Choice of technology, Firm heterogeneity, and Exports

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Abstract

This paper develops an international trade model where firms in a duopoly for strategic reasons may diversify their technologies. Both firms are located in the home country, but export to a foreign country. The firms are ex ante identical, but choose between different technologies based on a trade-off between marginal costs and fixed costs. For some configurations of variable and fixed production costs and trade costs a mixed technology appears, i.e. one of the firms chooses a technology with low variable costs while the other goes for a technology with low fixed costs, and in such cases both firm size and export orientation differ. Market integration, i.e. a decrease of variable trade costs, may induce a technological restructuring and/or a change of the market structure in the foreign market with implications for welfare in both countries. Cases exist, where a small reduction of variable trade costs triggers a technological restructuring which reduces welfare not only in the home country, but globally.

Keywords: Firm heterogeneity; duopoly, technology choice; exports; market integration.
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1. Introduction

The relation between trade and intra-industry specialization has attracted much interest in recent research in international trade theory. The basic analytical framework is imperfect competitive markets as in the 'new' trade theory from the last three decades, but the distinctive feature for recent research is firm heterogeneity caused by different productivities among firms of the specific industry. This new offshoot of trade theory has therefore been termed the 'new new' trade theory, see Schmitt and Yu (2001), Montagna (2001), Melitz (2003), and Helpman et al. (2004) for initial papers in this branch of literature.

The 'new new' trade theory specifically assumes that the industry is characterized by moderate scale economies and monopolistic competition. The productivity of the individual firm is perceived as a stochastic outcome of an initial investment of sunk costs. The prospective entrant at the market invests a given amount and then the firm draws its productivity parameter from a common distribution (Melitz, 2003).[1] In equilibrium, the most productive firms are the biggest (larger output and revenues) and the firms most involved in exports compared with less productive firms. These results are supported by empirical evidence; see e.g. Bernhard et al. (2003), Bernhard and Jensen (2004), and Greenaway and Kneller (2005) for a survey.

The aim of this paper is to develop a model which deviates from the abovementioned versions of the 'new new' trade theory by offering an alternative view on firm productivities related to their strategic choice of technology within the framework of oligopoly instead of monopolistic competition.

Casual observations indicate that firms within industries often use different technologies. An example is the US steel industry with an almost dualistic structure with large-scale

[1]Heterogeneity of productivities materializes in the parameters of the costs functions. The works by Schmitt and Yu (2001) and Jørgensen and Schröder (2006) use fixed cost heterogeneity in the form of firm-specific fixed export costs, while Montagna (2001), Melitz (2003) and Helpman et al. (2004) use marginal costs heterogeneity.

integrated mills producing basic steel and bulk steel products alongside smaller mini-mills producing batch niche steel products (Read, 2005). The same pattern is seen with the brewery industry with large breweries producing standard beers in large scale on highly automated plants together with small micro breweries producing (high quality) beers in small scale.

In the literature, a number of theoretical reasons are given to explain why different technologies may exist across firms in the same industry at the same time, (see e.g. Mills, 1990; Nelson, 1991; Mills and Smith, 1996; and Röller and Sinclair-Desgagné, 1996, for an overview). Factors may be related to uncertainty (uninsurable chance event); differences in the capabilities of the firms or the conscious strategic choice of managers. Only in the latter case, technology differences are clearly endogenous. We follow the tradition from industrial organization, where differences in firms are assumed to reflect differences in the market environment that they face.

The monopolistic competition framework dominates in the 'firm heterogeneity literature'. The models conclude that only the largest and most efficient firms are exporters, but for such a type of firms it is reasonable to assume strategic interactions for which reason the assumption of monopolistic competition is not the most obvious. But firm heterogeneity in oligopoly has also been researched intensively in recent years; see e.g. Lahiri and Ono (1997), Falvey (1998), and Collie (2006). Recently, Eckel and Neary (2006) demonstrated that firm heterogeneity may also exist in oligopoly with multi-product firms.

