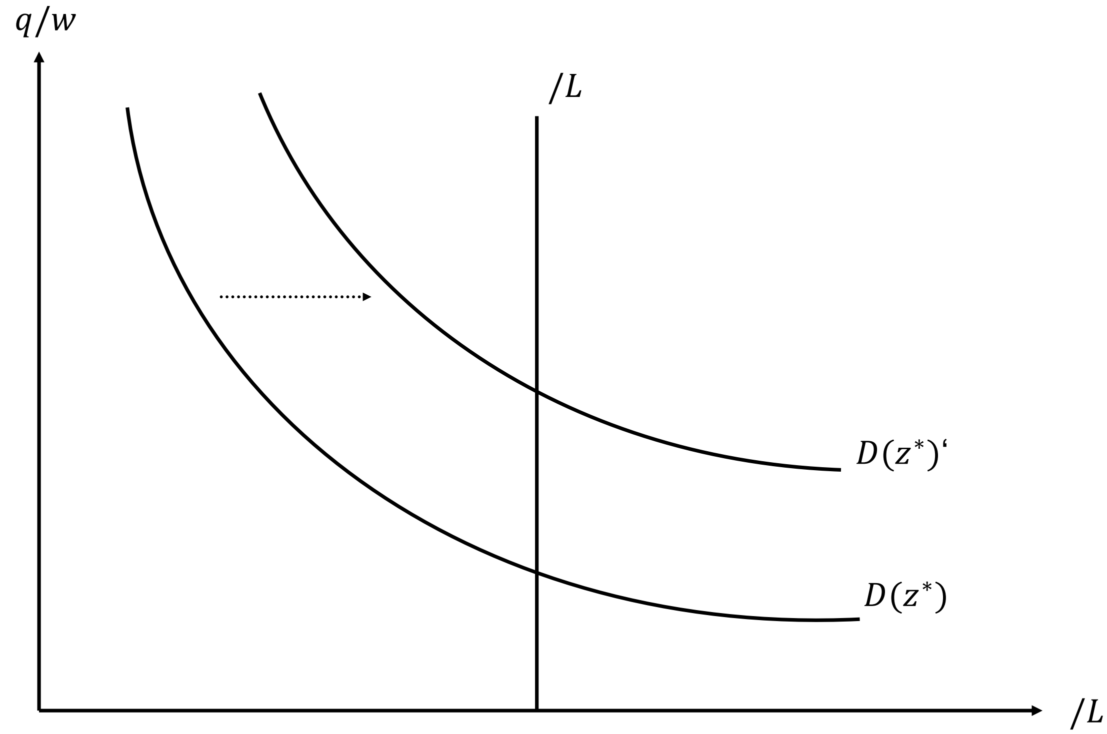

Figure 3.15: Labor market clearing after FDI

3.3 The role of the continuum of industries

One may argue that the results derived in the last section hinge on the assumption of a continuum of industries. To prove the generality of the results, we replicate the main insights in a model with two countries, where firms produce in two industries using inputs of high- and low-skill workers. The two intermediate goods are denoted by y_1 and y_2. Technologies are different in both industries such that optimal factor intensities have to differ as well. Both intermediate goods are assembled to make a final consumption good in the ultimate production step. Firms can assemble the final good using intermediate inputs produced either in Home or Foreign. Corner solutions where one or the other intermediate is entirely produced abroad are ruled out by assumption and the two intermediate input goods are produced according to

$$y_1 = f_1(L_1, H_1, K_1) \quad \text{and} \quad y_2 = f_2(L_2, H_2, K_2) \ . \tag{3.47}$$

We impose the assumption that y_1 is the unskilled-labor intensive good, whereas good y_2 is the high-skill labor intensive good. Both intermediates are tradeable and the variable x_i is an import or export indicator variable that is positive if the intermediate good is exported ($x_i > 0$) and negative if the intermediate good i is imported ($x_i < 0$). Prices of intermediate good 1 and 2 are summarized by the vector $p = (p_1, p_2)$. Under free trade, prices are exogenously given at the world market.

