International Competition, Downsizing and Wage Inequality

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A country with Cournot competition and free entry experiences an increase of its market size either due to economic growth or international integration of its goods markets. This implied increase in competition leads to shrinking mark-ups and forces firms to reduce overhead costs relative to output. This implies a reallocation at the aggregate level from administrative to productive activities. Relative factor rewards change and wage inequality increases. The factor which loses in relative terms can even lose in real terms. From a quantitative perspective, international competition is demonstrated to be the more plausible cause of rising wage inequality.

JEL–Classification: F12, J31

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1 Introduction

The increase in wage inequality especially in the U.S. is a well-documented fact (e.g. Katz and Autor, 1999). This increase can be split into increases within and between groups, defined e.g. by age, education, experience and other observable characteristics. Almost three quarters of the overall increase in wage inequality can be attributed to increases within groups.

Most of the theoretical explanations have been suggested for increases between groups. Biased technological change and international trade are the most commonly suggested causes (e.g. Acemoglu, 2002, Johnson and Stafford, 1999). This paper is concerned with increases in wage inequality within groups, given that this is the quantitatively more important source. It is part of a literature (cf. e.g. Neary, 2002 or the short overview by Feenstra, 2001)

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that resuscitates international trade as a potential explanation for rising wage inequality, reacting to the tendency that the trade channel had become less popular at some point (e.g. Krugman, 2000).[2] Mechanisms based on the Stolper-Samuelson theorem or on implicit strong labour supply increases were not regarded as empirically very relevant as relative prices did not change sufficiently and the factor content of trade was not sufficiently large.

We present a mechanism where neither changes in terms of trade nor international factor flows are required and nevertheless (the potential of) international trade causes rising wage inequality. We propose a simple model where many firms interact in an imperfectly competitive market and where an increase in the degree of competition requires firms to "downsize", i.e. reduce fixed costs relative to variable costs. We then show how downsizing and rising wage inequality are related.

In our static setup, the degree of competition among firms is captured by a markup of prices over marginal costs. Assuming Cournot competition between firms in a general equilibrium setting, the number of competitors active in a market determines the degree of market power an individual firm has. Allowing free entry and exit, which drives profits down to zero, the number of firms and thereby the markups are endogenous. When the number of firms rises, e.g. because the economy's resource base increases due to growth or because it opens up to trade, competition rises and markups of firms shrink. If a firm wants to stay in the market despite lower markups and implied lower operating profits, it needs to reduce overhead costs per unit of output. This reorganization at the firm level induces factor flows at the aggregate level away from administrative activities towards production.

A consequence of reallocating factors of production is a change in both relative and absolute wages. Factors of production that are more intensively used in production gain from reallocation and factors of production less intensively used lose from reallocation. In the model presented here, no changes in international goods prices and no increase in the volume of trade is required to understand wage changes.

This paper also shows that this channel can be of quantitative importance. Calibrating the model for the US economy will show that a sufficiently large reduction in the market power of firms can indeed account for up to 100% of the increase in wage inequality within groups. Since a reduction in endogenous market power is fundamentally caused by changes in the market size of an economy as measured by its factor endowment, accounting for the increase in wage inequality requires an increase of the economy's endowment by a factor of around 9. Clearly, such an increase could not be explained by economic growth alone: GDP in the US increased by a factor of "only" 2.8 from 1963 to 1995. When thinking of expanding market size, however, economic growth is not the only possible explanation. Such an increase can also be the result of integrating an economy into the world economy: using the active workforce as a proxy for market size, the active workforce (the size of the market) in OECD countries in 1995 is more than 6 times larger than the workforce of the US in 1963. An expansion of market size by factor 9 between 1963 and 1995 can therefore be split into a growth effect and an integration effect. Following this line of reasoning, the paper will conclude that integration in the world economy is the more plausible driving force behind

[2] There is a large body of literature analysing within group inequality from a technological change perspective. Contributions and surveys include Galor and Tsiddon (1997), Caselli (1999), Galor and Moav (2000), Gould, Moav and Weinberg (2001), Gould (2002), Rubinstein and Tsiddon (2004) and Hendel, Shapiro and Willen (2004).

downsizing and implied changes in the wage structure than economic growth. It will also be shown how the implied reductions in market power relate to estimates in the literature on markups by industry and how the central assumptions and predictions of the paper are supported by empirical evidence.

This mechanism is of interest also from a purely trade-theoretical perspective. Many economists believe (summarized e.g. by Bhagwati, 1994, or Markusen et al., 1995, ch. 11) that more competition resulting from international trade benefits the economy as a whole or even all factors of production. This is sometimes referred to as the "lifting-all-boats" effect. We show that more competition per se is indeed beneficial for all factors of production but the reallocation effects caused by more competition can lead to distributional effects including real losses for certain factors of production.

Clearly, the mechanism whereby international integration leads to more competition is well–understood from other models with Cournot competition (Dixit, 1984; Venables, 1985; Eaton and Grossman, 1986; Ruffin, 2003).[3] Distributional effects have not been studied in these models, however, as usually only one factor of production is used.

2 The model

2.1 A closed economy

The economy is endowed with a fixed amount of highly-skilled individuals H and less-skilled individuals L, also called labour. Production of the homogeneous consumption good X requires a production process and administration services. Production can take place only under administrative guidance. Administration requires both skilled individuals h_m and labour l_m and is provided under constant returns to scale,

$$m = m(h_m, l_m), \tag{1}$$

with $m(.)$ having standard neoclassical properties. Administrative services can be provided either in–house or bought on the market. In the former case, each firm minimizes the costs associated with the provision of m. Assuming perfect competition in the administration sector for the latter case, both interpretations are formally equivalent. In either case, the price p_m equals unit costs,

$$p_m = a_{lm} w_L + a_{hm} w_H, \tag{2}$$

where a_{lm} and a_{hm} indicate the amount of less-skilled and skilled workers used to produce one unit of administrative services and w_L and w_H are the respective factor rewards.

The amount of administration services required for production in each firm is fixed at $\bar{m}$. Hence, output $\tilde{x}$ of a representative firm is given by

$$\tilde{x} = \begin{cases} 0 & \text{if } \; m < \bar{m}, \\ x(h_x, l_x) & \text{if } \; m \geq \bar{m}, \end{cases} \tag{3}$$

[3] This result can also be obtained in a Dixit–Stiglitz–type imperfect competition setup. See e.g. Flam and Helpman's (1987) analysis of industrial policy in a two–country world.

where $x(.)$ has standard neoclassical properties with constant returns as well and skilled and less-skilled labour employed for production are denoted by h_x and l_x, respectively. Optimal behavior implies $m = \bar{m}$.[4]

Remember that the introduction stated our interest in wage inequality within groups. This means that we perceive h_j and l_j, $j = x, m$, to be observationally equivalent. This does not prevent us, however, to model them as imperfect substitutes as individuals might be identical in e.g. education, experience, sex and ethnic background but nevertheless differ in some skills that are usually not captured in standard datasets like quality of their degree, IQ or social skills.[5] As a consequence, we will later use w_H/w_L as a measure of within group wage inequality.

Total output is given by the sum of output x of all n firms in the market, $X = nx$.[6] As firms behave as Cournot competitors, the price p_x of the consumption good is given by

$$p_x = \mu \left[a_{lx}w_L + a_{hx}w_H\right], \quad \text{with } \mu = \frac{n}{n-1} > 1, \tag{4}$$

where unit input factors for factor i are given by a_{ix} and the parameter μ denotes the markup over the unit costs in squared brackets (see app. 8.1).

We assume throughout that the skill intensity ρ_x is higher in the production unit of the firm than in the administration unit,

$$\rho_x \equiv \frac{a_{hx}}{a_{lx}} > \frac{a_{hm}}{a_{lm}} \equiv \rho_m. \tag{5}$$

This assumption will be crucial for our results and we will therefore discuss it in detail in section 6.3.

With free entry, profits are driven to zero, so that $p_x x = (a_{lx}w_L + a_{hx}w_H)x + p_m\bar{m}$. Using the pricing equation (4), the zero profit condition requires the equality between operating profits (defined as the difference between revenues and variable production costs) and administration costs (see app. 8.1),

$$\frac{p_x x}{n} = p_m\bar{m}. \tag{6}$$

A factor market equilibrium requires the equality of labour supply L and labour demand from production, $a_{lx}nx$, and from administration, $a_{lm}n\bar{m}$. With an identical equation for skilled individuals, we obtain

$$L = a_{lx}nx + a_{lm}n\bar{m}, \tag{7}$$
$$H = a_{hx}nx + a_{hm}n\bar{m}. \tag{8}$$

The system of equations (2), (4) and (6) - (8) characterizes the equilibrium of the economy. We choose administration services as numeraire and normalize p_m to unity. These equations

[4]The existence of a fixed input requirement for administrative services is comparable to fixed costs. If factor rewards were constant (which they are not), a fixed requirement for administrative services would be identical to fixed costs of production. Here, the price for management services p_m and, therefore, the associated costs $p_m\bar{m}$ may respond to parameter changes. Fixed costs would not.

[5]Think of a sample of 100 PhDs in economics. It would be hard to argue that this is a homogeneous group.

[6]We anticipate the fact that all firms will have the same size as they all face identical marginal costs.

specify the values for the factor prices (w_L, w_H), the product price p_x, the number n of firms and the output x of an individual firm as a function of the exogenously given factor endowments H and L.

2.2 Equilibrium structure

The structure of the equilibrium in this model can easily be understood by thinking of an auxiliary variable $q \equiv p_x/\mu$, representing the price without the markup, i.e. marginal costs to produce one unit of x.[7] When taking q as exogenous for an instant, (2) and (4) determine w_L and w_H which in turn with (7) and (8) determine $X \equiv nx$ and $M \equiv n\bar{m}$. Knowing X and M, given that $\bar{m}$ is exogenous and constant, we know n and x as well. Equations (2), (4), (7) and (8) therefore determine endogenous variables w_L, w_H, n and x as a function of q and parameters of the model (like e.g. factor endowment and technology properties). This simply exploits the standard two by two structure of this model: thinking of q as "perfect-competition terms of trade" (given that p_m equals unity), this part of the model could be called the "small-open economy part". The equation which determines q is given by the free entry condition (6).

The zero-profit condition (6) and the small-open economy part of the model are jointly plotted in figure 1. The horizontal axis plots marginal costs q. The vertical axis plots $(n-1)\,M/X$. The 45°-line in this figure is q, the left-hand side (LHS) of $q = (n-1)\,M/X$, a rewritten version of the free entry condition (6). The RHS of this equation is captured by the function $Z(q) \equiv (M(q,\Pi)/\bar{m} - 1)\,M(q,\Pi)/X(q,\Pi)$. It plots $(n-1)\,M/X$ as a function of q and parameters Π. With q given on the horizontal axis, $Z(q)$ summarizes the behaviour of the economy that corresponds to the small-open economy part. We know that $Z(q)$ decreases as both M/X and M decrease in q (we move on the production possibility frontier in favour of X and observe the usual supply response). The unique equilibrium value of q can be found where $Z(q)$ intersects with the 45° line.

