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Kiel Working Paper, No. 921

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*Suggested Citation:* De Santis, Roberto A. (1999) : Intra-industry trade, endogenous technological change, wage inequality and welfare, Kiel Working Paper, No. 921, Kiel Institute of World Economics (IfW), Kiel

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ISSN 0342 - 0787

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April 1999

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* I am indebted to David Collie, Henning Klodt and Matthias Lücke for useful discussions, and Rolf Langhammer and Horst Siebert for helpful comments. All errors are my responsibility. This paper is part of the research project 'Globalisation and Social Exclusion', financed by the European Union under its Targeted Socio-Economic Research (TSER) programme and coordinated by Professor John Whalley at the Centre for the Study of Globalisation and Regionalisation at the University of Warwick.

## ABSTRACT

By using two alternative intra-industry trade models (1. - New goods cannot be introduced into the economy; 2. - The possibility for a set of capital goods available in the economy to vary; both models consider the existence of an intersectoral linkage), I show by means of Applied General Equilibrium (AGE) analysis that globalisation (either lower transport costs or lower tariffs) has an impact on the ratio between the wage rates of skilled and unskilled labours; but the impact on wage inequality is far larger, when countries are assumed to exchange differentiated capital goods. The latter result has been obtained by using an imperfect competitive model, which embodies a sector bias technological change that arises from trade. In addition, the gains from trade, insignificant under the standard trade hypotheses, are extraordinarily large when endogenous technological change is taken into account. The main policy conclusion is that if policy makers of flexible wage economies introduce trade barriers to reduce wage inequality, these protective measures, by affecting the diffusion of technology, would cause a large welfare loss.



KEYWORDS: Trade, Technical change, Wage Inequality, Applied General Equilibrium

JEL classification: D58, F12, F43, J3, O3.

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# 1. Introduction

> During the 1980s, a time when U.S. trade volumes were rising, the wages of skilled workers rose between 8 and 15 percent relative to those of unskilled workers (depending on how one defines 'skilled'). Given the rough coincidence of these changes, it is tempting to single out international trade as responsible for this increasing wage disparity. Moreover, a significant source of the expansion in world trade has been the entry into the world marketplace of many Asian economies well endowed with unskilled workers. Thus, casual observation seems to support the claim that free trade is detrimental to unskilled U.S. workers: these workers now compete with a vast pool of unskilled workers abroad, and the expected result of this competition is a decline in their wages. Most careful analysis of the direct evidence does not strongly support the notion that international trade is the major source of increasing wage inequality. Skill-biased technological change, for instance the use of computers and robotics, has been a more important source. The nature of this technological change has reduced demand for unskilled workers and increased demand for skilled workers. This phenomenon can be expected to reduce the wages of unskilled workers relative to those of skilled workers, and perhaps reduce them absolutely. Although the contribution of international trade to observed productivity changes has yet to be established, recent research indicates that international trade is responsible for only perhaps 10 to 15 percent of the observed increase in wage inequality during the 1980s.
>
> *The Economic Report of the U.S. President*, 1998, pp. 241-242.[1]

These statements well summarise the current debate in the literature, which attempts to explain the increasing wage inequality between skilled and unskilled workers, especially among those of the OECD countries which have flexible labour markets. Various econometric studies argue that this is due to rising trade with developing countries, due to lower international transportation and communication costs or lower tariff rates (Leamer, 1998; Sachs and Shatz,

[1] The 1998 Economic Report of the U.S. President can be downloaded from the following address: http://www.gpo.ucop.edu/catalog/erp98.html.

1998; Wood, 1998); whilst others argue that technological change is the main determinant of this new phenomenon (see Lawrence, 1996; and Slaughter, 1998; for a survey), mainly because the OECD trade volume with developing countries is relatively very small and the terms of trade of advanced nations have fluctuated with no discerning trend (see for example Krugman, 1995 and 1997). The studies, which argue that globalisation is to blame for the adverse effect against the less educated workers, base their analysis upon the two-factor, two-sector Heckscher-Ohlin (HO) model, which tells us that international trade has strong effects on income distribution in favour of the abundant factor. Since trade is based on differences in factor endowments, the HO model predicts an improvement in the relative factor prices in developing countries in favour of the unskilled workers. However, several studies have shown that wage inequality is increasing in several middle income developing countries (Hanson and Harrison, 1994, 1999; Feenstra and Hanson, 1997a; Robbins, 1996). If this is the case, then the HO theory is not the correct approach to examine whether international trade is affecting relative factor prices. In addition, an increasing share of trade is intra-industry rather than based on specialisation according to countries' comparative advantage.[2]

[2] In fact, according to the 1998 Economic Report of the U.S. President, the share of U.S. intra-industry trade (four-digit SITC commodity grouping) is increased from 51% in 1989 to 57% in 1996 and that, in the same period, the growth rates of both imports and exports with NICs were double those with industrialised countries..

Recent econometric studies conclude that the technology argument, as the main cause of the steady increase of the relative demand for more educated workers, is more convincing.[3] In particular, Autor *et. al* (1998) present evidence indicating that skill upgrading is concentrated in the most computer-intensive sectors of the U.S. economy. They calculate the growth in computer use between 1984 and 1993 for 140 industry groups, including services. Their results, in terms of the number of college workers employed, indicate that computer use has become especially prevalent in nontradable goods such as legal service, public administration, social services, insurance, business services, hospital, health services, communication, colleges, universities and schools (see Appendix Table A2 of Autor *et. al,* 1997). Murphy, *et al.* (1998) show that technological change has increased the demand for more educated labour, but that relative wage changes are not due to a factor bias technological change. Finally, Haskel and Slaughter (1998) find strong correlation between changes in relative factor prices and sector bias technological change.[4]

[3] Berman *et al.* (1998) present evidence that suggests that technological change not only is the major cause of wage inequality, but is also pervasive in the sense that it occurred in all sectors and in all developed or developing countries. Although Berman *et al.* (1998) present strong evidence that skill bias technological change occurred in many sectors (i.e. pervasiveness), it must be stressed that three industries, such as electrical machinery, machinery (including computers) and printing-publishing, account for 46 per cent of the within-industry increase in relative demand for skilled labour in their 28-industry 1980s sample.