Final goods in industry n are assembled using input of intermediates according to

$$y_n = f_n(y_1 - x_1, y_2 - x_2) \tag{3.48}$$

Thus, total factor demand in country n must satisfy the endowment-constraints

$$L_1 + L_2 = L_n, \ \ H_1 + H_2 = H_n, \ \ K_1 + K_2 = K_n \tag{3.49}$$

The value of output plus net-trade in intermediates can be determined by solving the maximization problem

$$G_n = \max_{x_i, L_i, H_i, K_i} p_n f_n(y_1 - x_1, y_2 - x_2) + p_1 x_1 + p_2 x_2 \qquad \text{s.t. (3.47) and (3.49)}$$

Countries choose the level of intermediate exports and imports, inputs of labor, inputs of capital and the inputs of high-skilled workers in a way that maximizes the value of final good output. Resource constraints (3.47), (3.49) are taken into account in order to avoid the choice of non-feasible solutions obtained from the maximization problem. Notice that p_n is the price for the final good. Thus, the final good producer's revenue is $p_n y_n$, which depends negatively on the amount of imported intermediates and positively on the amount of exported intermediates. Each country will specialize in producing imports and exports of either intermediate 1 or intermediate 2. We focus on one country. Prices are taken as given and trade is not necessarily balanced in this chapter.

The final good assemblers maximize output by deciding about the amount of intermediates produced in-house and the amount of intermediates imported from abroad. Final good production is illustrated using isoquants that summarize input bundles that give rise to the same level of final good production. Let y_n denote the isoquant in the initial scenario with only some imports of intermediate goods. The scenario we have chosen is one with $x_1 > 0$ and $x_2 < 0$. Is it possible to prove this result? Production is constrained by the full employment conditions that shape the Production Possibility Frontier. The production point must lie somewhere on the concave graph in Figure 3.16. It is the relative world market price for intermediates that determine the production point A. Moreover, the relative intermediate price also determines the maximum production at point B. Production is determined by point A. The difference must be imported so that $x_1 > 0$. Next, let us turn to production in sector 2. There, we find that point B is located below point A. Production of y_2 exceeds the level of inputs in Home and the difference between production and the quantity of this intermediate good used for the assembling process of the final good is exported to Foreign. The export volume is measured by $x_2 < 0$. All input combinations are represented by the isoquant that is again associated with a certain level of output of the final good. The output levels are held constant at the levels we have chosen for the initial scenario with outsourcing (trade in intermediates).

We are also able to determine the effects of an increase in the relative world market price of intermediates. Suppose that world market conditions change in a way that affects the terms of trade in favor of the Home country. Such a drop in the relative price of the imported intermediate is depicted in Figure 3.16. Production shifts towards the skill-intensive intermediate good represented by point A' and trade shifts to point B'. Home produces more of the relatively more expensive good in order to rise the level of exports above its initial level. The imported good becomes cheaper so that less resources are used in the production of the good that can be purchased even more cheaply on the world market. Resources shift towards the industry where Home has a comparative advantage. As result, the final good producer can produce more of the final good as indicated by the outward shift of the isoquant from y_n to y_n'. The intuition is that imported intermediates become cheaper whereas exports become more expensive due to the better terms of trade.