This paper investigates to which extent the use of the most simple oligopoly trade model may replicate the main results of the 'new new' trade theory based on monopolistic competition. To that purpose, this paper generalizes a duopoly model initially developed by Mills and Smith (1996) by including international trade. The two firms produce a homogenous product and both producers face an identical technology trade-off between a specialized and non-specialized technology. Between the two technologies a trade-off between marginal costs and fixed costs exists, i.e. the non-specialized technology has high marginal costs, but low fixed costs, and the opposite holds for the specialized technology.[2] [3] The two firms are involved in a two-stage game. Technology is chosen in the first game and output in the second, where firms play Cournot-Nash. The choice of technology is thus a result of the strategic game between the firms. So, compared to the main stream of research within the 'new new' trade theory using a monopolisitic competitive model with exogenous productivity differences (e.g. Melitz, 2003), this paper is based on an oligopoly model with endogenous technology choice.[4] Contrary to Mills and Smith (1996), the model below includes foreign trade in the analysis as the two producers may supply both a domestic and a foreign market. Per unit trade costs as well as fixed market access costs exist when operating on the foreign market.

These assumptions allow co-existence of different technologies for some cost structures and differences in the size of countries. Both variable and fixed trade costs influence the performance of the firms as well as their strategic choice of technologies. In case technology heterogeneity appears, the firm with low marginal costs turns out to be the most export-oriented and the largest. Market integration through a reduction in variable trade costs may induce a technological restructuring and/or a change of the market structure in the foreign market with implications for welfare in both countries. Sufficient large changes in variable trade costs increase welfare in both countries, while small reductions in variable trade costs, that trigger technological change, may reduce welfare not only in the home country, but also at the world level. Some of these results are very similar to the main conclusions in the 'new new' trade theory based on exogenous productivity differences and monopolistic competition.

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[2] Alternatively, we could call the two technologies 'capital-intensive' and 'labour-intensive'; 'modern' and 'traditional'; 'high-tech' and 'low-tech'; or 'large-scale' and 'small-scale'. In case of economies of scope, the two technologies could represent 'multi-product plants' and 'single-product plants' or 'flexible manufacturing' or' non-flexile manufacturing'.

[3] The general set-up in Mills and Smith (1996) is that the technology choice of firms is a continuous trade-off between fixed and variable costs. But in their specific analysis they rely on the case, where the continuous technology set is insufficiently convex, so equilibria only support two extreme technologies – those with minimal (maximal) fixed costs and maximal (minimal) variable costs.

[4] Yeaple (2005) is an example of a paper with monopolistic competition, where firm heterogeneity arises endogenously as an outcome of the firms' choice of technology and the mix of employment between different types of workers.

The paper is organized as follows. Section 2 develops the basic model. Market equilibrium is illustrated and cost structures consistent with co-existence of different technologies are described. Section 3 analyzes the impacts of market integration, i.e. a decrease of the variable trade costs on technology choice and welfare. Section 4 concludes.

2. The basic model

We look at a two-country, partial equilibrium model with two firms (*1* and *2*) producing a homogeneous product. Both firms are located in the home country *H*, for which reason the foreign country *F* is a pure importing country of the specific goods. The two countries may differ with respect to market size and are separated by specific trade costs *g* per unit of the good, including transport and trade barriers costs.

Demand

Consumers are of the same type in each country. Each consumer has a utility function separable and linear in a numeraire good, so a partial equilibrium analysis may be performed, since there are no income effects on the industry. The utility, *U*, is assumed to be quadratic and strictly concave in consumption (*q*) of the good like $U = aq - ½q^2 + z$, where *z* is the utility of all other consumption goods (see Singh and Vives, 1984: 547). The marginal utility is thus given by $\partial U / \partial q = a - q$. Assuming for simplicity the number of consumers in the home country is normalized to 1, and *S* in the foreign country, total direct demands of the product in the two countries become:

$$Q^H = (a - p^H) \quad (1a)$$

$$Q^F = S(a - p^F) \quad (1b)$$

where Q^j is quantity demanded; p^j consumer price (*j=H,F*) and *S* the number of consumers in the foreign country measuring the size of the foreign market relative to the home market. We assume the firms are located on the market, where operating profits are the highest. This is secured by assuming that the foreign market is not larger than the domestic market, i.e. $S \leq 1$.