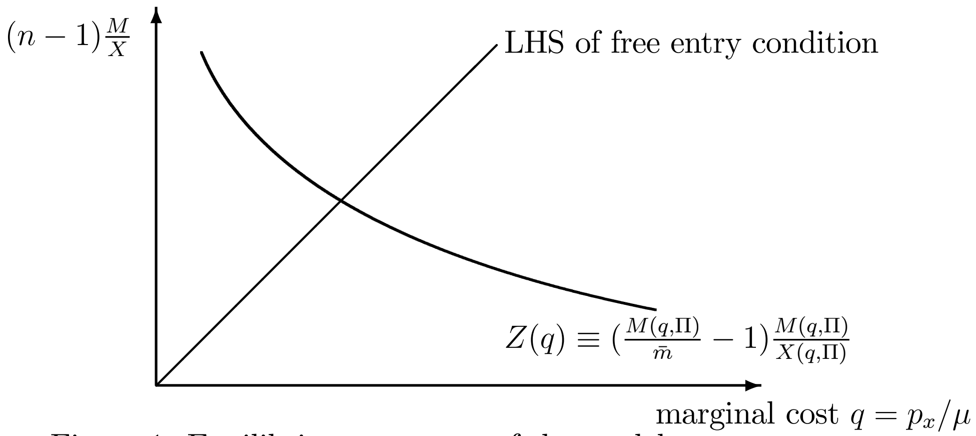

Figure 1: Equilibrium structure of the model

The advantage of this equilibrium representation is that any parameter change only affects the $Z(q)$ curve. Comparative static analyses can then be undertaken for a given q

[7] We are indebted to Kala Krishna for her detailed suggestions to go into this direction.

which then indicates whether the $Z(q)$ curve shifts up or down. This has the big intuitive advantage that results for a given q can be borrowed from results known from small open economy models.

2.3 Modelling international integration

We view international integration, economic growth or both as the driving force behind downsizing and changes in wage inequality. Both international integration and growth can be captured in a simple way by an increase in factor endowments of the economy. When economic growth is labour saving and the same for both technologies x and m, growth is identical to an increase in factor endowment. When growth stems from increases in workers' productivity due to human capital accumulation or learning by doing, this is again formally identical to an increase in factor endowment. While a fully dynamic model would be more complete, we believe that our main results are robust to this extension.

When integration in international goods markets in considered, this can again be captured by increases in the resource base. Imagine that an economy opens up to world markets where other countries are characterized by the same relative endowment H/L, i.e. a situation where integration takes place among countries with roughly similar education structures. The fundamental effect integration has is to embed the formerly autarkic economy in a world economy that has a larger factor endowment of H and L but the same ratio H/L. Hence, integration is identical to an equiproportional increase of H and L and we capture this in the main text by

$$\hat{L} = \hat{H} = \hat{s},$$

where a hat indicates a proportional increase, $\hat{z} \equiv dz/z$.[8]

3 Aggregate effects of an increasing resource base

We start by providing some aggregate results which are important for understanding the general argument of the paper. Some of them are known from the literature (e.g. Dixit and Norman, 1980) for Cournot models where fixed costs are given by some constant parameter and do not result from the provision of administrative services as here. All proofs for this and the next section are in app. 8.2.3.

Proposition 1 *An increase in the market size induces (i) the number n of firms to rise under–proportionally, (ii) output x of a firm to increase and (iii) output nx of the consumption good to rise over–proportionally, implying gains from trade,*

$$\hat{s} > 0 \Rightarrow 0 < \hat{n} < \hat{s}, \quad \hat{x} > 0, \quad \hat{n} + \hat{x} > \hat{s} \Leftrightarrow \textit{gains from trade.}$$

In a world where all countries are in autarky, the number of active firms is given by Σn_c^a firms in the market, where n_c^a is the number of firms in autarky in country c. In an integrated

[8] Appendix 8.2 derives the fundamental relationships in our model allowing for international differences in human capital richness. Appendix 8.3 then shows that the main point of our paper holds in this more general case as well.

world economy - i.e. when the market size s has increased - proposition 1 indicates that the number Σn_c^a of firms is not sustainable in the long run. Firms need to exit under trade as the markup μ in (4) reduces due to the increased number of competitors. For each country, the number of firms increases from autarky to trade, in the world as a whole the number of firms reduces.

As the markup is lower and production requires fixed administration services $\bar{m}$, the zero profit condition can be restored only by an expansion of output per firm, implying (ii). Finally, as integration reduces the number of firms, there are fewer administrative jobs. Factors of production move from administrative to productive activities and total output increases. As this effect also holds for each country individually, there are gains from trade.

All of these propositions can be illustrated by using figure 1. Looking at the "small-open-economy curve" $Z(q)$, an increase in the scale s of the economy (i.e. integration in the world economy) at fixed terms of trade q increases M but leaves M/X unchanged; the $Z(q)$ curve therefore shifts upwards. As a consequence, q increases when the equilibrium point moves up on the free entry condition. This increase in q now raises X/M: the number of firms therefore increases underproportionally, output increases overproportionally and there are gains from trade.

4 Distributional effects of an increasing resource base

4.1 General results

Proposition 2 *Let the production of the consumption good be more skill intensive than the production of administration services. An increase in the market size s, leaving relative factor endowment unchanged, increases human capital rewards w_H relative to wages w_L,*

$$\hat{s} > 0 \quad \textit{and} \quad \rho_x \gtrless \rho_m \quad \Rightarrow \quad \hat{w}_H - \hat{w}_L \gtrless 0.$$

The intuition behind this proposition is similar to the intuition behind changes of relative factor rewards in small open economies. When relative output of administrative services declines due to an increase of the economy, the proportion of less-skilled relative to skilled labour that becomes available is, at given relative factor prices, higher than the proportion that production is willing to absorb. Full employment can therefore only be restored if firms substitute less-skilled by skilled individuals. The latter takes place only if factor rewards for labour decrease relatively to factor rewards for the skilled.

While these relative changes are important, absolute changes allow a better prediction of changes in individual welfare. For real factor rewards we have

Proposition 3 *(i) The factor of production that gains relative to the other factor also gains in real terms,*

$$\hat{w}_H - \hat{w}_L \gtrless 0 \Rightarrow \begin{Bmatrix} \hat{w}_H \\ \hat{w}_L \end{Bmatrix} - \hat{p}_x > 0.$$

(ii) The factor of production that loses relative to the other factor gains in real terms if the price reduction effect from more competition is stronger than the wage reduction effect

coming from reallocation,

$$\hat{w}_L - \hat{p}_x \gtrless 0 \Leftrightarrow -\theta_{hx}\left[\hat{w}_H - \hat{w}_L\right] + \frac{1}{n-1}\hat{n} \gtrless 0.$$

Apparently, a relative decline of wages does not necessarily (as in the Stolper-Samuelson theorem for the perfect competition model) imply a decline of wages in terms of the consumption good. When we solve equation (22) for $\hat{w}_L - \hat{p}_x$, taking (27) and (18) into account, we obtain

$$\hat{w}_L - \hat{p}_x = -\theta_{hx}\left[\hat{w}_H - \hat{w}_L\right] + \frac{1}{n-1}\hat{n} \tag{9}$$

which nicely reveals the intuition behind proposition 3: changes in real factor rewards depend on changes in relative factor rewards caused by factor reallocation, as captured by the first term on the right-hand side, and on changes in the number of firms in the economy, the second term on the right-hand side of the equation. An increase of this second term represents an increase in competition and thereby a reduction in the distortion on the final good market. As economic growth or international integration increases the number of competitors, this second term stands for the reduction of the markup which implies, ceteris paribus, lower profits and therefore a larger share of output going to factors of production implying higher real factor rewards.

Real rewards for skilled workers therefore increase as both the relative change in factor rewards (i.e. the reallocation from administration to production) and the increase in competition imply higher rewards for skills. Real wages for unskilled workers decrease as in the perfect competition model if the beneficial effect from more competition is weak. Real wages increase if the competition effect outweighs the loss implied by the reallocation to production activities.

4.2 Cobb–Douglas and CES economies

Equation (9) provides intuition for potential negative distributional effects of international competition. This expression by itself, however, does not provide information on whether the positive effect of stronger competition (the second term) might not actually always overcompensate the negative effect for low-skilled resulting from reallocation (the first term). This section therefore studies a Cobb–Douglas and a CES economy for which more precise results are available.

In a Cobb–Douglas version of our economy, technologies (1) and (3) are given by $m(h_m, l_m) = h_m^\beta l_m^{1-\beta}$ and $x(h_x, l_x) = h_x^\alpha l_x^{1-\alpha}$, where $\alpha > \beta$. Going through similar steps as for deriving proposition 3 gives (cf. app. B[9] for a proof)

Proposition 4 *In a Cobb–Douglas economy, both factors gain in real terms.*

In the Cobb-Douglas case, more international competition "lifts all boats" indeed: international integration always reduces the inefficiency of imperfect competition sufficiently much.

[9] All sections starting with a letter are contained in a Referees' appendix which is available upon request and at www.waelde.com/publications.html.

In a CES specification, technologies are

$$
\begin{aligned}
m(h_m, l_m) &= A\left[\beta h_m^{(\varepsilon-1)/\varepsilon} + (1-\beta)\, l_m^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)}, \\
x(h_x, l_x) &= A\left[\alpha h_x^{(\varepsilon-1)/\varepsilon} + (1-\alpha)\, l_x^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)}.
\end{aligned} \tag{10}
$$

We assume identical elasticities of substitution ε across activities as this guarantees a more skill intensive production activity, as long as $\alpha > \beta$. Unfortunately, no analytical results more specific than (9) can be obtained. A numerical analysis, however, allows to plot the following figure[10].

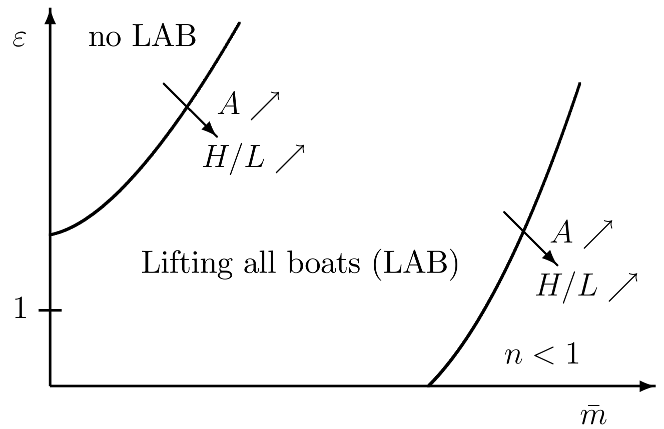

Figure 2: Lifting-all-boats (LAB) and real losses from trade (no LAB)

The figure divides the $(\bar{m}, \varepsilon)$ space into three regions. In the region to the left, denoted "no LAB", wages of labour fall in real terms, i.e. (9) is negative when the economy integrates into the world economy. In the middle region, there is lifting-all-boats, i.e. all factors of production experience real increases in their rewards. In the right region, the parameter set was such that the equilibrium number of firms was too small $(n < 1)$. An increase in total factor productivity A or in the human capital to labour ratio H/L (caused by an increase in H) shifts both curves to the right.