[4] The evidence by Haskel and Slaughter (1998) indicates that in countries where wage inequality was falling, technological change was generally concentrated in the unskill-intensive sectors, whereas in countries where wage inequality was increasing, technological change mainly occurred in the skill-intensive sectors.

However, even if sector bias technological change is one of the main causes of wage inequality, one might nevertheless conceive that trade favours technology diffusion. As Rodrik (1997, pg. 16) puts it: '*Trade may act as a conduit for technology and create pressures for technological change.*' This pressure can easily come from newly industrialising countries (NICs). In fact, the last twenty years have not only been characterised by rising wage inequality, but also by a large flow of foreign direct investment in NICs. Multinational enterprises can transfer technology, and competition by foreign affiliates in the host country can induce technological change in other firms. The technological improvements are embodied in the products, which are then exported to developed countries.[5] This leads to the conclusion that intra-industry trade of intermediate goods, not only among developed countries, but also with NICs, can act as a channel for technological change. In the literature, technology has been often treated as exogenous. Thus, the links between trade and

[5] A recent survey on multinationals, technology transfer through foreign direct investment and export performance of firms of the host country can be found in Blomström and Kokko (1997). Coe, *et al.* (1997) have found an extraordinarily positive relationship between total factor productivity in developing countries and both the amount of R&D in their industrial countries trade partners and their imports of machinery and equipment from the industrial countries. This result suggests that foreign trade boosts domestic productivity. Whereas, Connolly (1998) has presented empirical evidence in favour of the hypothesis that trade with developed countries does have a direct effect on domestic innovation and imitation in developing countries, and that trade with developed countries has a far greater effect on domestic growth than domestic innovation. The positive effect of trade in intermediate goods on productivity growth in developed countries is empirically examined by Keller (1997).

technological change have not been carefully examined.[6] If this can be substantiated, restrictive trade measures to protect the unskilled workers can be effective. It is important to note that Feenstra and Hanson (1996, 1997b) show evidence that outsourcing (that is, the import of intermediate inputs according to their data set) is one of the causes of the increase in the relative demand for skilled labour that occurred in U.S. manufacturing industries during the 1980s. Similarly, Lovely and Richardson (1998) show evidence that wage inequality in U.S. is in part due to the intermediate inputs imported from NICs.

In the last decade, a large number of AGE models for both developed and developing countries have shown, under alternative assumptions, including intra-industry trade, increasing returns to scale and imperfect competition, that the static gains from trade liberalisation are very small, less than 2% of a country's Gross National Product (GNP). Given these small estimates, and the increasing wage inequality among workers within the same country, policy makers and economists might be tempted to protect the factor income of the

[6] An exception is the growth model by Acemoglu (1998). In his study, technological progress is a function of both the relative price of intermediate goods and the skilled/unskilled labour intensity. Acemoglu argues that intersectoral trade with the South affects what technologies are developed in the North. If intellectual property rights are not protected, the market size of different technologies are unaffected, but the increase in the price of skilled goods, due to the standard trade effects, induces further skill-biased technical change and wage inequality. In contrast, if international property rights are enforced, trade openings between a developed and a developing country might reduce wage inequality. In this case, there are profits to be made by producing technologies which are complementary to unskilled labour. Trade openings, by increasing the demand for unskilled labour, would induce further unskill-biased technical change.

unskilled workers with trade protective measures. However, one drawback of the AGE models is that they do not embody any of the features of the growth theory developed in the last decade.

The intra-industry trade AGE models presented in this study have as their purpose to show that the static gains from trade become very large when endogenous technological change is embodied in the model. This implies that protective measures intended to back the wage rate of the less educated workers might reduce the GNP of a country at an alarming rate. In this model, I consider an economy with one tradable sector (i.e. manufacturing in the case of a developed country; chemicals-metals in the case of a developing country) and one nontradable sector (i.e. banking, insurance, communications, business and legal services in the case of a developed country; machinery in the case of a developing country). The latter is skill-intensive relative to the tradable sector.[7] The skill-intensive nontradable sector has a production function which is an extension of the technology employed by Romer (1990, 1994), where the size of transport costs or policy interventions do affect the rate of invention, and therefore the set of goods available in the economy. The model assumes that

[7] Surely, the mentioned services are *disembodied*, in the sense that they can be treaded across long distances without a substantial loss of the quality of the service provided (see Bhagwati, 1984 for a definition of *embodied* and *disembodied* services). However, they represent a small fraction of the trade volume, which indeed is dominated by goods, and *embodied* services such as retail trade and transport, which are less skill intensive. Hence, the assumption that the skill intensive sector is nontradable is not inappropriate.

imports are used in domestic production because it is true that most of real international flows involve intermediate commodities (Ethier, 1982; Francois and Nelson, 1998). The domestically produced (by the unskill-intensive exportable sector) capital goods and imports are assumed to be imperfect substitutes to capture both the intra-industry trade phenomenon, and the fact that the unskill-intensive sector can enjoy protection, if transport costs are high or if a tariff rate on the variety of capital goods is levied. In addition, the model uses a multi-stage production function to capture the fact that unskilled labour and capital goods are imperfect substitutes, and skilled labour and the composite unskilled labour-capital are relatively more complementary. In summary, (i) technological change can harm unskilled labour, and (ii) trade protective measures can back the wage rate of the unskilled workers.

The remaining sections of the paper have been organised as follows: Section 2 defines the algebraic specification of the model; Section 3 describes the benchmark data set; Section 4 explores the effects of the policy simulations, and the final section provides some conclusions.