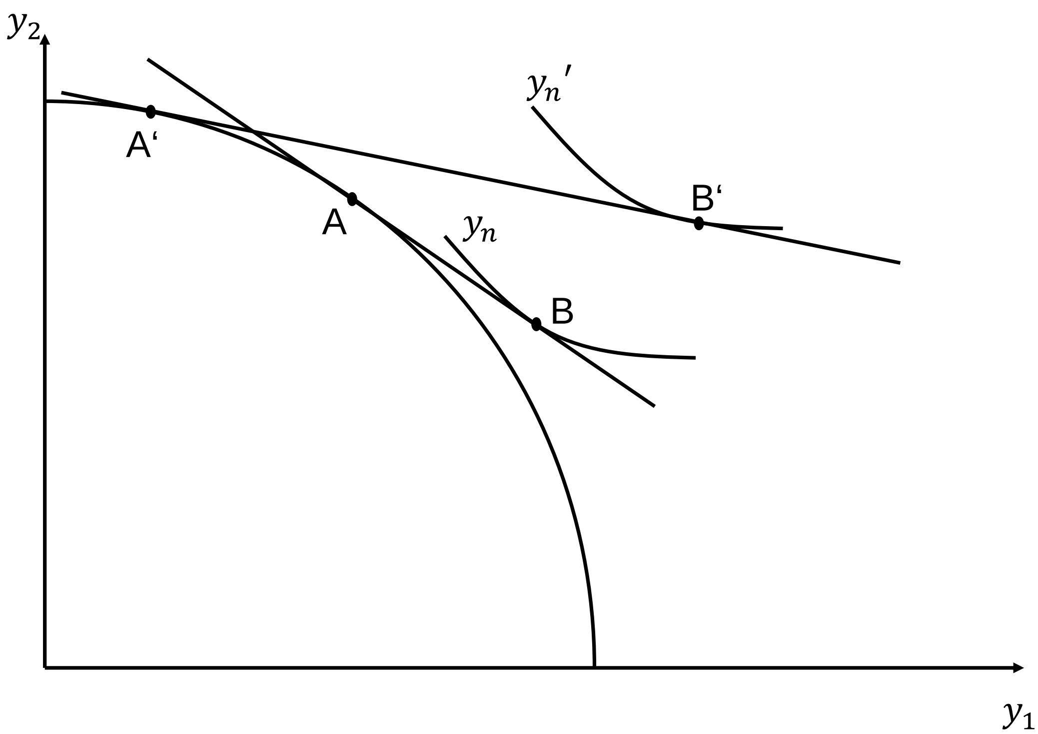

Figure 3.16: Autarky and trade equilibrium

Perfect competition and prices. The assumption of perfect competition is maintained throughout the entire chapter. Firms produce intermediates without generating profits. Thus, a Zero Profit Condition can be used in order to determine the prices of factors and intermediate goods. Can we conclude anything about the price of the final good in industry n? We ignored the price P_n so far because it is not relevant for the outcomes of the model. Intermediate good prices and factor prices are jointly determined in a first step and those intermediate good prices pin down the final goods price P_n. We can ignore P_n as long as we are not interested in discussing welfare effects associated with trade liberalization.

More important than final goods prices are the prices of the intermediate goods. Intermediate goods' prices affect factor prices in our model as the Zero Profit Condition

$$p_i = c_i(w, q, r)$$

applies due to the assumption of perfect competition. The price of intermediate good i must be equal to the unit production costs that depend on factor prices w (wage of the low skilled), q (wage of the high skilled), and r (capital rental). Under autarky prices are jointly determined with the price of the final goods. However, we focus on the free-trade equilibrium where these intermediate goods prices are given by the world market.

Figure 3.17 graphs the Zero Profit Conditions for the two intermediate goods $p_1 = c_1$ and $p_2 = c_2$. Capital rental rates are implicitly fixed by graphing the iso-curves in the w, q space. The intersection of both iso-curves determine equilibrium low- and high-skill wages at point B. More interestingly, we can analyze the effects of a decrease in the price of intermediate good 1 (p_1 decreases). Remember that good 1 is the low-skill labor intensive intermediate good. The wage of the factor used intensively in the respective sector decreases. High-skilled workers benefit from the decrease in the price of intermediate good 1 and inequality rises in the developed country - similar to the outcome in the model with a continuum of industries. That is not surprising. The models are almost identical as we take one particular industry n out of the continuum and look at this one particular slice of the economy in isolation from the remaining industries. We ignore all general equilibrium effects that arise due to the existence of other industries. Can we say something about the effects of offshoring in developing countries? We have seen that the major advantage of the continuum of industries was the result that more intense offshoring increased demand for high-skilled labor in both the developed and the developing country. In fact, this result does not require a general equilibrium framework with more than one industry. Countries that export the low-skill intensive intermediate good would lose from the terms of trade changes analyzed above. The price of their export good deteriorates, resulting in a shift to more high-skill intermediate good production. Wages of the low-skilled decrease relative to the wages of the high-skilled leading to higher inequality through the assumption that $q > w$ in both countries. However, the analysis lacks some clear micro-foundation of the determinants of offshoring. The partial equilibrium analysis is limited as we do not solve for world market prices in general equilibrium and we also do not investigate the reasons for offshoring. FDI would be a good candidate. One could analyze the effects of capital flows on the equilibrium capital rental rates but for the sake of tractability we neglect r in our analysis. More information about the production functions would be necessary to determine the effects of r on the Zero Profit Conditions to learn about the associated price effects. The Feenstra and Hanson model imposes very strong assumptions about the functional form of the production process. These assumptions allow us to draw unique solutions and unambiguous predictions about the effects of offshoring on inequality. The assumption of a Leontief production function is especially restrictive, albeit one may conclude that a fixed input relationship between high- and low-skilled is not as unrealistic as it appears on first sight.