The shape of these regions make intuitively sense: if management services $\bar{m}$ required for running a firm are too high, there will be no production at all and we are in the region to the right. Clearly, the higher TFP or the human capital stock (implying an increase in H/L), the more firms will exist in the economy and the smaller the no-production region $n < 1$.

For elasticities smaller or equal to unity, there is lifting-all-boats. A low elasticity of substitution between factors of production implies that the relative wage effect due to reallocation, the first term in (9), is weak and the competition effect dominates.[11] When the elasticity of substitution exceeds unity, the presence of LAB depends on the level of the fixed administration services $\bar{m}$. When they are low, the economy is in the "no LAB" region. Low $\bar{m}$ imply many firms in autarky and the competition increasing effect of trade is low. Further, a high elasticity of substitution implies that reallocation yields high relative wage

[10] All numerical solutions were computed in Mathematica. The programmes are available upon request. For a parameter set that leads to an increase of all real wages, cf. table 1 below.

[11] Remember that the relative wage effect of a terms of trade change in a small open economy is the stronger, the larger the elasticity of substition. Thanks are due to Willi Kohler for discussion of this point.

effects. With low gains from more competition and strong wage effects, the second term in (9) is not strong enough to compensate the first one.

This discussion directly implies the following

Corollary 1 *(i) If a country characterized by a strong domestic inefficiency (few domestic firms and high markups caused by high $\bar{m}$) integrates, there are gains from integration and both factors of production gain in real terms.*

(ii) If a country with low markups starts trading (low $\bar{m}$) and the elasticity of substitution ε is high, skilled workers profit and less-skilled workers lose in real terms.

When we think of trade as an integration between two identical countries and let administrative service be non-tradable, both results hold even though there are no changes in terms of trade (there is only one traded good) and (implied) factor flows are zero. If we think of administrative services as being tradable or we look at within firm terms of trade between production and administration, the relative price p_x/p_m can in- or decrease (cf. app. 8.2.3), depending on parameter values. Hence, even with tradable administrative services, terms of trade do not need to change at all while factor rewards do change.

This analysis formalizes and partially contradicts an argument dear to many trade economists. Rising competition by opening up to trade is beneficial for all factors of production as it reduces domestic inefficiencies. Our setup shows that this is not necessarily the case. In fact, rising international competition is the source of more wage inequality and can even lead to a drop in real wages of the less favoured factor of production.

5 Wage inequality and trade

Even though the discussion so far often referred to international trade, the fundamental driving force has been an increase in factor endowment. This increase can result both from economic growth and international integration. This section will therefore use a CES economy in order to compute by how much the resource base needs to increase in order to explain a sufficiently large increase in wage inequality. By doing so, international integration turns out to be the more plausible source for a rise in wage inequality through the channel presented here than economic growth.

5.1 Calibration

The variance of log weekly wages of full-time, full-year (male and female) workers increased in the United States from .25 in 1963 to .36 in 1995 i.e. by .11 (Katz and Autor, 1999, Tables 1 and 5). One-quarter of this change can be attributed to changes between groups, three-quarters are changes within groups, i.e. due to unobserved factors different from education, experience etc. When wage inequality is measured by the 90/10 log weekly wage differential, inequality increased for male workers from roughly 1.2 to roughly 1.55 within the same period (Katz and Autor, 1999, Figure 4), i.e. wage income of the 90th percentile worker was 3.3 times wage income of the 10th percentile worker in 1963 and 4.7 times in 1995.

Can the mechanism presented above account for this increase? Looking at the structure of the CES version of the model shows that the model can be calibrated to reflect the situation in 1963 with 100% precision. Equilibrium can be described by a free-entry condition and two labor market clearing conditions (cf. app. C),

$$\left(\frac{a_{lx}}{a_{lm}}\right)^{1/\varepsilon}\frac{1}{n-1}\frac{x}{\bar{m}}=\frac{1-\alpha}{1-\beta},$$
$$\frac{L}{n}=a_{lx}x+a_{lm}\bar{m},\qquad \frac{L}{n}\frac{H}{L}=a_{hx}x+a_{hm}\bar{m},$$

where a_{ij} are the CES versions of unit demand functions. These three equations determine the endogenous variables x, n and $\omega\equiv w_L/w_H$. If we want a certain relative wage to be the equilibrium wage, we fix all parameter values and modify H/L to obtain the desired relative wage. By modifying also L, a reasonable degree of competition, i.e. a reasonable mark-up, can be obtained. The number n of firms should thereby not be seen as the number of independent firms in some actual economy but rather as representing a certain degree of competition. A more realistic modelling would imply many sectors and certain demand elasticities (which equal unity here). The following table gives an overview of parameters for the 1963 calibration.

exogenous			imposed		computed		
α	β	ε	w_L/w_H	μ	H	L	x
.7	.3	5	1/3.3	3	.1	3.1	.2

Table 1: Parameter choices

We first set the elasticity of substitution at some sufficiently high value, $\varepsilon=5$, to capture inequality within groups where factors are good (though not perfect) substitutes and perform very similar jobs. Parameters for technologies in (10) are chosen symmetric around .5 such that a shift towards production implies higher demand for skilled, i.e. $\alpha>\beta$. In order to obtain the 1963 90/10 wage ratio, ω is set equal to 1/3.3, corresponding to the stylized facts reported above.[12] We further impose $\mu=3$ which means that 2/3 of revenue is used to pay fixed costs and 1/3 is used to cover variable costs. Fixed administrative input is set at unity.

The implied values for H and L, i.e. factor endowments which would give the imposed values of ω and μ as equilibrium outcomes are .1 and 3.1. In *efficiency units* there are 30 times more less-skilled than skilled.[13] Output of a representative firm amounts to $x=.2$. All this is relative to fixed management requirements which is set equal to one (and which could be chosen to match some other variable of interest).

5.2 Trade or growth?

We now increase H and L equiproportionally, representing an integration into a world economy that has the same high-skill to skill ratio. Focusing on relative wages, we get the following picture.

[12] Setting $\omega=1/3.3$ implicitly assumes that relative productivity h of skilled to less-skilled is one. If some reasonable ratio N_H/N_L of the *number* of skilled to unskilled workers should be reflected as well, one can choose relative productivity h different from one to determine $H/L\equiv N_Hh/N_L$. The relative observed wage would then be $w_L/(hw_H)$.

[13] Again, this is a consequence of the assumption that $h=1$ and would be smaller with $h>1$.

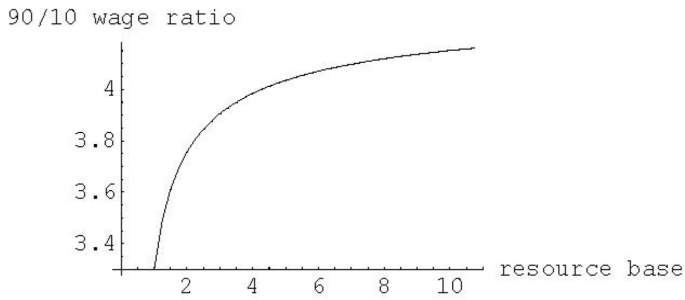

Figure 3: Relative wages under increasing international competition

The relative wage ratio in 1963, where the relative market size of the US is 1 (meaning that the country is in autarky), is 3.3. Over time, the relative market size, i.e. the market in which US firms are active, increases. Measuring the exact increase in the market size is very difficult and depends on the industry, growth in this industry and its openness. In terms of the model, the size is measured by the increase in factor endowments H and L from a country in autarky to factor endowments of all economies taken together in an integrated world economy. If we measure this endowment in 1963 by the active workforce of the US (approx. 67 million, full time equivalent) and endowment of the integrated world economy in 1995 by the active workforce of OECD countries (approx. 418 million), endowment increased from 67 to 418 by a factor of 6.2. Real US GDP over this period increased by a factor of approx. 2.8. The total increase of the resource-base, i.e. the size of the market in the sense of the above model, therefore amounts to 9.

Looking at figure 3 shows that the relative wage predicted by the model increases from 3.3 at a resource base of 1 to 4.1 after a 9-fold increase. The observed increase is from 3.3 to 4.7. Taking into account that only three quarters are intended to be explained by the present model (as we focus on within group wage inequality), the observed increase that should be explained is from 3.3 to 4.35. As this is 75% of the observed increase, the model is able to capture roughly the entire increase in within group wage inequality.

Recalling that the overall increase in the resource base by a factor of 9 splits into an increase due to international trade of 6.2 and only 2.8 due to growth, one can argue that, given this theoretical background, the overwhelming share of the increase in wage inequality within groups is accounted for by international trade.[14]

6 Empirical aspects

Our model makes two central predictions and relies on one crucial assumption. This section will review what is known empirically about predictions and assumptions and will point out how future work can improve upon existing empirical knowledge.

[14] Clearly, this does not rule out the relevance of explanations based on biased technological change or other mechanisms. An ultimative judgement would require a model that encompasses all these mechanisms. The main point here is to stress the importance international integration can have.

6.1 Markups

The first central prediction concerns the drop in the markup of prices over marginal costs due to rising international competition. In the calibration presented above, the markup shrinks from $\mu = 3$ in 1963 to $\mu = 1.36$ in 1995.

	Hall 1988	Roeger 1995	Basu and Fernald 1995
returns	1 (imposed)	1 (imposed)	<1
markup μ	2.06; 3.10	1.45; 1.48	1.15

Table 2: Estimates of average markups for 1953-1984 (Hall, Roeger) and 1953-1985 (Basu and Fernald)

There is a considerable body of literature that provides estimates of the markup of prices over marginal costs. This literature started with Hall (1988, 1990) and was followed by Roeger (1995), Basu and Fernald (1995) and others.[15] An overview of findings is given in table 2.

Hall (1988) derived the specification for his regression equation under the assumption of constant returns to scale. Markup estimates were obtained for up to 26 industries and for industry groups. Estimates for durable goods and non-durable goods are 2.06 and 3.10, respectively. This is broadly in the range of the initial markup of $\mu = 3$ we set above. Subsequently, estimates of markups became smaller as the upward bias in Hall's approach could be removed by also taking relationships for prices into account: Roeger (1995) only finds values of 1.45 and 1.48. Basu and Fernald (1995) allow for non-constant returns to scale and use output rather than value added data. They find decreasing returns to scale (cf. also Basu and Fernald, 1997) and a markup of 1.15, i.e. even lower than Roeger's results.

Given that none of these studies provides evidence on a possible time trend for markups, one could conclude that markups are fundamentally constant (even though a cyclical movement of markups is well-documented; e.g. Altug and Filiztekin, 2002). This would mean that any explanation that builds on shrinking markups is not convincing.