Supply

The producers face ex ante the same set of blueprints of technologies based on a trade-off between marginal and fixed costs. To restrict the technology analysis, only two technologies are assumed relevant. The producer i ($i=1,2$) may decide to produce the quantity q_i at a plant with low (constant) marginal costs (c), but then incurs high fixed costs (f), or at a plant with high (constant) marginal costs (c^*) and low fixed costs (f^*). The total costs C_i (C_i^*) for alternative technologies are thus given by:

$$C_i = cq_i + f \qquad (i=1,2) \qquad (2)$$

$$C_i^* = c^* q_i + f^* \qquad (i=1,2) \qquad (3)$$

where $c^*>c$ and $f>f^*$.

More generally, the technology space reflects the specialization of the firm. By deepening the capital equipment, a single good producer raises the efficiency of the variable input and hence obtains low marginal costs at the expense of high fixed costs. For a multi-product producer specialization may also take place by reducing the number of product lines. This allows for a specialization of the capital equipment to the reduced number of goods the firm produces ensuring lower marginal production costs, but higher fixed costs per product line, see e.g. Hansen and Jørgensen (2001) and Zhou (2002) for such representations. For the sake of simplification, we have assumed single-product producers and we use the two terms 'specialized' and 'non-specialized' for the two technologies.

Trade costs

To operate in the foreign market, the home producers have to pay a variable trade cost at g per unit of output sold in the foreign market and a market access fixed cost of marketing his products, m.[5] The variable trade costs capture transport costs as well as tariffs, duties and other institutional costs for selling in foreign markets. Fixed market

[5] Melitz (2003) operates with fixed market access cost for both the domestic and foreign markets, with the latter of the largest size.

access costs are the costs of participation in foreign markets independent of the volume of exports. It consists of the costs of acquiring information on foreign markets and of creating a distribution network in the foreign country. It may also be costly to adapt products to foreign markets to ensure they are conforming to the foreign standards and regulations (testing, packaging and labeling requirements). If the importing country hosts domestic producers in the industry, such costs may even be manipulated by governments to function as protection of the domestic industry.

Market equilibrium

Each firm maximizes profit with respect to technology, market presence on the domestic and foreign markets respectively, and output. The condition for presence on the individual market is non-negative operating profit, and for presence at all in at least one market, the total operating profit must at least be equal to the total fixed costs. The options on market presence leave several configurations depending on the parameters of demand and costs. As trade is in focus in this paper, we only look at the cases, where both firms are operating in the domestic market, and at least one of the firms is also present in the foreign market.

If both firms are present in both markets, duopoly prevails. Depending on the strategic choice of production technology, the following four outcomes may be considered: Both firms establish a specialized technology (*I*); firm *1* establishes a specialized technology, firm *2* establishes a non-specialized technology (*II*); firm *1* establishes a non-specialized technology, firm *2* establishes a specialized technology (*III*); both firms establish a non-specialized technology (*IV*). Case (*II*) and (*III*) are symmetric and hence only the cases (*I*), (*II*) and (*IV*) will be dealt with in the following.

The firms play a two-stage duopoly game. In the first stage, they decide on technology ((2) or (3)), and in the second stage they optimize output by playing Cournot. The model is solved by backward induction, i.e. quantities, prices and operating profits for the foreign and home markets are determined for a given technology in the first step. The next step is then to consider whether any of the firms have an incentive to change their technology or to leave one or both markets.

Using the standard Cournot analysis, *Table 1* shows the solutions for profits for the case, where both producers are active in the home market as well as in the foreign market (see Appendix for the full solutions for output, prices and operating profits).

Table 1. Profit matrix for alternative divisions of technologies across producers.

		Firm 2	
		Specialized technology	*Non-specialized technology*
Firm 1	*Specialized technology*	(*I*) $\left(\frac{a-c}{3}\right)^2+S\left(\frac{a-c-g}{3}\right)^2-f-m$; $\left(\frac{a-c}{3}\right)^2+S\left(\frac{a-c-g}{3}\right)^2-f-m$	(*II*) $\left(\frac{a-2c+c^*}{3}\right)^2+S\left(\frac{a-2c+c^*-g}{3}\right)^2-f-m$; $\left(\frac{a-2c^*+c}{3}\right)^2+S\left(\frac{a-2c^*+c-g}{3}\right)^2-f^*-m$
	Non-specialized technology	(*III*) $\left(\frac{a-2c^*+c}{3}\right)^2+S\left(\frac{a-2c^*+c-g}{3}\right)^2-f^*-m$; $\left(\frac{a-2c+c^*}{3}\right)^2+S\left(\frac{a-2c+c^*-g}{3}\right)^2-f-m$;	(*IV*) $\left(\frac{a-c^*}{3}\right)^2+S\left(\frac{a-c^*-g}{3}\right)^2-f^*-m$; $\left(\frac{a-c^*}{3}\right)^2+S\left(\frac{a-c^*-g}{3}\right)^2-f^*-m$

Note: It is assumed that both producers *1* and *2* produce and sell in both markets, *H* and *F*.