## 2. An open economy model

The intra-industry trade model of this study is based upon the assumptions that preferences are homothetic, sectoral productions functions are linear homogenous and strictly-concave; and that the primary inputs are perfectly mobile between sectors, but perfectly immobile among countries. Under this framework, consider an economy where there are two labour factor inputs of production (skilled labour and unskilled labour), which are used to produce both the tradable good $\tilde{Y}$ and, together with an endogenous variety of capital goods, the nontradable good $Y$. The nontradable good $Y$ is skilled labour intensive relative to the tradable good $\tilde{Y}$ and it is used only for final consumption.[8] Its price is the numeraire of the model. Conversely, the tradable good $\tilde{Y}$ is produced to satisfy final demand, intermediate demand and export demand. $\tilde{Y}$, which is unskilled labour intensive, is therefore the only exportable

[8] The assumption that the nontradable sector is more skill intensive that the tradable sector is supported by various studies. Sachs and Shatz (1998, pg. 231, table 5-3) show that the ratio between skilled labour (college educated) and unskilled labour (high school educated) in U.S. in 1979 was equal to 0.42 in manufacturing and 0.85 in nontradables, including construction, transport wholesale and retail trade, which are typically unskilled labour intensive. The evidence presented by Autor *et al.* (1997) for the U.S. suggests that sectors such as legal service, public administration, social services, insurance, business services, hospital, health services, communication, colleges, universities and schools, use more computers and, as a result, are more skill intensive. Schimmelpfennig (1998) indicates that in the middle eighties in Germany the share of skilled labour was equal to 32% in manufacturing and 55% in services, such as banking, insurance, communications, business and legal services.

good. The price of $\tilde{Y}$ is given by the world markets and is set equal to one. The assumption that a country cannot affect the price of the exportable good by altering its volume of trade is made to simplify the analysis, and to avoid all the complications which would arise when optimal export taxes can be levied. Hence, technological change occurs in an economy with flexible wages that faces fixed goods prices. The intra-industry trade model is based upon two main assumptions: (i) it considers the existence of an intersectoral linkage; (ii) it allows the set of capital goods available in the economy to vary.

The unskill-intensive sector (~) is characterised by a Cobb-Douglas production function with two factor inputs: unskilled labour, $\tilde{L}$, and skilled labour, $\tilde{H}$:

$$(1) \quad \tilde{Y} = \tilde{\Phi}\, \tilde{L}^{\beta}\, \tilde{H}^{1-\beta},$$

where $\tilde{\Phi}$ is an indicator of the state of technology, and $\beta$ the relative share of unskilled labour in the total product. The first order conditions yield the factor inputs demand:

$$(2) \quad \tilde{L} = \beta \frac{\tilde{Y}}{w^{L}},$$

$$\tilde{H} = (1-b)\frac{\tilde{Y}}{w^H}, \quad (3)$$

where $w^L$ and $w^H$ denote the wage rates for unskilled and skilled labour, respectively.

The specification of the skill-intensive production function is an extension of the technology used in Romer (1990). Output, $Y$, is a function of skilled labour, $H$, unskilled labour, $L$, the domestic capital good, $\tilde{Z}$, and a set of imported differentiated capital goods $x_i$ indexed by the variable $i$.[9] The production function is characterised by a multistage CES function in order to capture two economic facts: firstly, capital inputs and unskilled labour are imperfect substitutes, which implies that technical change can reduce the wage rate of unskilled labour (Murphy *et al.*, 1998); secondly, the variety of imported capital inputs, and the domestically produced capital goods, are also imperfect substitutes,[10] which implies that policy-makers can protect the unskill-intensive sector with trade policies. Hence, the fundamental assumptions are that many

[9] As pointed out by Romer (1994), instead of thinking of just two broad categories, domestic capital and imported capital, let $i$ index many different types of imported capital goods, such as computers, fax machines, printers, electronic machinery, etc., that are not perfect substitutes for each other.

[10] This assumption is not unrealistic. Indeed, Keller (1997) has presented evidence according to which domestic and foreign intermediate inputs embodying technology are not perfect substitutes in their effect on growth in developed countries. In this study, I assume that only imported goods embody technological change, which implies that the foreign trade partner is the country investing in research and development (R&D).

types of capital goods used in production are imported, that they are not perfect substitutes, that they compete against the domestically produced capital good, and that the composite capital good can partly substitute unskilled labour in the production process of the final good *Y*.

The first fact is captured by the following CES production function:

$$(4) \qquad Y = \Phi\left\{\gamma H^{\rho^1} + (1-\gamma)\left[\delta L^{\rho^2} + (1-\delta)X^{\rho^2}\right]^{\rho^1/\rho^2}\right\}^{1/\rho^1},$$

where $\delta$ and $\gamma$ are the distribution parameters of the two-stage CES function, $\Phi$ the efficiency parameter, $\rho^1$ and $\rho^2$ the substitution parameters, and $X$ the composite capital good. In order to capture the fact that $L$ and $X$ are relatively substitutes as compared with $H$, I impose the condition that $\rho^1 < \rho^2$. The solution of the two-stage dual problem yields the following factor demands:

$$(5) \qquad H = \Phi^{\rho^1/(1-\rho^1)}\left(\frac{\gamma}{w^H}\right)^{1/(1-\rho^1)} Y,$$

$$(6) \qquad L = \Phi^{\rho^1/(1-\rho^1)}(1-\gamma)^{1/(1-\rho^1)}\left(\frac{\delta}{w^L}\right)^{1/(1-\rho^2)} \left[\delta^{1/(1-\rho^2)} w^{L\rho^2/(\rho^2-1)} + (1-\delta)^{1/(1-\rho^2)} P^{\rho^2/(\rho^2-1)}\right]^{(\rho^1-\rho^2)/\rho^2(1-\rho^1)} Y,$$

$$X=\Phi^{\rho^1/(1-\rho^1)}(1-\gamma)^{1/(1-\rho^1)}\left(\frac{1-\delta}{P}\right)^{1/(1-\rho^2)}$$

(7)

$$\left[\delta^{2/(1-\rho^2)}{}_W L^{\rho^2/(\rho^2-1)}+(1-\delta)^{1/(1-\rho^2)}P^{\rho^2/(\rho^2-1)}\right]^{(\rho^1-\rho^2)/\rho^2(1-\rho^1)}Y,$$

where the price index $P=\left[\varphi^{1/(1-\rho^3)}+(1-\varphi)^{1/(1-\rho^3)}\sum_{i=1}^{n}p_i{}^{\rho^3/(\rho^3-1)}\right]^{(\rho^3-1)/\rho^3}$ is the price of the composite capital good, and $p_i$ the price of the differentiated imported capital goods.