We close the discussion about theories of trade in intermediates by applying Jones algebra to the simplified model of offshoring. As a first step we compute the total

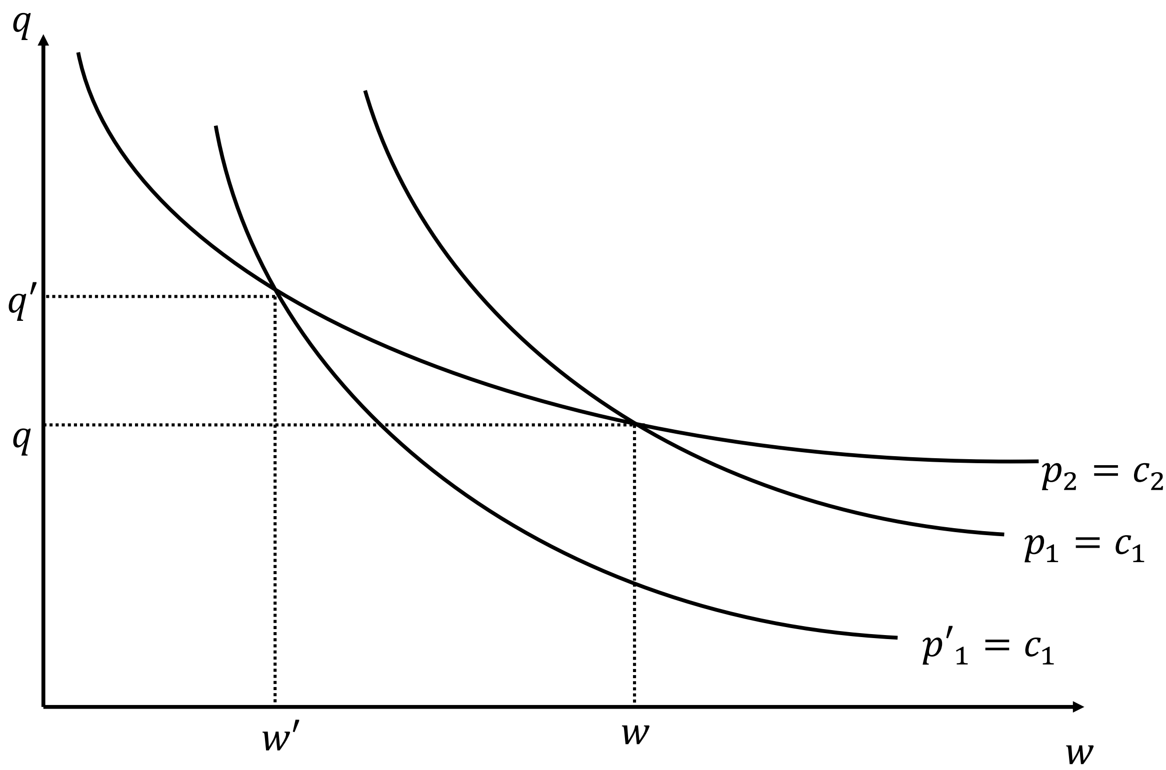

Figure 3.17: Zero profit conditions and the effects on factor prices

differential of the Zero Profit Condition as

$$dp_i = dw\ a_{il} + dq\ a_{iH} + dr\ a_{iK} \tag{3.50}$$

Dividing both sides by the price of the intermediate good and accounting for the Zero Profit Condition on the left-hand side we obtain

$$\frac{dp_i}{p_i} = \frac{dw\ w\ a_{iL}}{c_i\ w} + \frac{dq\ qa_{iH}}{c_i\ q} + \frac{dr\ r\ a_{iK}}{c_i\ r} \tag{3.51}$$