The first term in each cell for producers 1 and 2, respectively, is the operating profit in the domestic market. The second term is the operating profit in the foreign market and the last two terms are fixed production costs and fixed market access costs.

Technology choice[6]

Having solved the second stage, the Cournot optimization, we now turn to the first stage of choice of technology. The interesting result is that firm heterogeneity may turn out to

[6] In this and the following sub-section, we assume that parameters secure that there is duopolistic competition in both markets.

be possible market equilibrium, i.e. one of the firms establishes a low variable and the other a low fixed cost technology. Case *II* (or case *III*) may thus be a sub-game perfect Nash-equilibrium for some values of the parameters.

As the cases *II* and *III* are symmetric, we only look at case *II*. If case *II*, with mixed technologies, should be a sub-game perfect Nash equilibrium, neither of the two producers should have an incentive to reconsider their technology choice. This requires the following conditions for each of the two producers. Producer *1* will stay in *II*, if the profit in the specialized technology is higher than in the non-specialized technology case shown in cell *IV*. We are particularly interested in the role of trade costs for the optimum technology, and with this focus we get the following condition for producer *1* to abstain from shifting technology to a small scale technology:

$$
\begin{aligned}
&\left(\frac{a-2c+c^*}{3}\right)^2 + S\left(\frac{a-2c+c^*-g}{3}\right)^2 - f - m > \\
&\left(\frac{a-c^*}{3}\right)^2 + S\left(\frac{a-c^*-g}{3}\right)^2 - f^* - m \qquad \Rightarrow \\
&\frac{(c^*-c)}{(f+m)-(f^*+m)} > \frac{9/4}{(a-c)+(a-(c+g))S} \Rightarrow \\
&g < g_{max} = \left(\frac{1+S}{S}\right)(a-c) - \frac{9}{4S}\left(\frac{(f+m)-(f^*+m)}{(c^*-c)}\right) \\
&= \left(\frac{1+S}{S}\right)(a-c) - \frac{9}{4S}r; \\
&\text{where: } r = \frac{(f+m)-(f^*+m)}{(c^*-c)} > 0
\end{aligned}
\tag{4}
$$

The interpretation is the following: The advantage of a low variable cost technology is contingent on large production runs. To deter firm *1*, which uses the low variable cost technology, from shifting to low fixed costs technology, trade costs should therefore not exceed a specific threshold value called g_{max}. The threshold value, g_{max}, depends positively on the size of the total market (*a* and/or *S*), because a larger market makes it more easy to realize large total production runs.[7] The threshold value depends negatively on a ratio of cost parameters, *r*, which illustrates the cost advantage of using a low fixed

[7] An increase in *S* (for given *a*) is both an absolute and a relative increase in the foreign market, while an increase in *a* is an absolute increase in the size of both markets, with unchanged relative sizes.

cost technology compared to a low variable cost technology. A small value of r caused by a large marginal cost difference (c*-c) and/or a small fixed cost difference (f+m)-(f*+m) indicates a favourable cost structure for a technology based on a low variable cost technology that is the specialized technology.[8]

Similarly, the condition for firm *2* to keep its non-specialized technology in cell *II* is:

$$\begin{aligned}
&\left(\frac{a-2c^*+c}{3}\right)^2+S\left(\frac{a-2c^*+c-g}{3}\right)^2-f^*-m> \\
&\left(\frac{a-c}{3}\right)^2+S\left(\frac{a-c-g}{3}\right)^2-f-m \qquad \Rightarrow \\
&\frac{(c^*-c)}{(f+m)-(f^*+m)})<\frac{9/4}{(a-c^*)+(a-(c^*+g))S}\Rightarrow \qquad (5)\\
&g>\mathrm{g}_{\min}=(\frac{1+S}{S})(a-c^*)-\frac{9}{4S}(\frac{(f+m)-(f^*+m)}{(c^*-c)}) \\
&=(\frac{1+S}{S})(a-c^*)-\frac{9}{4S}r
\end{aligned}$$