One should take into consideration, however, that any empirical analysis that takes the above model as its starting point would end up with a different regression specification than those used so far. Estimates of markups in the literature usually start from a representation of an aggregate technology like

$$\hat{Y} = \hat{A} + (\alpha + \beta)\,\hat{K} + \frac{1}{1-\eta^{-1}}\frac{w^L L}{pY}\left[\hat{L} - \hat{K}\right], \tag{11}$$

where again $\hat{z} \equiv dz/z$, α and β are the output elasticities of capital K and labour L, respectively, A is total factor productivity and $\left(1-\eta^{-1}\right)^{-1}$ is the markup (e.g. eq. (5.26) in Hall, 1990, or eq. (2) in Basu and Fernald, 1997). The degree of increasing returns is given by $\alpha + \beta$.

In order to derive a corresponding equation for our case, one would have to imagine an extension of the above model that allows for capital and (given that there are no observations

[15] A more recent analysis providing also further references is by Altug and Filiztekin (2002).

on L and H) that merges all workers in one group L. The starting point for regressions would then be (the derivation is available upon request)

$$\hat{x} = \hat{A} + \hat{K}_x + \frac{1}{1-\eta^{-1}} \frac{w^L L_x}{px} \left[\hat{L}_x - \hat{K}_x \right]. \tag{12}$$

The crucial difference from (11) consists in the expression $w^L L_x / (px)$. Instead of the share of *total* labour in output, $w^L L / (pY)$, this equation contains only the share of labour used in production. If the prediction of the above model on shrinking markups is to be tested, only labour constituting variable costs should be taken into account and not labour being employed in administrative activities and constituting fixed costs. If firms downsize in the real world, $w^L L_x / (px)$ in (12) increases. As rates of growth in (12) should be constant on average, the estimate of the markup $(1-\eta^{-1})^{-1}$ would have to decrease.

In summary, future work on markups should take into account fixed costs and the possibility of a variable ratio of fixed costs to total costs or output. When this is done, insight about the empirical relevance of the above theoretical model can be gained.

6.2 Downsizing

The second central prediction, related to the first one, is the reduction in overhead costs relative to production costs of firms. According to our model, one should observe a shift of workers from administration to production, especially over those decades where wage inequality increased the most.

The ideal dataset to test whether this is true would contain a representative sample of firms over all sectors of the USA from 1970 to today and a description of activities of (a representative sample of) workers. This would allow splitting individuals (or hours of work of individuals) into administrative and productive tasks. An accountant would probably spend 100% of her time in administrative activities but a manager uses part of his time for productive activities (e.g. meeting clients or banks) and the other part for administration (e.g. designing internal promotion schemes). Our central argument on wage inequality implies that time spent on administrative activities relative to productive activities decreased over the 1980s and 1990s.

To the best of our knowledge, such a dataset has not been collected so far - even though the data in principle exists. A lot of general evidence, however, indicates that firms reduced overhead costs indeed, which in terms of our model means more production relative to administration. This evidence is related to the concept of "downsizing", a concept widely discussed in the management literature of the 1980s.[16]

According to one of the leading authors in the field, the objectives of downsizing comprise - inter alia - a reduction in overhead and bureaucracy and increases in productivity (Cascio, 1993, p. 97). Downsizing is a widespread phenomenon of the 1980s ("more than 85% of the Fortune 1000 downsized their white-collar workforce between 1987 and 1991", Buch, 1992).

[16] Downsizing was not so much of an issue in the 1970s with few articles being written on it. This can be seen from e.g. Whetten (1980) who entitled his paper "Organizational decline: A neglected topic in organizational science" or from performing a paper count on "downsizing" in a typical database like Business Source Premier.

Many authors believe (e.g. Budros, 1999, p. 70; Tomasko, 1987, p. 32) that downsizing in the 1980s was different than before as the elimination of jobs was not concentrated during recessions (as e.g. in the 1982 recession) but also became common in the mid 80s where the US economy was relatively strong. Budros (1999, p. 73) argues that one of its causes was the merger wave that started in the 1980s (see also Cascio, 1993, p. 102). It is further generally acknowledged (e.g. Cascio, 1993, p. 98; Cameron, 1994) that expectations are often disappointed - i.e. profits or shareholder's returns do not increase as much as expected.

These analyses can be taken as evidence that firms indeed reduced overheads in the 1980s to a much stronger degree than in the 1970s. Remembering also that the increase in wage inequality was concentrated in the 1980s and at the beginning of the 1990s (see fig. 4 in Katz and Autor, 1999), this would lend support to the idea that downsizing, in the sense as modelled here, is indeed one possible perspective for understanding where rising inequality comes from.

6.3 Skill intensities

The crucial assumption of our argument is that production is more human capital intensive than administration, see (5). Whether this is empirically convincing can not be answered at this stage, as no studies (to the best of our knowledge and literature-searching efforts) analyzing this question exist. We therefore discuss here what such a study would have to take into account and which results one would expect.

One would first have to define what production and administration mean for any real-world firm. If one starts from a "typical" organigram, a firm can be split into three types of organizational units: units for products A, B, C, ...; management; and central units like accounting, a personnel department, security or marketing. Administration in the sense of our model would then comprise - to start the discussion - management and central units; production would cover all product units.

In order to develop an intuition about the question of whether administration as defined above is less skill-intensive than production (in the sense of unobservable skills), one should distinguish between various industries an economy typically consists of. When we look at the industry structure in the US (neglecting that sectors differ in their exposure to international competition) in 1980 (when the rise in wage really took off), the big sectors measured in terms of employment are manufacturing (approx. 19% employment, all data is from OECD's STAN database), trade, restaurants and hotels (24%), financing and insurance (11%) and community and social and personal services (31%). When starting with a low-skill intensive service firm (like professional cleaning services for firms or public institutions), the production process (cleaning) is probably less skill-intensive than the administrative units of these firms. The same would be true for some manufacturing firms where the classic distinction between white-collar workers in administration and blue-collar workers in production would work. When thinking about more sophisticated manufacturing firms (e.g. the chemical industries), about banks and insurance companies or consulting firms and universities, the skill intensity might easily be reversed. While it is true that all administrative units contain one or several managers, these units also contain a lot of support personnel. When one compares accounting activities with consulting or teaching or producing and selling biotechnologies, production is clearly more skill intensive and the assumption in (5) is much more convincing.

This discussion uses a very loose definition of fixed vs. variable costs: central units constitute fixed costs, product units constitute variable costs. Taking a view more consistent with standard definitions from management literature, fixed costs are defined to be costs that are independent of a firm's activity, measured e.g. in output x. Examples for fixed costs are rental costs for buildings or costs for labour that needs to be hired for a certain period of time and without which production could not start. Clearly, over time and when output changes "a lot" (i.e. requiring the building of a new production site), fixed costs become variable. Given this definition, it is no longer clear whether managers should be counted as constituting fixed costs. A manager who meets with clients or banks should be classified as variable costs as he will spend more time with clients when more is produced. Hence, taking this more precise approach to fixed vs. variable costs, some highly-skilled individuals in central units would have to be counted in a variable costs sense and the skill-intensity of production would tend to be higher than that of administration.[17]

6.4 What future empirical work could tell us

The discussion in the previous sections shows that there is support for the model predictions and assumptions but, without doubt, more evidence would be useful. The downsizing literature provides case studies and summaries of firm surveys but no strict statistical testing is undertaken. We will therefore briefly state some questions which should be investigated in order to better understand the empirical importance of the mechanism suggested here.

What is known about the concept of downsizing when using representative employer-employee datasets (see e.g. Abowd and Kramarz, 1999)? Were layoffs (or job switches within a firm) higher in the years where wage inequality was growing strongest? How do layoffs differ between skill groups and within skill groups according to wage income? If the model is correct, moving from jobs that are more administrative to more production-oriented jobs (both within but also between firms) should have become more frequent in the 1980s and 1990s. Individuals with low wages should have experienced job switches more often than those with high wages (after controlling for observable characteristics - given our interest in within-group inequality). Finally, the number of firms that merged with others should also have increased more than proportionally in periods of increases of wage inequality and this should at the same time be positively correlated with layoffs, especially from administrative jobs.

7 Conclusion

We have analyzed a model with Cournot competition and free entry and exit where production requires a fixed amount of administration services. The number of firms active in such an economy and the markup of firms decrease when competition rises. When international integration takes place, competition increases and some domestic and foreign firms exit the market. The number of firms producing in an integrated world economy is therefore

[17] Following the same line of reasoning, employment in x and m should not be associated with production- and non-production workers. The manager interacting with clients would be a production worker just like an engineer or technician.

lower than the sum of the number of firms producing in autarkic economies. Nevertheless, it is higher than the number of firms in each country in autarky. This is the competition-increasing effect of integration.

More international competition leading to shrinking markups implies an expansion of plant size for surviving firms. Assuming that the production technology is more skill intensive than the administration technology, these factor movements lead to a decrease in skill intensity in all sectors and therefore an increase of factor rewards for skills. When integration takes place between countries with identical factor endowment, integration does not affect relative prices. Nevertheless, relative factor rewards change.

Measuring factor rewards in real terms, integration implies an increase in real rewards for skilled individuals. Real wages for the less-skilled may fall or rise, depending on the degree of domestic distortions before opening up to trade. If domestic distortions were weak (e.g. in a large country with small markups), more competition would imply a real decrease in wages. If domestic distortions were strong (in a country with high markups), integration would lead to a considerable increase in the number of firms and therefore to a strong reduction of the distortion. This positive effect can outweigh the negative effect of wage reductions caused by factor relocation from administration to production. In summary, more international competition has a lifting-all-boats effect if the increase in competition is sufficiently large. If not, more international competition implies that certain factors of production lose in real terms.

When calibrating the model, we found that the increase in within-group wage inequality in the US from 1963 to 1995 can be attributed both to economic growth and integration in the world economy. Given our theoretical analysis, however, integration in the world economy plays a substantially larger role than economic growth in explaining the increase in wage inequality.

When thinking about extensions of this model, the issue of skill-intensity deserves more attention. The robust mechanism of the model presented here is the reallocation effect due to more competition. Could one think of mechanisms that lead to rising wage inequality due to reallocation even without the assumption of skill-intensity? Imagine that sectors have identical technologies (or all labour groups are perfect substitutes) but labour differs with respect to innate abilities. When globalization implies lower markups and downsizing of firms and there are training costs associated with moving from one activity to another, workers with higher ability would move (think of a comparative advantage model in the sense of Roy as recently used e.g. by Gould, 2002). This reallocation of labour could by itself imply higher wage dispersion, and globalization as portrayed here would remain a valid explanation for increasing wage inequality even without any assumptions about skill intensities. Future work could check the validity of this conjecture.

The model could also be extended to analyze trade, growth and biased technological change. The effects of trade and growth are captured by an increasing resource base (as quantified by $6.2 + 2.8$ above). Such an increase could be modelled endogenously by allowing for skill accumulation (for both H and L-workers) or by learning-by-doing. The effects of biased technological change could be captured by a decrease in fixed administrative services $\bar{m}$. New technologies make communication so much easier that production of one unit of

x requires fewer $\bar{m}$.[18] As administrative services are low-skill intensive, demand for low-skilled workers shrinks. Extending the above analysis by varying $\bar{m}$ as well would provide a framework that allows joint evaluation of the relative importance of biased technological change, growth and international trade for rising wage inequality (or rising unemployment rates for unskilled workers if some wage rigidity is introduced).