Accounting for the familiar cost shares θ allows us to rewrite the Zero Profit Conditions as

$$\hat{p}_i = \theta_{iL}\hat{w} + \theta_{iH}\hat{q} + \theta_{iK}\hat{r} \tag{3.52}$$

Notice that θ denotes the share of costs falling on one particular input-factor in total unit costs. The shares must sum up to unity as $\sum_j \theta_{ij} = 1$ where j identifies the input-factor (low-skill labor, high-skill labor, or capital in our example). The system is not fully specified since we only have two equations determining three endogenous variables. We solve this problem by fixing capital. Capital has the same cost-share in both intermediates, which implies that $\theta_{1K} = \theta_{2K}$.

We take the difference between the two intermediate-goods prices determined by (3.52) as

$$\hat{p}_1 - \hat{p}_2 = (\theta_{1L} - \theta_{2L})\hat{w} - (\theta_{1L} - \theta_{2L})\hat{q} \tag{3.53}$$

The cost shares of capital not only drop out in equation (3.53), but also imply that the cost share for total labor (low- plus high-skill labor) must also be equal in both sectors. If the share of capital costs in total production costs is equal in both sectors and the total costs consist of labor and capital costs, then the labor cost share is also equal in both sectors. However, that does not mean that the high- and low-skill cost share is equalized across sectors as well. Suppose that the price of the intermediate input increases such that $\hat{p}_1 - \hat{p}_2 < 0$ leads to a decrease in the relative price of unskilled workers wage rate because

$$(\hat{w} - \hat{q}) = \frac{(\hat{p}_1 - \hat{p}_2)}{(\theta_{1L} - \theta_{2L})} < 0 \tag{3.54}$$

The model predicts that in high-skill abundant countries high-skill workers benefit from outsourcing: high-skill workers' wages are increasing due to offshoring.

3.4 Empirical tests of the Feenstra and Hanson model

The focus in this sub-section is on an empirical test of the predictions derived from the two models of offshoring. First, a testable equation will be derived based on the assumption of a translog cost function that is supposed to describe the functional form of the unit cost function. Reverse engineering enables us to choose a cost function that gives rise to an equation that can be taken to the data in order to quantify the effects at work. It turns out that the translog cost function has the desired properties. A detailed description of the function itself and the steps needed to derive the testable equation can be found in the textbook by Feenstra (2004). We skip further discussions and directly dip into the empirical model without spending too many words on the details behind the translog function. The test of this model builds on the description in Feenstra and Hanson (1995). The empirics shed light on the contribution of skill-biased technological change and offshoring to the observable rise of the high-skill cost share in production.

Suppose that the model discussed in this subsection can be characterized by a translog function that gives rise to the first derivative

$$\frac{\partial \ln C}{\partial \ln w_i} = \alpha_i + \sum_{j=1}^{M} \gamma_{ij} \ln w_j + \sum_{k=1}^{K} \phi_{ik} \ln x_k, \quad i = 1, ..., M. \tag{3.55}$$

We know that $\frac{\partial \ln C}{\partial \ln w_i} \approx \frac{\partial C}{\partial w_i} \frac{w_i}{C}$. Thus, the first derivative of log-costs with respect to the log-wage is approximately equal to the percentage change of total costs as a percentage change in the wage of input factor i. Put differently, $\frac{\partial \ln C}{\partial \ln w_i} = s_i$ is the growth rate of the cost share of factor i. We can easily set up this equation for skilled-workers as one particular input factor of interest instead of one general factor i. The variable α_i is a constant that determines the average demand for high-skilled workers. Remember that the expression is part of the first derivative of unit costs with respect to the wage of the high-skilled. According to Sheppard's Lemma, this constant is a measure for high-skill labor demand. The γ coefficients are associated with the indirect effects of the other input factors. The last sum is a summary of all other factors that influence unit costs indirectly through the high-skilled wages. Possible factors include skill-biased technological change, offshoring or substitution of labor by capital. Thus, the ϕ terms are the variable of interest in our setup. We want to isolate the separate effects of technology and offshoring on high-skilled wages. The aim is to back out estimates of the parameters γ_{ij} and ϕ_{ik} by fitting

$$\Delta s_{nH} = \phi_0 + \phi_K \Delta \ln K_n + \phi_y \Delta \ln Y_n + \phi_z' \Delta z_n, \quad n = 1, ..., N \ . \tag{3.56}$$