The second fact which implies that the domestic capital good and the variety of imported capital goods are imperfect substitutes is captured by the following specification:

(8) $$X=\left\{\varphi\tilde{Z}^{\rho^3}+(1-\varphi)\sum_{i=1}^{n}x_i{}^{\rho^3}\right\}^{1/\rho^3},$$

where $\varphi$ and $\rho^3$ are respectively the distribution and the substitution parameters, and $x_i$ denotes the amount of capital goods produced by the foreign firm *i*. The number of firms is large enough to avoid problems associated with integer values. This implies that the production of *Y* requires many different types of foreign capital goods, which are not perfect substitutes for each other. The cost associated with the purchase of capital inputs is represented by

(9) $$PX=\tilde{Z}+\sum_{i=1}^{n}p_i x_i,$$

where $p_i$ is gross of the transportation and communication costs in the transport costs fall scenario, or gross of the *ad valorem* tariff rate in the trade liberalisation scenario. In the tariff case, the skill-intensive sector is receiving negative protection, because producers could have received a higher return if they faced border prices instead of domestic prices on traded capital goods. Thus, the skill-intensive nontradable sector is discriminated against the unskill-intensive tradable sector. If $x_i$ enter symmetrically as inputs in final production and are excludable (namely, foreign firms have strong property rights on the invention of the good $x_i$), then the solution of the dual problem at the third stage, which is obtained by minimising (9) subject to (8), yields the downward sloping import demand function for the variety of imported capital goods:

$$(10) \quad x_i = \left(\frac{1-\varphi}{\varphi}\right)^{1/(1-\rho^3)} p_i^{1/(\rho^3-1)} \tilde{Z}.$$

The price $p_i$ is jointly determined by (10) and by the profit maximising behaviour of the monopolistic foreign firms, which takes the following form:

$$(11) \quad p_i(1-t)\left(1-\frac{1}{\mu_i}\right) = c_i, \qquad \mu_i > 1,$$

where $c_i$ denotes the constant marginal cost, $t$ the unit transport cost to ship goods or the uniform *ad valorem* tariff rate on $x_i$, and $\mu_i$ the absolute value of

the price elasticity perceived by the foreign firm *i*. Given the three stage production function, it can be shown that under Cournot[11]

$$(12)\quad \frac{1}{\mu_i}=\left(1-\rho^3\right)+\frac{p_i x_i}{PX}\left\{\left(1-\rho^2\right)-\left(1-\rho^3\right)+\frac{PX}{w^L L+PX}\left[\left(1-\rho^1\right)\left(1-\frac{w^L L+PX}{Y}\right)-\left(1-\rho^2\right)\right]\right\}.$$

The assertion that new goods can be introduced into an economy implies that the production possibilities sets of foreign firms are nonconvex. The nonconvexity takes the form of a fixed cost (i.e. R&D expenditure). This technical device is essential for the solution of a general equilibrium model with new goods (Romer, 1990 and 1994). In fact, the assumption that $x_i$ are symmetric allows one to determine the equilibrium number of inputs by equating net revenues and fixed costs, $f$; namely:

$$(13)\quad \left[p_i(1-t)-c_i\right]x_i = f\,.$$

Romer (1994) assumes that the fixed costs of introducing the marginal good is a linear function of the number of goods. This assumption is cardinal in solving for both the input level and the equilibrium number of inputs, because terms of trade are given in the Romer model. In this paper, terms of trade are endogenously specified, because the net price of the imported capital goods is endogenously determined. As a result, I can assume that a new invention can be brought to light, once a firm has incurred a constant fixed cost for machinery

[11] See Harrison, *et al.* (1997) and De Santis (1999) for proof.

and human capital. Under this setting, the equilibrium number of new goods is inversely related to the given fixed cost, and this is in accordance with trade models which assume imperfect competition and increasing returns to scale.

The equilibrium conditions for the labour market are given by:

(14) $LF = \tilde{L} + L$,

(15) $HF = \tilde{H} + H$,

where $LF$ and $HF$ respectively denote the total unskilled and skilled labour force available in fixed supply. The market equilibrium for the goods produced by the unskill-intensive sector is:

(16) $\tilde{Y} = \tilde{Z} + \tilde{F} + \tilde{E}$,

where $\tilde{F}$ denotes the amount of goods purchased by the domestic consumer, and $\tilde{E}$ export sales. In this specification, one unit of any capital good can be produced, if one unit of consumption or exported good is foregone. This specification is very useful because globalisation (that is, a decline in $t$) would boost the unskill-intensive sector via $\tilde{E}$, but would limit its expansion due to a contraction in $\tilde{Z}$, being an imperfect substitute of the imported differentiated capital goods $x_i$.

The trade balance is always in equilibrium, which implies that

(17a) $(1-t)\tilde{E} = \sum_{i=1}^{n} p_i x_i$ in the transport costs fall scenario,[12]

or

(17b) $\tilde{E} = (1-t)\sum_{i=1}^{n} p_i x_i$ in the trade liberalisation scenario.

The income of the representative household, $I$, is given by:

(18a) $I = w^L LF + w^H HF$ in the transport costs fall scenario,

or

(18b) $I = w^L LF + w^H HF + t\sum_{i=1}^{n} p_i x_i$ in the trade liberalisation scenario.

The system of equations 1-18 is a full description of the general equilibrium model characterised by zero profits and by the clearance of both factor markets and commodity markets. There are 18 unknowns: $\tilde{Y}$, $\tilde{L}$, $\tilde{H}$, $Y$, $L$, $H$; $X$, $\tilde{Z}$, $\tilde{F}$, $\tilde{E}$, $I$, $x$, $w^L$, $w^H$, $P$, $p$, $n$, $\mu$, where $x$ stands for the symmetric output level of a single representative foreign firm, $p$ for the price of the monopolistic competitive capital goods, $\mu$ for the price elasticity perceived by the symmetric foreign firm and $n$ for the number of imported differentiated capital goods. The variables $c_i$, $t$, $f$, $HF$, and $LF$ are exogenously specified. The

[12] In the transport costs fall scenario, trade goods incur iceberg transport costs at a rate $t$. This implies that a proportion (1-$t$) of goods can be exported and that the price of goods imported is gross of $t$.

welfare function is defined by the GNP (18), which, by Walras' law, can be also written as: $I = Y + \tilde{F}$.