8 Appendix

8.1 Deriving equations (4) and (6)

Following the suggestion of a Referee, we derive the markup in equation (4) and the zero-profit condition in (6) here.

- The markup in (4)

The profit function of a firm producing good x is $\pi(x) = p(x)x - c(x) - p_m\bar{m}$. The first order condition with respect to output x is $\pi'(x) = p'(x)x + p(x) - c'(x) = 0 \Leftrightarrow \left(p'(x)\frac{x}{p(x)} + 1\right)p(x) = c'(x)$. As $p'(x)\frac{x}{p(x)} = p'(x)\frac{X/n}{p(x)}$, given that all firms are identical (Varian, 1992, ch. 16.3. treats also the more general case) and $p'(x)\frac{X/n}{p(x)} = (n\varepsilon)^{-1}$ where ε is the demand elasticity (which in our case is -1), we have $(1-n^{-1})p(x) = c'(x) \Leftrightarrow p(x) = (1-n^{-1})^{-1}c'(x) = \frac{n}{n-1}c'(x)$. As the technology x has constant returns to scale, marginal costs $c'(x)$ equal unit costs. Therefore, $p(x) = \frac{n}{n-1}[a_{lx}w_L + a_{hx}w_H]$ which is (4).

- The zero-profit condition (6)

Profits of good x producers are zero if $\pi(x) = p(x)x - c(x) - p_m\bar{m} = 0$. Given the argument about constant returns in x just made, we can write the cost function as $c(x) = [a_{lx}w_L + a_{hx}w_H]x$. With our pricing equation (4), this equation becomes $c(x) = p(x)\frac{n-1}{n}x$. The zero profit condition therefore reads $p(x)x - p(x)\frac{n-1}{n}x = p_m\bar{m} \Leftrightarrow p(x)x/n = p_m\bar{m}$ which is (6).

8.2 Proofs for section 3 and 4

Before we can provide proofs, we need to derive the effects a change in exogenous quantities has on endogenous variables.

8.2.1 Some definitions

We define a matrix λ that shows the fraction of factors used in the production of the consumption good and in administration services,

$$\lambda = \begin{bmatrix}\lambda_{lx} & \lambda_{lm}\\ \lambda_{hx} & \lambda_{hm}\end{bmatrix} \equiv \begin{bmatrix}a_{lx}nx/L & a_{lm}n\bar{m}/L\\ a_{hx}nx/H & a_{hm}n\bar{m}/H\end{bmatrix} \tag{13}$$

[18] We are grateful to Harry Bowen for raising this point.

As factors i are fully employed, rows in this matrix add to unity,

$$\lambda_{ix} + \lambda_{im} = 1, \quad i = l, h. \tag{14}$$

The determinant of λ is negative if and only if the production is more skill intensive than administration,

$$|\lambda| = \frac{nxn\bar{m}}{LH} \left(a_{lx} a_{hm} - a_{hx} a_{lm} \right) \lesseqgtr 0 \Leftrightarrow \rho_x \equiv \frac{a_{hx}}{a_{lx}} \gtreqless \rho_m \equiv \frac{a_{hm}}{a_{lm}}. \tag{15}$$

Using (14), the determinant of λ can be written as

$$|\lambda| = \lambda_{lx} - \lambda_{hx}. \tag{16}$$

The matrix θ consists of elements θ_{ij} which denote the share of value added (adjusted for markups) going to factor i in activity j,

$$\theta = \begin{bmatrix} \theta_{lx} & \theta_{hx} \\ \theta_{lm} & \theta_{hm} \end{bmatrix} \equiv \begin{bmatrix} \mu a_{lx} w_L / p_x & \mu a_{hx} w_H / p_x \\ a_{lm} w_L & a_{hm} w_H \end{bmatrix}. \tag{17}$$

Due to this adjustment for the markup, the rows of the matrix θ add to one, i.e.

$$\theta_{lj} + \theta_{hj} = 1, \quad j = x, m. \tag{18}$$

The determinant of θ is negative if the same condition as in (15) is met,

$$|\theta| \lesseqgtr 0 \quad \Leftrightarrow \quad \rho_x \gtreqless \rho_m. \tag{19}$$

Using (18), the determinant of θ reads

$$|\theta| = \theta_{lx} - \theta_{lm}. \tag{20}$$

8.2.2 Deriving the reduced form

Given the arguments of section 2.3, all results concerning downsizing, reallocation of factors of production and changes in the wage structure are derived by analyzing a closed economy where the factor endowment H and L changes proportionally, while keeping the ratio

$$\kappa \equiv H/L \tag{21}$$

constant.[19] Here, we allow κ to vary. We can use the same approach as Jones (1965), despite the presence of imperfect competition features in our model. The following set of equations (derived from (2), (4) and (6) to (8) in app. A) determines the proportional changes of x, n, w_L, w_H, p_x as functions of the proportional change in the market size s and relative factor endowment κ. We denote proportional changes by a hat 'ˆ', i.e. $\hat{z} = dz/z$ and

[19] We need factor price equalisation (FPE) in order to be able to represent integration in a world economy by an expansion of factor endowments of a closed economy. FPE is present if either countries are symmetric or countries are not too asymmetric and firms can outsource their administrative activities such that they are tradeable. FPE in the latter case then follows from (2) and (4).

exogenous changes in endowments by $\hat{L} = \hat{s}$ and $\hat{H} = \hat{\kappa} + \hat{s}$, where $\hat{\kappa} = 0$ in the main part of the paper, as discussed above.

$$\hat{p}_x - (\theta_{lx}\hat{a}_{lx} + \theta_{hx}\hat{a}_{hx}) = \theta_{lx}\hat{w}_L + \theta_{hx}\hat{w}_H + \hat{\mu}, \quad \hat{\mu} = -\frac{\hat{n}}{n-1} \tag{22}$$

$$-(\theta_{lm}\hat{a}_{lm} + \theta_{hm}\hat{a}_{hm}) = \theta_{lm}\hat{w}_L + \theta_{hm}\hat{w}_H \tag{23}$$

$$\hat{p}_x = \hat{n} - \hat{x} \tag{24}$$

$$\hat{s} - (\lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm}) = \lambda_{lx}\hat{x} + \hat{n} \tag{25}$$

$$\hat{\kappa} + \hat{s} - (\lambda_{hx}\hat{a}_{hx} + \lambda_{hm}\hat{a}_{hm}) = \lambda_{hx}\hat{x} + \hat{n} \tag{26}$$

Equations (22) and (23) describe how prices and wages respond to parameter changes. For the oligopolistic production of the consumption good (22), changes in factor rewards are accommodated by changes in the price p_x, in technologies (the term in brackets on the left-hand side) and by changes in the markup. The definition of the markup in (4) implies that its proportional change is given by $\hat{\mu} = -\hat{n}/(n-1)$. For administrative activities, equation (23) illustrates that changes in the factor prices are balanced by adjustments in technologies only as the price p_m was set to unity.

Equation (24) stems from the zero profit condition (6). As again p_m is constant and a fixed amount of administration services is required, zero profits prevail only if the operating profits from sales of the consumption good remain constant.

Equations (25) and (26) describe factor markets. An increase $\hat{s}$ is accommodated by changes in the technology (the term in the brackets on the left-hand side) and in the supply (the right-hand side). As the demand of a single firm for administration services is fixed, supply can only vary when either output x of the representative firm or the number n of firms change. Since the factor shares of both activities add to one, $\hat{n}$ is not weighted.

Equations (22)–(26) can be simplified. As both oligopolistic consumption good firms and perfectly competitive administration firms minimize production costs and are price takers on the factor markets, we obtain

$$\theta_{lj}\hat{a}_{lj} + \theta_{hj}\hat{a}_{hj} = 0, \quad j = x, m \tag{27}$$

for both types of activities (cf. app. A.2). This condition simplifies the pricing equations (22) and (23) as the brackets on the left-hand side disappear.

The zero profit condition (24) can be used in equation (22). Subtracting equation (23) from the resulting condition yields

$$\hat{x} - \mu\hat{n} + |\theta|\,(\hat{w}_L - \hat{w}_H) = 0, \tag{28}$$

where $|\theta|$ is the determinant of the factor share matrix from (20). Equation (19) shows that the determinant $|\theta|$ is negative for our factor intensity assumption. This equation is the first one to be used in the reduced form.

With linear homogenous production functions and perfect competition on factor markets, the elasticity of substitution between the factors of production in activity j can be written as $\sigma_j = (\hat{a}_{hj} - \hat{a}_{lj})/(\hat{w}_L - \hat{w}_H)$. Together with the appropriate equation from (27), we obtain (cf. app. A.3)

$$\lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm} = \delta_l(\hat{w}_L - \hat{w}_H), \tag{29}$$

$$\lambda_{hx}\hat{a}_{hx} + \lambda_{hm}\hat{a}_{hm} = -\delta_h(\hat{w}_L - \hat{w}_H), \tag{30}$$

where

$$\delta_l \equiv \lambda_{lx}\theta_{hx}\sigma_x + \lambda_{lm}\theta_{hm}\sigma_m, \quad \delta_h \equiv \lambda_{hx}\theta_{lx}\sigma_x + \lambda_{hm}\theta_{lm}\sigma_m. \tag{31}$$

These equations can be used to replace changes in technology in factor market conditions (25) and (26) by changes in relative factor rewards. This yields

$$\lambda_{lx}\hat{x} + \hat{n} - \delta_l(\hat{w}_L - \hat{w}_H) = \hat{s} \tag{32}$$

$$\lambda_{hx}\hat{x} + \hat{n} + \delta_h(\hat{w}_L - \hat{w}_H) = \hat{s} + \hat{\kappa} \tag{33}$$

Together with equation (28), the modified factor market equilibrium conditions (32) and (33) constitute a system of equations which determines the effect of changes in the exogenous variables s and κ on the endogenous variables $(n, x, w_L/w_H)$. For later purposes, we summarize these equations as

$$J\ b = d \quad \text{with} \tag{34}$$

$$J = \begin{bmatrix} \lambda_{lx} & 1 & -\delta_l \\ \lambda_{hx} & 1 & \delta_h \\ 1 & -\mu & |\theta| \end{bmatrix}, \quad b = \begin{bmatrix} \hat{x} \\ \hat{n} \\ \hat{w}_L - \hat{w}_H \end{bmatrix}, \quad d = \begin{bmatrix} \hat{s} \\ \hat{s} + \hat{\kappa} \\ 0 \end{bmatrix}$$

8.2.3 Proofs for sections 3 and 4

Proof for proposition 1: (i) Define $j_1 \equiv |\theta|\,|\lambda|$, $j_2 \equiv \delta_l + \delta_h$ and $j_3 \equiv \mu\left[\delta_l\lambda_{hx} + \delta_h\lambda_{lx}\right]$. This definition directly implies $j_2, j_3 > 0$. From (15) and (19) $j_1 > 0$ as well. Using (16), the determinant of the Jacobi matrix in (34) can be written as

$$|J| = j_1 + j_2 + j_3 > 0 \tag{35}$$

and the second element of adj Jd is $\hat{s}\left[j_1 + j_2\right] \equiv J_n\hat{s}$. Hence, $\hat{n} = \hat{s}\left[j_1 + j_2\right] / |J|$. As $j_1 + j_2 < |J|$, it follows that $0 < \hat{n} < \hat{s}$ if $\hat{s} > 0$.