The dependent variable is the cost share of high-skill workers, ϕ_0, which is a constant. We know from the model that we have to control for capital and output by including proxies for K_n and Y_n. The vector z_n contains variables that shift unit costs, which has an indirect effect on wages of the high skilled. We previously discussed the problem that we are not able to say how offshoring or FDI affects wages of the high- and low-skilled in Figure 3.16 without knowing the exact form of the production functions. FDI and offshoring shifts the unit cost functions in Figure 3.16 but we don't know how q and w react without further knowledge about the production functions and the form of the unit cost function associated with it. Thus, ϕ_z are the coefficients that have to be estimated. The model can be translated into the question "If the high-skill cost share increases, how much of the increase is due to an increase in capital, output, and the structural variables technology and offshoring?".

The authors use the following data:

- Data source: NBER Productivity Database at the 4-digit Standard Industrial Classification (SIC) level
- Coverage of the data: 447 industries within the U.S. manufacturing sector over 1979-90
- Change of the non-production wage share over all manufacturing industries from 35.4% to 42.4% used as proxy for low-skill labor wage share
- Regressors included:
  - A proxy for output
  - A proxy for the capital share in production

- Outsourcing measured as imported intermediate inputs as share of total materials purchases
- The shares of computers and other high-tech capital in the total capital stock
- The share of expenditures on computers in total investment

Table 3.18 reports some of the results reported in Feenstra and Hanson (1995). The dependent variable is the change in non-production workers' wage share in total production costs. The authors look at changes between 1979 and 1990, which is a relatively long period of time that featured both increases in offshoring and skill-biased technological change. The change in the high-skill cost share is explained using different regressors listed in the first column of Table 3.18. The second row presents some summary statistics, row 3 to 5 present the coefficients associated with the different regressors and their standard errors in parentheses. The latter allows us to evaluate statistical significance of the estimated coefficients.

Notice that the regressions differ with respect to the regressors included. Different proxies for skill-biased technological change are included in order to prove robustness of the reported results. The last column reports the contribution of each variable to the change in the dependent variable. These figure allow us to asses the relative importance of each variable of interest. Notice that the contribution is reported for each variable except for the variable Other high-tech share. It is the only variable that is insignificant. This can be seen from a simple comparison of the coefficient and the standard error reported below the coefficient.

Change in Nonproduction Wage Share, 1979-90, as Dependent Variable

	Mean	Regression 1	Regression 2	Regression 3	Contribution
$\Delta \ln(K/Y)$	0.71	0.05	0.04	0.04	7-9%
		(0.01)	(0.01)	(0.009)	
$\Delta \ln(Y)$	1.54	0.02	0.02	0.01	4-8%
		(0.006)	(0.006)	(0.006)	
Outsourcing	0.42	0.20	0.22	0.14	15-24%
		(0.096)	(0.10)	(0.09)	
Computer share	0.25	0.20			13%
		(0.091)			
Other high-tech share	0.14	-0.07			-
		(0.14)			
Computer share (alt. measure 1)	0.07		0.43		8%
			(0.17)		
Other high-tech share (alt. measure 1)	0.17		0.005		0.2%
			(0.07)		
Computer share (alt. measure 2)	6.56			0.02	31%
				(0.01)	
High-tech share (alt. measure 2)	0.40			0.03	3%
				(0.05)	
R^2		0.16	0.16	0.19	
N		447	447	447	

Source: Feenstra and Hanson 2003, Table 3, as simplified from Feenstra and Hanson 1999, Table III, and empirical exercise 4.2.