The alternative model which postulates that policy interventions do not affect the set of goods available in the economy (i.e. the standard intra-industry trade model) can be easily obtained by assuming that $x_i$ are homogenous and the production possibilities sets of foreign firms are convex (that is, $f = 0$). This implies that the market price for $x_i$ is given and outside the control of the now competitive foreign firms. In other words, expression (11) is substituted by

(11c) $p_i(1-t) = c_i$,

and both expressions (12) and (13) are eliminated by the system of equations. The remaining 16 equations simultaneously determine the following 16 unknowns: $\tilde{Y}$, $\tilde{L}$, $\tilde{H}$, $Y$, $L$, $H$, $X$, $\tilde{Z}$, $\tilde{F}$, $\tilde{E}$, $I$, $x$, $w^L$, $w^H$, $P$, $p$, where now $x$ stands for total import volume.

In summary, the circular flow of the economy is schematically outlined in Figure 1.

## 3. The benchmark data set

The benchmark is based upon a fictitious data set, which has been constructed under the assumptions that prices are all equal to one in the base year and that $Y$

is skill-intensive relative to $\tilde{Y}$: $H/L > \tilde{H}/\tilde{L}$. The variables are assumed to have the following values: $t_0 = 0.15$, $Y_0 = 200$, $\tilde{Z}_0 = 50$, $\tilde{F}_0 = 700$, $X_0 = 0.3Y_0$, $L_0 = 0.21Y_0$, $H_0 = 0.49Y_0$, $n_0 = 50$, $x_0 = \left(X_0 - \tilde{Z}_0\right)/n_0$, $\tilde{E}_0 = n_0 x_0/(1-t_0)$ in the transport costs fall scenario, and $\tilde{E}_0 = (1-t_0)n_0 x_0$ in the trade liberalisation scenario, $\tilde{Y}_0 = \tilde{Z}_0 + \tilde{F}_0 + \tilde{E}_0$, $\tilde{L}_0 = 0.68\tilde{Y}_0$, $\tilde{H}_0 = 0.32\tilde{Y}_0$. This implies that $H_0/L_0 = 2.33$, $\tilde{H}_0/\tilde{L}_0 = 0.47$, the skilled labour force represents the 37.9% of total labour force; the trade volume/GNP ratio is equal to 2.42% in the transport costs scenario, and 1.89% in the trade liberalisation scenario; the demand of intermediate foreign goods is 16.7% total intermediate demand; the contribution of the skill-intensive sector in total expenditure is equal to 22.22%; whereas the contribution of the skill-intensive sector in total production is respectively equal to 20.79% in the transport costs fall scenario and 20.87% in the trade liberalisation scenario. The substitution parameters have been chosen such that the price cost margin is positive and decreases as the number of new goods expands (see De Santis, 1999). Two alternative sets of elasticity values are considered to verify the robustness of the results and to simulate the case of economies where the substitutability among factors of production varies. The values are as follows: $\rho^1 = 0.29$, $\rho^2 = 0.75$, $\rho^3 = 0.9$ in the case of a *more*

*flexible economy*; $\rho^1 = -0.43$, $\rho^2 = 0.67$, $\rho^3 = 0.86$ in the case of a *less flexible economy*.[13] This implies that capital goods are relatively more substitute than composite capital and unskilled labour and, in turn, composite capital and unskilled labour are more substitute than skilled labour and composite capital/unskilled labour. The remaining variables, and all the parameters of the model, have been calibrated by using the standard approach widely used in AGE literature (Mansur and Whalley, 1984). By calibration procedure I mean the estimation of unknown parameters, such that the observed values of endogenous variables constitute an equilibrium of the numerical model. It is important to stress that the numerical calibration does not involve any econometric testing procedure.

## 4. The scenarios

The simulations are run under two hypotheses: (i) the imported capital goods are assumed to be differentiated, which implies that policy interventions do affect the rate of invention of new goods abroad (*Model with new goods*); (ii) the imported capital goods are homogenous, which implies that new goods

[13] Several studies present evidence that the aggregate elasticity of substitution between highly educated and less educated workers in the U.S. tends to be between 1.3 and 1.7 (Katz and Murphy, 1992; Heckman, *et al.*, 1998; Krusell, *et al.*, 1997). In one scenario (i.e. *more flexible scenario*), I assume that the elasticity of substitution between skilled labour and the composite capital/unskilled labour is 1.4.

cannot be introduced into the economy (*Standard model*). The experiment consists of moving from $t=0.15$ to $t=0$ under the assumption that the prices of the final goods do not vary. Tables 1 and 2 present the results under the assumption that $t$ is respectively the transport costs and the tariff rate.

**Table 1: The impact of a fall in transport costs** (percentage variation)

The case of a developed country?

| | *Model with new goods* (1) | | *Standard model* (2) | |
|---|---|---|---|---|
| | More flexible economy | Less flexible economy | More flexible economy | Less flexible economy |
| *GNP - Welfare* | 6.59 | 4.03 | 0.57 | 0.49 |
| *Wage gap* | 66.68 | 43.96 | 5.85 | 4.65 |
| *Skilled labour wage rate* | 41.54 | 28.12 | 3.94 | 3.14 |
| *Unskilled labour wage rate* | - 15.08 | - 11.01 | - 1.80 | - 1.45 |
| *Output in skill-intensive sector* | 270.05 | 121.65 | 24.44 | 16.09 |
| *Output in unskill-intensive sector* | - 31.03 | - 16.36 | - 3.53 | - 2.50 |
| *Skilled labour in skill-intensive sector* | 127.35 | 86.36 | 17.88 | 13.60 |
| *Unskilled labour in skill-intensive sector* | 231.63 | 74.22 | 21.69 | 13.19 |
| *Skilled labour in unskill-intensive sector* | - 51.27 | - 34.72 | - 7.19 | - 5.47 |
| *Unskilled labour in unskill-intensive sector* | - 18.78 | - 6.02 | - 1.76 | - 1.07 |
| *Intermediate demand for domestic capital* | - 80.31 | - 67.94 | - 15.63 | - 7.86 |
| *Number of new goods* | 3366.41 | 1399.73 | - | - |
| *Import volume* | 3389.14 | 1409.31 | 328.57 | 187.41 |
| *Trade volume - GNP ratio* | 2460.25 | 1034.46 | 233.50 | 123.84 |
| *Terms of trade* | - 0.59 | - 0.54 | 0.00 | 0.00 |

*More flexible economy*: The elasticity of substitution among imported and domestic capital goods is 10; the elasticity of substitution between composite capital and unskilled labour is 4: the elasticity of substitution between skilled labour and composite capital/unskilled labour is 1.4. *Less flexible economy*: the elasticity of substitution among imported and domestic capital goods is 7; the elasticity of substitution between composite capital and unskilled labour is 3: the elasticity of substitution between skilled labour and composite capital/unskilled labour is 0.7.