(ii) From (34), $\hat{x} = \hat{s}\mu j_2 / |J|$. As $|J| > 0$ from (35), it follows that $\hat{x} > 0$ if $\hat{s} > 0$.

(iii) Let j_1, j_2, j_3, $|J|$, J_x and J_n be defined as above. Then, $\hat{n} + \hat{x} = \hat{s}(J_n + J_x)/|J|$. As $\lambda_{hx}, \lambda_{lx} < 1$, $\mu j_2 > j_3$ so that $J_n + J_x > |J|$ and $\hat{n} + \hat{x} > \hat{s}$. Concerning gains from trade, for monotonous utility functions, social welfare u is an increasing function of output X of the consumption good normalized by country size s, $u = u(X/s)$, $u'(\cdot) > 0$. As $\hat{n} + \hat{x} - \hat{s} > 0$ by the last proposition, X/s increases as country size increases. Welfare u therefore rises when countries integrate.

Proof for proposition 2: Let the determinant of the Jacobi matrix be defined as above. The third element of adj Jd is $\hat{s}\mu\,|\lambda|$ so that $\hat{w}_H - \hat{w}_L = -\hat{s}\mu\,|\lambda| / |J|$. Then, the proposition follows directly from equation (15).

Proof for the relative price p_x/p_m : With p_m being set to unity, from (24) and with $\hat{n}$ and $\hat{x}$ from the proof for proposition 1, $\hat{p}_x = \hat{s}\left[j_1 + j_2\right] / |J| - \hat{s}\mu j_2 / |J| > 0 \Leftrightarrow j_1 + j_2 > \mu j_2$ for $\hat{s} > 0$. As $\mu > 1$ and given the definition of j_1 and j_2 from above, the relative price can increase, decrease or remain constant, depending on parameter values and the initial size of the economy.

8.3 Differing skill richness

This appendix looks at distributional effects of integrating with an economy that has a different skilled to less-skilled labour ratio than the economy under consideration. In terms of our reduced form (34), this means that we now allow for changes in κ as well. In what follows, we assume factor price equalization. Differences in skill endowment of trading economies should therefore be not too large.

The traditional effect is summarized in the following generalization of proposition 2 which directly follows from (34):

Proposition 5 *Human capital rewards w_H rise relative to wages w_L* ceteris paribus *whenever skill richness κ falls,*

$$\hat{w}_H - \hat{w}_L = -\frac{1}{|J|}\left[\mu\,|\lambda|\,\hat{s} + (1 + \mu\lambda_{lx})\,\hat{\kappa}\right]. \tag{36}$$

Understanding this equation is straightforward: integration implies relative gains of skills due to the effect studied before. Integration with a skill-poor country, i.e. $\hat{\kappa} < 0$, makes skills more scarce and skilled individuals gain further. Relative skill gains can be (over-) compensated if the country integrates with a skill-rich country, i.e. for $\hat{\kappa} > 0$.

More important for policy discussions are the effects on real factor rewards. We can repeat the results of proposition 3:

Proposition 6 *The factor of production that gains relative to the other factor, also gains in real terms,*

$$\hat{w}_H - \hat{p}_x = \theta_{lx}\,(\hat{w}_H - \hat{w}_L) + \frac{\hat{n}}{n-1}. \tag{37}$$

$$\hat{w}_L - \hat{p}_x = \theta_{hx}\,(\hat{w}_L - \hat{w}_H) + \frac{\hat{n}}{n-1}. \tag{38}$$

Proof. These expressions were derived in (9) and the proof of proposition 3. ■

The lifting-all-boats effect $\hat{n}/(n-1)$ is present in both equations: whether a country starts trading with another country that has more or less skilled individuals relative to its labour endowment, an integrated world economy always has more resources than a country in autarky. As a consequence, the number of firms under integration is larger, $\hat{n}/(n-1) > 0$, and competition therefore fiercer. Both factors of production gain from this effect. Clearly, the factor that gains in relative terms also gains in real terms, as both expressions in (37) or (38) would then be positive.

The potential loss in real wages of a factor of production induced by changes in relative endowment κ therefore works entirely through the relative-wage channel (36) and not through the pro-competitive effect. This also makes clear why proposition 3 (ii) remains unchanged, despite changes in κ.

One could now analyze the extreme case where an increase in L, keeping H constant, i.e. taking up trade with a country that is very labour rich, leads to increases in real wages of unskilled workers. It can be shown and it is intuitively clear that the number of firms increases as long as the resource base of an integrated world economy rises. Hence, workers benefit from more competition among firms. This effect is not strong enough, however, to balance the decrease in wages due to more labor supply. Summarizing, the endowment effect of more labour supply is always stronger than the induced competition effect and real factor rewards for labour fall.

8.4 A simple model

The results in the main part of the paper are derived for general production functions. Following the suggestion of one Referee, we present here the simplest possible version of the model. Administration is performed by low-skilled only, $m = l_m$ and production requires both types, $x(h_x, l_x) = h_x^{\alpha} l_x^{1-\alpha}$. From this, one obtains (see app. B, eqs. (41) to (45) and (47) with $\beta = 0$)

$$\frac{w_L}{w_H} = \frac{(1-\alpha)(n-1)+1}{\alpha(n-1)}\frac{H}{L} = \frac{n-\alpha(n-1)}{\alpha(n-1)}\frac{H}{L}. \tag{39}$$

The free-entry condition becomes (compare (48) in app. B)

$$n = \frac{p_x x}{p_m \bar{m}} = \frac{n^{-1}(w_L L + w_H H)}{w_L \bar{m}} \Leftrightarrow n^2 = \frac{L + \frac{w_H}{w_L} H}{\bar{m}}.$$

These two equations jointly determine n and w_L/w_H.

When we insert the first into the second, we get $n^2 = \frac{L+\frac{\alpha(n-1)}{n-\alpha(n-1)}L}{\bar{m}} = \left(1 + \frac{\alpha(n-1)}{n-\alpha(n-1)}\right)\frac{L}{\bar{m}} = \frac{n}{n-\alpha(n-1)}\frac{L}{\bar{m}} \Leftrightarrow n\left[n-\alpha(n-1)\right] = \frac{L}{\bar{m}} \Leftrightarrow (1-\alpha)\,n^2 - \alpha n = \frac{L}{\bar{m}} \Leftrightarrow n^2 - \frac{\alpha}{1-\alpha}n - \frac{L}{(1-\alpha)\bar{m}} = 0$. This implies that $n_{1,2} = .5\left(\frac{\alpha}{1-\alpha} \pm \sqrt{\left(\frac{\alpha}{1-\alpha}\right)^2 + 4\frac{L}{(1-\alpha)\bar{m}}}\right)$. As only one n is positive, the number of firms is given by

$$n = \frac{\alpha + \sqrt{\alpha^2 + 4(1-\alpha)L/\bar{m}}}{2(1-\alpha)}. \tag{40}$$

One can then use this simple model to illustrate the more general results obtained in the paper: when the economy integrates in the world as a whole (L increases), the number of firms increases, but it does so underproportionally due to the square root in (40). In the world as a whole, firms therefore exit, output increases and there are gains from trade.

At the same time, (39) shows that the relative wage of low-skilled drops: integration implies that H/L remains unchanged but the term $\frac{n-\alpha(n-1)}{\alpha(n-1)} = \frac{1}{\alpha(1-n^{-1})} - 1$ falls. There is lifting-all-boats, however, as we know from the Cobb-Douglas result in proposition 4.

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Referees' appendix

for "International Competition, Downsizing and Wage Inequality"
by Klaus Wälde and Pia Weiß

A The general approach

A.1 The system of equations (22) – (26)

Using the logarithm on both sides of the labour market equilibrium condition (7) yields $\ln L = \ln(a_{lx}nx + a_{lm}n\bar{m})$. Forming the total differential gives $\hat{L} = (\lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm}) + \lambda_{lx}\hat{x} + (\lambda_{lx} + \lambda_{lm})\hat{n}$, where λ_{lj} was defined in (13). The "hat" indicates proportional changes, i.e. e.g. $\hat{L} = dL/L$. As λ_{lx} and λ_{lm} add to unity in equation (14), the labour market equilibrium expressed in proportional changes reads

$$\hat{L} = (\lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm}) + \lambda_{lx}\hat{x} + \hat{n}.$$

By analogy, an equilibrium on the market for skilled individuals requires

$$\hat{H} = (\lambda_{hx}\hat{a}_{hx} + \lambda_{hm}\hat{a}_{hm}) + \lambda_{hx}\hat{x} + \hat{n}.$$

Noting that $\hat{H} = \hat{\kappa} + \hat{L}$, where $\kappa = H/L$ is the skill richness of the economy, we can replace the increase in the number of skilled individuals by an increase in labour plus an increase in skill richness of the economy. Renaming the increase in labour $\hat{L}$ by $\hat{s}$, we obtain the expressions used in the main text,

$$\hat{s} = (\lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm}) + \lambda_{lx}\hat{x} + \hat{n},$$
$$\hat{\kappa} + \hat{s} = (\lambda_{hx}\hat{a}_{hx} + \lambda_{hm}\hat{a}_{hm}) + \lambda_{hx}\hat{x} + \hat{n}.$$

An increase in s captures an increase of the economy where both factors increase by the same percentage amount. In our trade interpretation, it captures the opening up to trade with an economy that has an identical skill to labour ratio. An increase (decrease) in skill richness κ means free trade with an economy that has a higher (lower) skill to labour ratio.

Using the logarithm on both sides of the pricing equation (2) of administration services and noting that the price p_m was set to unity, the equation can be rewritten to $0 = \ln(a_{lm}w_L + a_{hm}w_H)$. Forming the total differential yields

$$0 = (\theta_{lm}\hat{a}_{lm} + \theta_{hm}\hat{a}_{hm}) + \theta_{lm}\hat{w}_L + \theta_{hm}\hat{w}_H,$$

to where the shares of factor returns θ_{ij} are defined in (17). Applying the logarithm and computing the total differential on both sides of the pricing equation (4) for the consumption good gives

$$\hat{p}_x = (\theta_{lx}\hat{a}_{lx} + \theta_{hx}\hat{a}_{hx}) + \theta_{lx}\hat{w}_L + \theta_{hx}\hat{w}_H + \hat{\mu},$$

where $\hat{\mu} = \hat{n}(1-\mu)$ is the proportional change of the markup over unit costs.

Finally, in terms of changes, the zero profit condition (6) can be written as

$$\hat{p}_x = \hat{n} - \hat{x}.$$

A.2 Deriving equation (27)

We prove the relationship for an oligopolistic firm. The principle for the proof for perfectly competitive firms is the same.