Figure 3.18: Regression results to equation (3.56)

The value associated with "other high-tech share" is -0.5. The coefficient is insignificant indicating that the variable has no impact on the change in the high-skill cost share. The range of contribution is reported for the variables that show up more than once. To understand how the contribution is computed one must understand how to interpret the coefficient itself. In our linear regression model the coefficient is equal to the marginal effect of each variable. It tells us the reaction of the dependent variable in a change of the respective regressors. The counterpart is the first derivative of equation (3.56) with respect to each variable. For instance, the coefficient of the variable "Outsourcing" can be interpreted as the first derivative of equation (3.56) with respect to $\ln K$, which is $\partial \Delta s / \partial \ln K$. Thus, the coefficient allows us to infer the effect of a change in capital on the high-skilled wage share. The authors report that the mean of the dependent variable is 0.389. This information together with the mean of the respective variable of interest allows us to construct standardized coefficients, which are directly comparable to each other. We are interested in the information about how a one per cent increase in capital is associated with outsourcing. A change by some certain value is meaningless if we are not able to relate that number to some benchmark value. Is the increase by one big or small? We don't know without taking some further information about the distribution of the variables into account. We normalize the coefficients by multiplying the coefficient with its mean and dividing the result by the mean of the dependent variable. The lower bound of the contribution of the first variable in Table 3.18 is $0.04 \times 0.71/0.389 = 0.07 = 7\%$.

Outsourcing turns out to be more important than skill-biased technological change in most regressions. Only the regressions that use the second alternative way of measuring the computer share skilled-bias technological change turns out to be more important than outsourcing. The Other high-tech share variables are either insignificant or quantitatively unimportant.

Standardized coefficients are plagued by many statistical problems. When the number of observations is low one may argue that the mean values are not accurate, thereby biasing the standardized coefficients. Moreover, the distribution of the the variables must be identical otherwise the means are not comparable.

The Table also reports information about the number of observations N and R^2 is a measure of the overall fit of the model to the data.

Do we find the same results in developing countries? The model discussed at the beginning of this section predicted similar effects of offshoring on high-skilled wages through offshoring in developed and developing countries. The remainder of this section deals with some empirical evidence for Mexico presented in Feenstra and Hanson (1995). Mexico provides an ideal experiment for this question due to massive FDI flows from the US to Mexico after the restrictions on capital flows were relaxed by the Mexican government in the early 1980s. Feenstra and Hanson (1995) report an increase in FDI from 478 million US Dollar to 3,635 million US Dollars. Most of the capital flows went to so called Maquiladoras - mainly foreign owned enterprises that are located close to the border in order to assemble products for their affiliated firms in the US. The model would predict that these firms are the more skill-intensive firms in Mexico. FDI flows trigger offshoring to the relatively more skill-intensive industries in Mexico. This increases relative demand for high-skill workers who see their wages rising relative to the wages of the low-skilled. Feenstra and Hanson (1995) report interesting stylized facts about the change in wages during the transition from capital restrictions to capital market liberalization.

The test discussed in this subsection exploits regional variation in the data. If the changes in wages are mainly due to FDI and offshoring one would expect more pronounced changes in the border regions where most Maquiladoras are located. The authors use rich establishment-level data covering 2,354 manufacturing plants for the period 1984 to 1990. The authors compare wage measures that relate the individual plant wage to the industry benchmark and distinguish between annual and hourly wages paid to the employees in the plant. The left panel reports the mean values and

Region	Mean for 1984-1990* RLWGE1	Mean for 1984-1990* RLWGE2	Change for 1984-1990 RLWGE1	Change for 1984-1990 RLWGE2
Border	0.0539 (0.0281)	0.0575 (0.0288)	0.0561	0.0506
North	0.0356 (0.0762)	0.0552 (0.0727)	-0.0484	-0.0801
Center	-0.0263 (0.0159)	-0.0340 (0.0154)	-0.0484	0.0130
Mexico City	-0.0134 (0.0127)	-0.0161 (0.0089)	0.0345	0.0163
South	-0.0169 (0.0193)	-0.0129 (0.0190)	0.0111	-0.0024

Notes:

Figures are the regional weighted sums of variables defined below, where the weights are plant share of the regional wage bill, and relative wage is the nonproduction/production wage. Industries are defined at the four-digit level.