**Table 2: The impact of trade liberalisation** (percentage variation)

The case of a developing country?

| | *Model with new goods* (1) | | *Standard model* (2) | |
|---|---|---|---|---|
| | More flexible economy | Less flexible economy | More flexible economy | Less flexible economy |
| *GNP - Welfare* | 6.20 | 3.65 | 0.21 | 0.13 |
| *Wage gap* | 66.55 | 43.89 | 5.85 | 4.65 |
| *Skilled labour wage rate* | 41.46 | 28.08 | 3.94 | 3.14 |
| *Unskilled labour wage rate* | - 15.06 | - 10.99 | - 1.80 | - 1.45 |
| *Output in skill-intensive sector* | 268.71 | 121.05 | 24.37 | 16.03 |
| *Output in unskill-intensive sector* | - 31.00 | - 16.34 | - 3.53 | - 2.50 |
| *Skilled labour in skill-intensive sector* | 126.87 | 85.90 | 17.81 | 13.54 |
| *Unskilled labour in skill-intensive sector* | 230.43 | 73.82 | 21.61 | 13.13 |
| *Skilled labour in unskill-intensive sector* | - 51.22 | - 34.68 | - 7.19 | - 5.47 |
| *Unskilled labour in unskill-intensive sector* | - 18.76 | - 6.01 | - 1.76 | - 1.07 |
| *Intermediate demand for domestic capital* | - 80.31 | - 67.94 | - 15.68 | - 7.91 |
| *Number of new goods* | 3352.25 | 1395.04 | - | - |
| *Import volume* | 3374.87 | 1404.58 | 328.30 | 187.27 |
| *Trade volume - GNP ratio* | 3169.96 | 1350.28 | 327.41 | 186.90 |
| *Terms of trade* | - 0.59 | - 0.54 | 0.00 | 0.00 |

*More flexible economy*: The elasticity of substitution among imported and domestic capital goods is 10; the elasticity of substitution between composite capital and unskilled labour is 4: the elasticity of substitution between skilled labour and composite capital/unskilled labour is 1.4. *Less flexible economy*: the elasticity of substitution among imported and domestic capital goods is 7; the elasticity of substitution between composite capital and unskilled labour is 3: the elasticity of substitution between skilled labour and composite capital/unskilled labour is 0.7.

Given the lower tariff rates among developed countries in the eighties, the scenario with transportation and communication costs might better represent the case of a developed country, whereas the scenario with tariffs might describe

the case of a developing country. The results are very similar, so I will focus on those of Table 1.

As one would expect from trade theory, the results indicate that trade volume and welfare (that is, GNP) increase under both scenarios. The gains from trade are due to a better reallocation of resources (i.e. efficiency effect) or to technological improvements. The negative terms of trade effect is negligible. In particular, the welfare gains are computed to be very small (0.49%-0.57% of the consumer income)[14] under the standard model scenario, as it is typically found in most of static AGE models. Conversely, the welfare gains are very large (4.03%-6.59% of the consumer income) when the scale effect is taken into account, and this in accordance with the argument proposed by Romer (1994), who claims that if international trade can bring new goods into an economy, the impact of trade has a far greater positive effect on welfare.

The new equilibrium is characterised by a larger number of new goods, which expand by a factor of 14-34 and by a larger ratio between trade volume and GNP, which increases from 2.42% to 27.43%-61.91% in the model with new goods, and from 2.42% to 5.41%-8.07% in the model characterised by the standard assumptions that the number of goods available into the economy is invariant.

[14] The first percentage always indicates the impact on the variable under consideration in the scenario with a *less flexible economy*.

Regarding the impact on the wage gap between the wage rate of skilled labour and the wage rate of unskilled labour, the numerical results suggest that the fall in transport costs leads to an increase in wage inequality under both scenarios. But the impact on the wage gap is computed to be significantly larger (43.96%-66.68%) when sector bias technological change is embodied into the model. This result is due to both a larger output expansion of the skill-intensive sector (121.65%-270.05%) following technological improvements, and a larger output contraction of the unskill-intensive sector (16.36%-31.03%), despite export sales rise extraordinarily by a factor of 14-34 (see the results on import volume). Since the results of the '*Standard model*' are driven by the globalisation process, and those of the '*Model with new goods*' incorporate both the effects of globalisation and the effects of technological change, the scenarios suggest that globalisation is responsible for only 8.77%-10.58% of the increase in wage inequality, a figure which has been reported in the 1998 Economic Report of the U.S. President. Another interesting finding is that both models capture the fact that the wage rate of the unskilled labour input used intensively in the previously protected sector declines with trade, whereas the wage rate of the skilled labour rises. Indeed, this is one of the stylised facts of all advanced economies with flexible labour markets, such as the U.S.. Also in this case, the impact is far larger when new goods are allowed to enter into the

economy. The results are driven by the assumption that domestic capital goods and imported goods are imperfect substitutes.[15] In fact, intermediate demand for the domestic capital goods drops by 67.94%-80.31% when new goods can be invented, and by 7.86%-15.63% when these are not available. The full employment assumption, and the general equilibrium approach, imply that workers are perfectly mobile among sectors. As a result, despite the demand for unskilled labour in the skill-intensive sector rising, the fall of transport costs can harm the unskilled workers via a decline in their wage rate. When technological change is embodied into the trade model in a way that new imported goods can substitute unskilled labour, then the decline in the wage rate is far greater. Hence, the assumption that both trade and technology can harm unskilled labour is clearly captured by the numerical model via a decline in the wage rate of the unskilled workers. Whereas, the assumption that new goods can be invented and imported plays a key role in explaining this remarkable result on both wage inequality and welfare.