Starting with the equality of revenue, adjusted for the markup, and costs,

$$\left(1-\frac{1}{n}\right)p_x x = w_L l_x + w_H h_x,$$

its differential (with respect to all variables under control of the firm) reads

$$\left(1-\frac{1}{n}\right)p_x dx = w_L dl_x + w_H dh_x.$$

This can be written as

$$\frac{dx}{x} = \frac{w_L l_x}{\left(1-\frac{1}{n}\right)p_x x}\frac{dl_x}{l_x} + \frac{w_H h_x}{\left(1-\frac{1}{n}\right)p_x x}\frac{dh_x}{h_x}.$$

Applying definitions introduced before e.g. in (17), this is identical to

$$\hat{x} = \theta_{lx}\hat{l}_x + \theta_{hx}\hat{h}_x \Leftrightarrow \theta_{lx}\left(\hat{l}_x - \hat{x}\right) + \theta_{hx}\left(\hat{h}_x - \hat{x}\right) = 0 \Leftrightarrow \theta_{lx}\hat{a}_{lx} + \theta_{hx}\hat{a}_{hx} = 0.$$

A.3 Deriving equations (29) and (30)

The elasticities of substitution σ_j can be rearranged to yield $-\hat{a}_{lj} + \hat{a}_{hj} = (\hat{w}_L - \hat{w}_H)\sigma_j, \quad j = x, m$. Together with the appropriate equation (27), they form a system of equations which in matrix form reads

$$\begin{bmatrix} -1 & 1 \\ \theta_{lj} & \theta_{hj} \end{bmatrix}\begin{bmatrix} \hat{a}_{lj} \\ \hat{a}_{hj} \end{bmatrix} = \begin{bmatrix} (\hat{w}_L - \hat{w}_H)\sigma_j \\ 0 \end{bmatrix} \qquad j = x, m.$$

Solving with respect to the proportional changes in the factor coefficients gives

$$\begin{aligned} \hat{a}_{lj} &= \theta_{hj}\sigma_j(\hat{w}_L - \hat{w}_H), \\ \hat{a}_{hj} &= -\theta_{lj}\sigma_j(\hat{w}_L - \hat{w}_H), \end{aligned} \qquad j = x, m.$$

Weighting the changes in the factor coefficients with the appropriate factor shares finally yields

$$\begin{aligned} \lambda_{lx}\hat{a}_{lx} + \lambda_{lm}\hat{a}_{lm} &= (\lambda_{lx}\theta_{hx}\sigma_x + \lambda_{lm}\theta_{hm}\sigma_m)(\hat{w}_L - \hat{w}_H) \equiv \delta_l(\hat{w}_L - \hat{w}_H), \\ \lambda_{hx}\hat{a}_{hx} + \lambda_{hm}\hat{a}_{hm} &= -(\lambda_{hx}\theta_{lx}\sigma_x + \lambda_{hm}\theta_{lm}\sigma_m)(\hat{w}_L - \hat{w}_H) \equiv -\delta_h(\hat{w}_L - \hat{w}_H), \end{aligned}$$

where the last equalities define the δ_i.

B The Cobb–Douglas case

B.1 The economy

In the Cobb-Douglas case, the economy is described by (41)–(45)

$$p_x = w_H^\alpha w_L^{1-\alpha} \frac{n}{n-1} \tag{41}$$

$$p_m = w_H^\beta w_L^{1-\beta} \tag{42}$$

$$\frac{p_x x}{n} = p_m \bar{m} \tag{43}$$

$$L = (1-\alpha)\left(\frac{w_H}{w_L}\right)^\alpha nx + (1-\beta)\left(\frac{w_H}{w_L}\right)^\beta n\bar{m} \tag{44}$$

$$H = \alpha\left(\frac{w_L}{w_H}\right)^{1-\alpha} nx + \beta\left(\frac{w_L}{w_H}\right)^{1-\beta} n\bar{m} \tag{45}$$

plus the equation for consumption demand

$$nx = \frac{E}{p_x}, \tag{46}$$

where expenditure E equals factor income (profits are zero) $E = w_L L + w_H H$.

B.2 Reduced form

Inserting (41)–(43) and (46) in (44) after some rearrangements yields $L = [(1-\alpha)(n-1)+1-\beta]\, E/w_L$. Inserting (41)–(43) and (46) in (45) gives $H = [\alpha(n-1)+\beta]\, E/w_H$. Dividing these two equations gives with (21) relative factor rewards as

$$\omega \equiv \frac{w_L}{w_H} = \frac{(1-\alpha)(n-1)+1-\beta}{\alpha(n-1)+\beta}\kappa \tag{47}$$

The number of firms can be deduced from the zero profit condition (43) together with (42), (46) and $E = w_L L + w_H H$ as

$$n = \frac{p_x x}{p_m \bar{m}} = \frac{n^{-1}(w_L L + w_H H)}{w_H^\beta w_L^{1-\beta}\bar{m}} \quad \Leftrightarrow \quad n^2 = \frac{\omega L + H}{\omega^{1-\beta}\bar{m}}. \tag{48}$$

Equations (47) and (48) determine relative factor rewards w_L/w_H and the number n of firms.

B.3 The condition for real gains

The proof of proposition 3 has shown in all generality that workers gain in real terms (assuming they lose in relative terms) if $-\theta_{hx}(\hat{w}_H - \hat{w}_L) + \frac{1}{n-1}\hat{n} > 0$. Together with expressions from the proofs of propositions 1 and 2, this condition reads

$$|\theta|\,|\lambda| + \delta_l + \delta_h > -\theta_{hx} n\,|\lambda|\,. \tag{49}$$

For the Cobb-Douglas case considered here, it is easy to show that $\theta_{hx} = \alpha$: replacing the price p_x in the definition of θ_{hx} given in equation (17) by equation (4) yields

$$\theta_{hx} = \frac{a_{hx} w_H}{a_{hx} w_H + a_{lx} w_L} = \frac{1}{1 + \frac{a_{lx}}{a_{hx}} \frac{w_L}{w_H}}.$$

As $a_{hx}/a_{lx} = \omega\alpha/(1-\alpha)$ in the Cobb-Douglas case, we get $\theta_{hx} = \alpha$.

Using the definition of δ_l and δ_h from (31) it can be shown further that $\delta_l + \delta_h = 1 - |\theta| \, |\lambda|$. Therefore, the condition (49) becomes, together with (16),

$$1 > -\alpha n \, |\lambda| = \alpha n \left[\lambda_{hx} - \lambda_{lx} \right] = \alpha n \left[a_{hx} \frac{nx}{H} - a_{lx} \frac{nx}{L} \right], \tag{50}$$

where the last equality uses the definition of λ_{ij} from (13).

From the two factor market conditions (7) and (8), output of the consumption good x can be determined as

$$nx = \frac{L a_{hm} - H a_{lm}}{a_{lx} a_{hm} - a_{hx} a_{lm}} = \frac{1}{a_{lx}} \frac{L \frac{a_{hm}}{a_{lm}} - H}{\frac{a_{hm}}{a_{lm}} - \frac{a_{hx}}{a_{lx}}}.$$

Rewriting (50) and inserting yields

$$\begin{aligned} n \;&<\; \frac{1}{\alpha} \frac{1}{a_{hx} \frac{nx}{H} - a_{lx} \frac{nx}{L}} = \frac{1}{\alpha} \frac{\frac{a_{hm}}{a_{lm}} - \frac{a_{hx}}{a_{lx}}}{\left(a_{hx} \frac{1}{H} - a_{lx} \frac{1}{L} \right) \frac{1}{a_{lx}} \left(L \frac{a_{hm}}{a_{lm}} - H \right)} \\ &=\; \frac{1}{\alpha} \frac{H}{L} \frac{\frac{a_{hm}}{a_{lm}} - \frac{a_{hx}}{a_{lx}}}{\left(\frac{a_{hx}}{a_{lx}} - \frac{H}{L} \right) \left(\frac{a_{hm}}{a_{lm}} - \frac{H}{L} \right)}. \end{aligned}$$

In the Cobb-Douglas case, $a_{hm}/a_{lm} = \omega\beta/(1-\beta)$ and $a_{hx}/a_{lx} = \omega\alpha/(1-\alpha)$ so that finally

$$n < \frac{1}{\alpha} \frac{H}{L} \omega \frac{\frac{\beta}{1-\beta} - \frac{\alpha}{1-\alpha}}{\left(\omega \frac{\alpha}{1-\alpha} - \frac{H}{L} \right) \left(\omega \frac{\beta}{1-\beta} - \frac{H}{L} \right)}. \tag{51}$$

Let $\nu \equiv (1-\alpha)(n-1) + 1 - \beta$ and $\zeta \equiv \alpha(n-1) + \beta$. Then, the relative factor prices (47) can be written as $\omega = \frac{H}{L} \frac{\nu}{\zeta}$ and inserting in (51) yields

$$n < \frac{1}{\alpha} \frac{H}{L} \frac{H}{L} \frac{\nu}{\zeta} \frac{\frac{\beta}{1-\beta} - \frac{\alpha}{1-\alpha}}{\left(\frac{H}{L} \frac{\nu}{\zeta} \frac{\alpha}{1-\alpha} - \frac{H}{L} \right) \left(\frac{H}{L} \frac{\nu}{\zeta} \frac{\beta}{1-\beta} - \frac{H}{L} \right)} = -\frac{1}{\alpha} \frac{\nu}{\zeta} \frac{\frac{\beta}{1-\beta} - \frac{\alpha}{1-\alpha}}{\left(\frac{\nu}{\zeta} \frac{\alpha}{1-\alpha} - 1 \right) \left(1 - \frac{\nu}{\zeta} \frac{\beta}{1-\beta} \right)}.$$

Rearranging yields

$$\begin{aligned} n &< -\frac{1}{\alpha} \frac{\nu}{\zeta} \frac{\frac{\beta-\alpha}{(1-\beta)(1-\alpha)}}{\left(\frac{\nu}{\zeta} \frac{\beta}{1-\beta} - 1 \right) \left(1 - \frac{\nu}{\zeta} \frac{\alpha}{1-\alpha} \right)} = -\frac{1}{\alpha} \frac{\nu}{\zeta} \frac{\beta - \alpha}{\left[\frac{\nu}{\zeta} \beta - (1-\beta) \right] \left[1 - \alpha - \frac{\nu}{\zeta} \alpha \right]} \\ &= -\frac{1}{\alpha} \frac{\zeta\nu(\beta - \alpha)}{[\beta\nu - (1-\beta)\zeta][(1-\alpha)\zeta - \alpha\nu]}. \end{aligned}$$