RLWGE1 = log plant relative annual wage - log industry relative annual wage
RLWGE2 = log plant relative hourly wage - log industry relative hourly wage

* Means and standard deviations (in parentheses) are taken over the seven years for which the weighted sums are calculated.

Figure 3.19: Regional variation in the wage gap
Source: Feenstra and Hanson (1995)

the right panel reports changes over the period 1984 to 1990. The relative high- to low-skill wage rate is approximated by the non-production to production wage ratio. The data does not provide further information about different skills but the assumption is that production workers are low-skilled.

High-skilled workers in coastal regions receive wages that are indeed much higher than the standard wages paid elsewhere. Wages of the high-skilled relative to wages of the low-skilled in more remote areas located in the South or Mexico City are below average. One may conclude that FDI and outsourcing are natural candidates that help explain higher wages paid by firms that are located closer to the US. The analysis of the changes over time reinforce this explanation. Wages in regions that are more closely connected to the US were rising after the ban on capital inflows was lifted due to trade agreements. Others authors also report positive wage growth but the changes are much smaller in magnitude.

Figure 3.20 provides a comparison of the Mexican and the US wage gap. Especially after 1985, the time when both offshoring accelerated in both countries, the wage gap between high- and low-skilled began to rise in both the developed US and the developing Mexico. This pattern further supports the theoretical considerations outlined in the Feenstra and Hanson (1995) model.

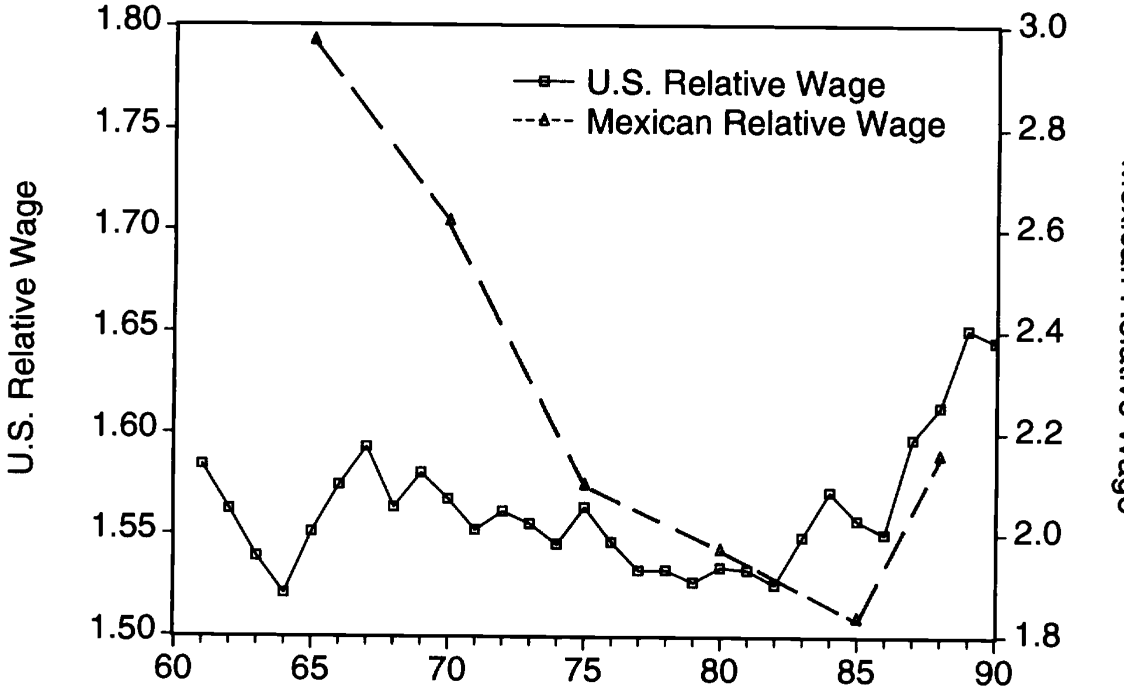

Figure 3.20: The evolution of the wage gap in comparison to the US
Source: Feenstra and Hanson (1995)