[15] Krugman (1981) uses an intra-industry trade model with imperfect competition and increasing returns to scale to show that trade openings would indeed benefit both the scarce factor and the abundant factor. This result is mainly due to the fact that his model assumes that imports enter in final consumption; whereas the model presented in this study assumes that imports are used in production and compete against the domestically produced goods. Similarly, Krugman (1995) uses a stylised numerical AGE two-country model with two productive inputs, skilled labour and unskilled labour, and two goods, one exportable and one importable, to study the impact of trade on relative wages. His model predicts a small impact on wage inequality, because it is based upon standard assumptions. Indeed, my results on wages in the 'standard model' scenarios are similar to those suggested by Krugman.

The results of Table 2 are very similar to those of Table 1. Thus, further explanation is not required. However, it is interesting to note that the welfare gains are slightly smaller due to a loss in tariff revenues, which were *ex-ante* distributed in a lump-sum fashion. Hence, if policy makers decide to eliminate the trade barriers used to protect the exportable sector $\bar{Y}$, one could argue from the numerical results shown in Table 2 that the labour input, used intensively in the production of $Y$, would strongly benefit in terms of wage increase, whereas the labour input, used intensively in the production of $\bar{Y}$, would incur a wage decline; but at the same time all society would be better off. The results of both models are robust to different values of the elasticities. However, when the substitutability among factor inputs is smaller, the impact on variables is reduced.

I argue that this model can be applied to both developed and developing economies with flexible wages. The results, regarding the impact on output in the unskill-intensive sector, capture the de-industrialisation process, which has been occurring in countries, such as U.S. and U.K., and the fall of agricultural share in the GDP in developing countries, such as Mexico and Turkey (see Fig. 2). These four countries have all documented an increase in wage inequality (U.S.: Lawrence, 1996; U.K.: Hine and Wright, 1998; Mexico: Feenstra and Hanson, 1997a, Hanson and Harrison, 1994, 1999; Turkey: OECD, 1997).

## 5. Conclusions

The stylised facts indicate that wage inequality has increased in several OECD countries in the last twenty years. In particular, the wage of skilled workers increased over time, whereas the wage rate of the unskilled workers showed a declining trend. The quantitative analysis of the trade/technology-wage debate is very important for the adoption of correct economic policies. Several econometric studies have tried to understand the causes of this new phenomenon. Some authors believe that trade with developing countries is primarily to blame, others firmly maintain that the major factor responsible is technological change. However, exchange of intermediate inputs with either NICs or developed countries might favour technological change. If this can be substantiated, then trade protective measures to protect the less educated workers can be effective. The typical model employed in the literature is the two-factor, two-sector HO model, which is probably the most powerful approach in explaining the impact of trade on income distribution in a general equilibrium setting. However, if international trade is causing an increase in wage inequality in developing countries, as several studies suggest, then the HO setting is not the appropriate model to study the trade-wage issue. In this paper,

I argue that intra-industry trade with developed countries or NICs can lead to a rise in wage inequality. I consider two alternative intra-industry trade models. The first model embodies a sector bias endogenous technological change which arises from trade. It is modelled *à la* Romer in the sense that new goods can be invented and are inputs in production of the skill-intensive sector. The second model is based upon the standard assumptions that the number of goods available into the economy is invariant. Both models assume intersectoral labour mobility and the existence of an intersectoral linkage through a demand of unskill-intensive tradable goods by the skill-intensive nontradable sector. These two alternative specifications allow one to better understand how important technological change and/or globalisation are in the trade/technology-wage debate.

The results of the two alternative AGE models are striking. The numerical simulations indicate that both globalisation (via either a fall in transportation and communication costs or lower tariff rates) and sector bias endogenous technological changes bring about an increase in the wage ratio between skilled and unskilled labour. Trade can harm unskilled workers because it causes the contraction of the exportable unskill-intensive sector, which enjoyed some form of protection before. But technical changes, which arise from trade, have a more important role in explaining wage inequality, because it also boosts the skill-

intensive sector by an extraordinarily large rate. In particular, the results indicate that globalisation is responsible for only 8%-11% of the increase in wage inequality, as suggested by the 1998 Economic Report of the U.S. President. It is also interesting to note that with trade liberalisation, under both modelling frameworks, the wage rate of skilled labour increases, whereas the wage rate of the unskilled labour declines. Indeed, this is one of the stylised facts of all advanced economies with flexible labour markets. This happens because capital goods can substitute for unskilled workers in production. The second striking result is that the impact on welfare is estimated to be very large when the economy embodies possible improvements in technology; whereas the gains from trade are insignificant under the standard modelling assumptions, which is typically found in the AGE models dealing with trade liberalisation issues. Finally, the contraction of the unskill-intensive exportable sector might describe the de-industrialisation process which has occurred among developed countries.

The model presented in this study can also be applied to developing countries, where wage inequality is rising rather than declining. In fact, the model captures the infant industry argument, which is often used by policy makers to protect the developing domestic industries with import substitution policies. Trade liberalisation in a developing country would cause a fall in the

unskill-intensive sector and a rise in wage inequality, contradicting the Stolper-Samuelson theorem, which states that the factor of production, which is intensively used in the production of the exportable good, gains with trade.

In conclusion, the numerical models show that international trade can contribute to a rise in wage inequality. Policy makers of both developed and developing countries might be tempted into applying protective measures to eliminate the adverse effect on unskilled workers. However, textbooks on trade theory point out that even in this case, protection is not the first-best response. In turn, economists might be tempted into permitting the action against trade, if the estimated welfare loss from trade protection is small, as indicated in most of (if not all) trade AGE models. I argue that this would be misleading, because trade indeed contributes to the diffusion of technology among countries, and the existing AGE models do not embody endogenous technological change. The numerical findings clearly indicate that trade protective measures, by affecting the diffusion of technology, would cause a very large loss in GNP.