Inserting the definitions of ν and ζ into the first and second term of the denominator yields

$$\begin{aligned}\beta\nu-(1-\beta)\zeta &= \beta(1-\alpha)(n-1)+\beta(1-\beta)-(1-\beta)\alpha(n-1)-(1-\beta)\beta \\ &= (\beta-\alpha)(n-1),\end{aligned}$$

and

$$\begin{aligned}(1-\alpha)\zeta-\alpha\nu &= (1-\alpha)\alpha(n-1)+(1-\alpha)\beta-\alpha(1-\alpha)(n-1)-\alpha(1-\beta) \\ &= \beta-\alpha,\end{aligned}$$

respectively, so that we obtain

$$\begin{aligned}n &< \frac{[\alpha-\beta+(1-\alpha)n][(n-1)\alpha+\beta]}{(n-1)\alpha(\alpha-\beta)} \\ &= \frac{(\alpha-\beta)[(n-1)\alpha+\beta]+(1-\alpha)n(n-1)\alpha+(1-\alpha)n\beta}{(n-1)\alpha(\alpha-\beta)}.\end{aligned}$$

B.4 Solving the condition

When this expression holds, workers that lose in relative terms nevertheless gain in real terms. Rearranging gives

$$\begin{aligned}n\,(n-1)\,\alpha\,(\alpha-\beta) &< (\alpha-\beta)[(n-1)\alpha+\beta]+(1-\alpha)n(n-1)\alpha+(1-\alpha)n\beta \Leftrightarrow \\ 0 &< (\alpha-\beta)[(n-1)\alpha+\beta]+(1-\alpha-(\alpha-\beta))n(n-1)\alpha+(1-\alpha)n\beta.\end{aligned}$$

This is a U-form quadratic equation in n whose roots are

$$n_{1,2}=(\alpha-\beta)\,\frac{(1-3\alpha)\pm\sqrt{1-2\alpha+\alpha^2+4\alpha\beta}}{2\alpha(1-2\alpha+\beta)}.$$

Now observe that

$$1-2\alpha+\alpha^2+4\alpha\beta>0\Leftrightarrow\alpha^{-1}+\alpha+4\beta>2$$

which always holds as the minimum of $\alpha^{-1}+\alpha$ is at $\alpha=1$ and given by $1^{-1}+1=2$. This shows that there are two distinct real roots. Now take the larger one, i.e. $n_2=(\alpha-\beta)\,\frac{(1-3\alpha)\pm\sqrt{1-2\alpha+\alpha^2+4\alpha\beta}}{2\alpha(1-2\alpha+\beta)}$. By numerically computing the value n_2 for all $(\alpha,\beta)\in\,]0,1[\,\times\,]0,1[$ where $\alpha>\beta$, it can be shown that unity is an upper bound for n_2. Hence, for any $n>1$, the nominator is positive.

As a consequence, whatever the solution for n (which must be larger than unity to make economically sense), condition (49) for Cobb-Douglas economies always holds and theorem 4 is proven.[20]

[20] Strictly speaking, this sentence requires an identical proof for real gains of w_H when w_H loses relatively. Due to the symmetry, such a proof is identical with factor intensities reversed.

C CES economies

C.1 The factor coefficients

For the CES economy, the factor coefficients can be derived as

$$a_{hx} = \frac{\left(\frac{w_H}{\alpha}\right)^{-\varepsilon}}{\left[\alpha\left(\frac{w_H}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{w_L}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}} = \frac{\alpha^{\varepsilon}}{\left[\alpha\left(\frac{1}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{\omega}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}}, \tag{52}$$

$$a_{lx} = \frac{\left(\frac{w_L}{1-\alpha}\right)^{-\varepsilon}}{\left[\alpha\left(\frac{w_H}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{w_L}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}} = \frac{\left(\frac{\omega}{1-\alpha}\right)^{-\varepsilon}}{\left[\alpha\left(\frac{1}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{\omega}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}}, \tag{53}$$

$$a_{hm} = \frac{\left(\frac{w_H}{\beta}\right)^{-\varepsilon}}{\left[\beta\left(\frac{w_H}{\beta}\right)^{1-\varepsilon} + (1-\beta)\left(\frac{w_L}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}} = \frac{\beta^{\varepsilon}}{\left[\beta\left(\frac{1}{\beta}\right)^{1-\varepsilon} + (1-\beta)\left(\frac{\omega}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}}, \tag{54}$$

$$a_{lm} = \frac{\left(\frac{w_L}{1-\beta}\right)^{-\varepsilon}}{\left[\beta\left(\frac{w_H}{\beta}\right)^{1-\varepsilon} + (1-\beta)\left(\frac{w_L}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}} = \frac{\left(\frac{\omega}{1-\beta}\right)^{-\varepsilon}}{\left[\beta\left(\frac{1}{\beta}\right)^{1-\varepsilon} + (1-\beta)\left(\frac{\omega}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}}}. \tag{55}$$

The first term is the usual demand function, the second one expresses everything in terms of relative factor prices $\omega = w_L/w_H$.

Note that the skill intensities can be obtained with $\rho_j = a_{hj}/a_{lj} = \omega_j^{\sigma_j}$, where $\omega_x = \alpha w_L/[w_H(1-\alpha)]$ and $\omega_m = \beta w_L/[w_H(1-\beta)]$.

C.2 The reduced form

Given the factor coefficients in (52)–(55), the reduced form reads

$$p_x = \frac{1}{\left[\alpha\left(\frac{w_H}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{w_L}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{1}{\varepsilon-1}}}\frac{n}{n-1}, \tag{56}$$

$$p_m = \frac{1}{\left[\beta\left(\frac{w_H}{\beta}\right)^{1-\varepsilon} + (1-\beta)\left(\frac{w_L}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{1}{\varepsilon-1}}}, \tag{57}$$

$$\frac{p_x x}{n} = p_m \bar{m},$$

$$L = a_{lx} n x + a_{lm} n \bar{m}, \qquad H = a_{hx} n x + a_{hm} n \bar{m}.$$

With

$$a_{lx}^{1/\varepsilon}\frac{w_L}{1-\alpha} = \frac{1}{\left[\alpha\left(\frac{w_H}{\alpha}\right)^{1-\varepsilon}+(1-\alpha)\left(\frac{w_L}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{1}{\varepsilon-1}}},$$

$$a_{lm}^{1/\varepsilon}\frac{w_L}{1-\beta} = \frac{1}{\left[\beta\left(\frac{w_H}{\beta}\right)^{1-\varepsilon}+(1-\beta)\left(\frac{w_L}{1-\beta}\right)^{1-\varepsilon}\right]^{\frac{1}{\varepsilon-1}}},$$

from (53) and (55) we get

$$p_x = a_{lx}^{1/\varepsilon}\frac{w_L}{1-\alpha}\frac{n}{n-1}, \quad p_m = a_{lm}^{1/\varepsilon}\frac{w_L}{1-\beta} \tag{58}$$

and the reduced form becomes

$$\begin{aligned} a_{lx}^{1/\varepsilon}\frac{1}{n-1}\frac{x}{\bar{m}} &= a_{lm}^{1/\varepsilon}\frac{1-\alpha}{1-\beta} \Leftrightarrow \left(\frac{a_{lx}}{a_{lm}}\right)^{1/\varepsilon}\frac{1}{n-1}\frac{x}{\bar{m}} = \frac{1-\alpha}{1-\beta}, \\ \frac{L}{n} &= a_{lx}x + a_{lm}\bar{m}, \qquad \frac{H}{n} = a_{hx}x + a_{hm}\bar{m}. \end{aligned}$$

It can be solved for the endogenous variables x, n and ω.

C.3 The numerical figure

Figure 2 divides the parameters space into two regions, one where there is lifting-all-boats, i.e. $\hat{w}_L - \hat{p}_x$ and $\hat{w}_H - \hat{p}_x$ are both positive and one where only the highly-skilled gain, i.e. $\hat{w}_L - \hat{p}_x < 0$ and $\hat{w}_H - \hat{p}_x > 0$. These regions are divided by the curve where $\hat{w}_L - \hat{p}_x = 0$, i.e. where by (9), $\theta_{hx}[\hat{w}_H - \hat{w}_L] = \frac{1}{n-1}\hat{n}$. In order to be able to plot this curve numerically, we now express it more completely.

The change in relative factor rewards is given by (34) as (we set $\hat{\kappa} = 0$ here)

$$\hat{w}_H - \hat{w}_L = -\begin{vmatrix} \lambda_{lx} & 1 & \hat{s} \\ \lambda_{hx} & 1 & \hat{s} \\ 1 & -\mu & 0 \end{vmatrix} / |J| = -\frac{\hat{s} - \hat{s}\lambda_{hx}\mu - \hat{s} + \mu\hat{s}\lambda_{lx}}{|J|} = \frac{(\lambda_{hx} - \lambda_{lx})\mu}{|J|}\hat{s}.$$

The change in the number of firms follows from (34) as well,

$$\begin{aligned} \hat{n} &= \begin{vmatrix} \lambda_{lx} & \hat{s} & -\delta_l \\ \lambda_{hx} & \hat{s} & \delta_h \\ 1 & 0 & |\theta| \end{vmatrix} / |J| = \left(\lambda_{lx}\hat{s}|\theta| + \hat{s}\delta_h + \hat{s}\delta_l - |\theta|\lambda_{hx}\hat{s}\right) / |J| \\ &= \left((\lambda_{lx} - \lambda_{hx})|\theta| + \delta_h + \delta_l\right)\hat{s} / |J|. \end{aligned}$$

Hence, there is LAB iff, using (9) and (35),

$$\begin{aligned} \hat{w}_L - \hat{p}_x &\geq 0 \Leftrightarrow -\theta_{hx}[\hat{w}_H - \hat{w}_L] + \frac{1}{n-1}\hat{n} \geq 0 \\ &\Leftrightarrow \frac{1}{n-1}\frac{\left((\lambda_{lx} - \lambda_{hx})|\theta| + \delta_h + \delta_l\right)\hat{s}}{|J|} \geq \theta_{hx}\frac{(\lambda_{hx} - \lambda_{lx})\hat{s}\mu}{|J|} \\ &\Leftrightarrow \frac{(\lambda_{lx} - \lambda_{hx})|\theta| + \delta_h + \delta_l}{n-1} \geq \theta_{hx}[\lambda_{hx} - \lambda_{lx}]\mu. \end{aligned}$$

For an implementation in Mathematica, the a_{ij} are taken from section C.1, λ_{ij}, θ_{hx} and $|\theta|$ are from section 8.2.1 and δ_i were defined in (31) with $\sigma_x = \sigma_m = \varepsilon$, i.e. the elasticity of substitution between factors of production is the same in both sectors; see (10).

C.4 Real wages

The real wage for labour can be computed from (58) as $\frac{w_L}{p_x} = (1-\alpha)\, a_{lx}^{-1/\varepsilon} \frac{n-1}{n}$. The real wage for human capital can be deduced from (52) and (56). First write (52) as

$$\alpha a_{hx}^{-1/\varepsilon} = \frac{w_H}{\left[\alpha \left(\frac{w_H}{\alpha}\right)^{1-\varepsilon} + (1-\alpha)\left(\frac{w_L}{1-\alpha}\right)^{1-\varepsilon}\right]^{\frac{-1}{\varepsilon-1}}}$$

and then replace the denominator by the expression resulting from (56),

$$\frac{w_H}{p_x} = \alpha a_{hx}^{-1/\varepsilon} \frac{n-1}{n}.$$