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Figure 1: Schematic outline of demand and production structure

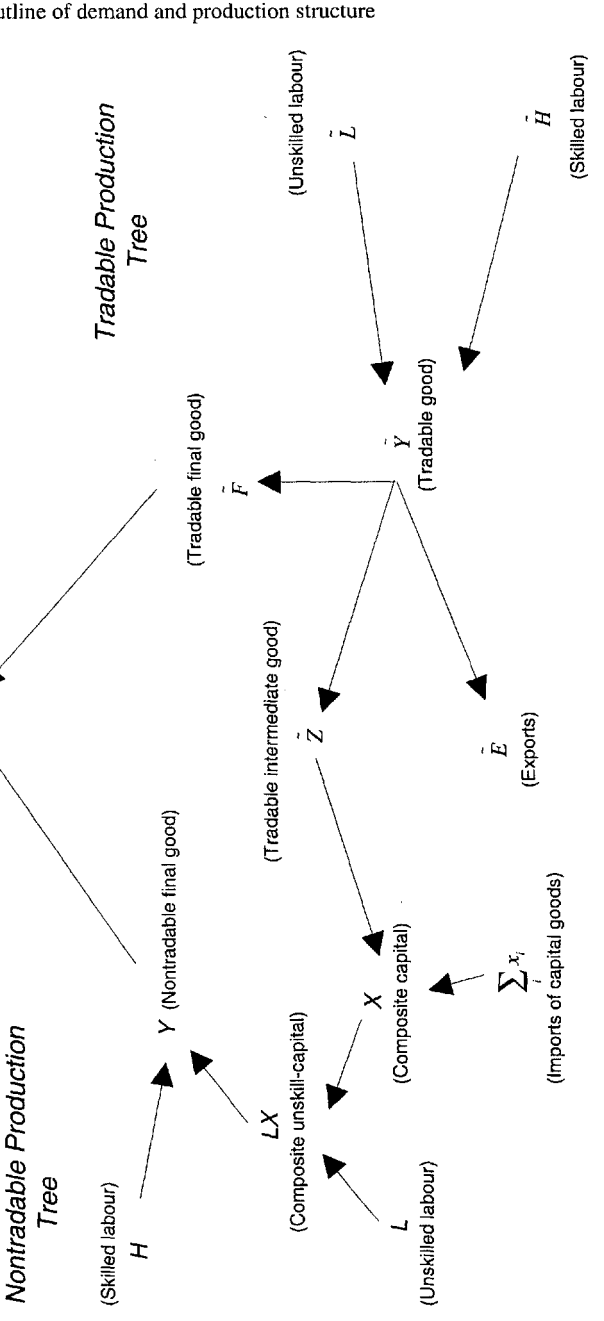
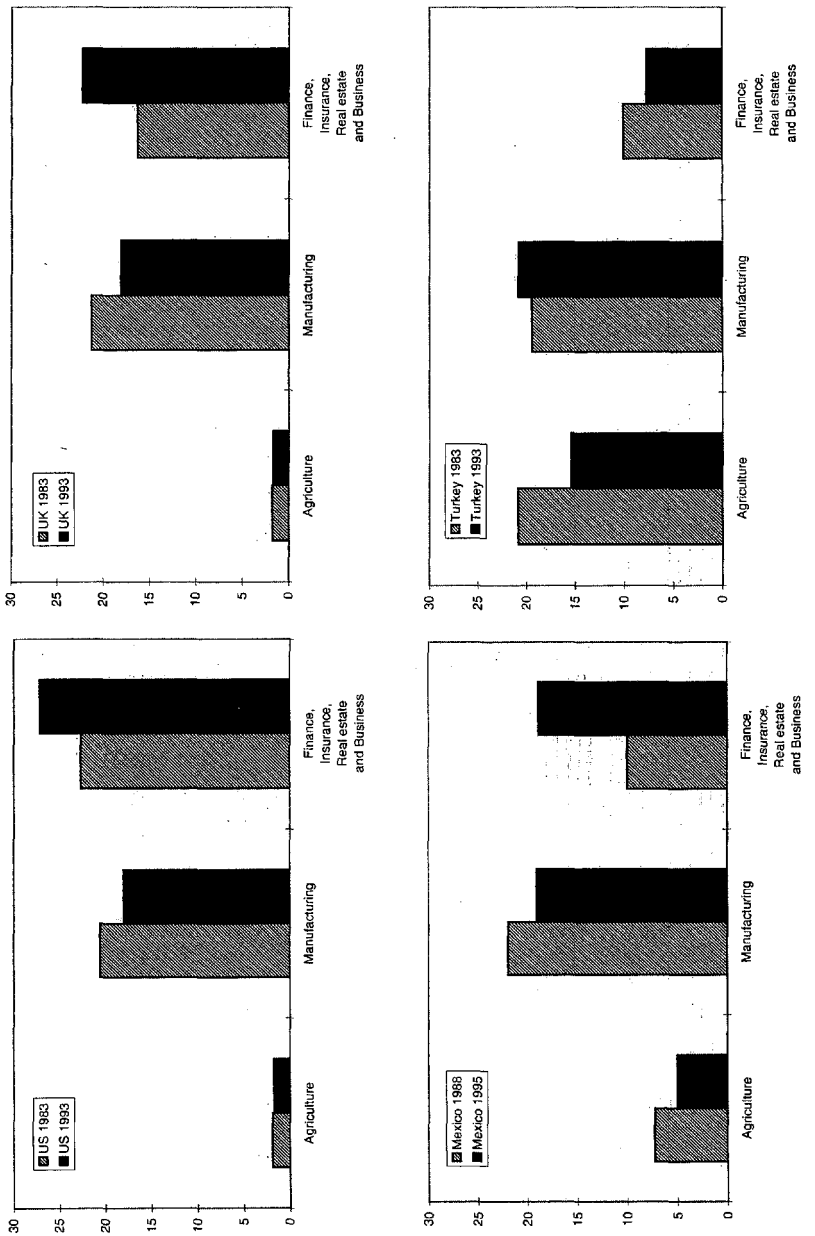


Figure 2: GDP by some kind of activity




Source: OECD (1997), National Accounts 1983-1995, Paris.