The interpretation is similar to that of firm *1* above. Now the problem is that to deter producer *2*, using a non-specialized technology, from changing to a specialized technology, total production should be relatively limited. This demands trade costs g to be above threshold value of g_{min}, where g_{min} depends positively on total market size (a and/or S) and negatively on the relative cost advantage, r, operating on a specialized plant. Note, that since $c^*>c$, $g_{max}>g_{min}$. Hence, if g_{max} is positive, cases exist where a mixed technology will be chosen. If g_{min} is negative, the mixed technology will appear for $g<g_{max}$, even in the case where g=0.

Figure 1 summarizes the conclusions so far. In case of high trade costs ($g>g_{max}$), both firms establish the non-specialized technology, i.e., the firms are symmetrical in technology. For medium trade costs ($g_{min}<g<g_{max}$), one of the firms chooses the non-specialized technology and the other the specialized. Beforehand, it is not possible, in this

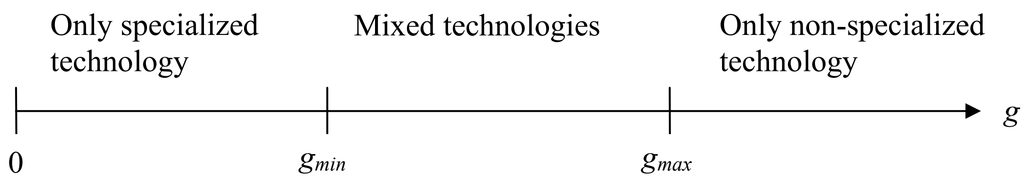
[8] Since we assume the same fixed market access costs for the two technologies, the fixed costs difference is (f+m)-(f*+m) = (f-f*).

case of asymmetrical technologies, to tell how each of the two technologies will be assigned to each firm. As profit is largest for the firm with the specialized technology, this firm may have benefited from a first mover advantage. Finally, for low trade costs ($g<g_{min}$) both firms choose the specialized technology, i.e. establish a symmetrical technology.

Both g_{min} and g_{max} increase with market size (a and/or S), i.e. on a larger market the producers are more inclined to produce with the specialized technology. The fixed market access costs are basically irrelevant for the results, as the choice of technology only relates to the plant level, i.e. the market access costs are identical for the two alternative technologies.

The basic reason why technology heterogeneity arises in the model is lumpiness of fixed capital reflected in indivisibility of fixed costs. The domestic and foreign markets are constrained in size. Moreover, the potential for sales in the foreign market is limited by trade costs. For medium trade costs ($g_{min}<g<g_{max}$), the total quantity demanded in both markets will also loosely speaking be at a medium level. The invisible hand at the market will match this by inducing one of the producers to be specialized and the other to be non-specialized. The specialized producer covers most of the total demand on the two markets utilizing his advantages of low marginal costs. The non-specialized producer covers the residual smaller part of the total demand utilizing his advantages of low fixed costs.

Figure 1. The structure of technologies and trade costs.



Note: Trade subsidies are disregarded and hence only values of $g\geq 0$ have relevance. Furthermore, the following analysis only looks at the case, where the values g_{min} and g_{max}, calculated on the basis of duopolistic competition in both markets, are assumed to be positive.

Firm size and exports

The heterogeneity of technology in case *II* (and *III*) translates not only into differences in firm size but also in export status. The differences in firm size follow from calculating the difference of total output of the firm using specialized technology, Q_I^{II}, and the firm using a non-specialized technology, Q_2^{II} (see the Appendix). The difference in output of the two firms is proportionate to the differences in marginal costs of production, i.e.:

$$Q_I^{II} - Q_2^{II} = (1+S)(c^* - c) > 0 \qquad (6)$$

The firm using the low variable cost technology is more export-oriented than the firm using the low fixed cost technology. This follows from inspection of the ratio of export to output on the home market for each of the two firms (see the Appendix). We get:

$$\frac{q_I^{F,II}}{q_I^{H,II}} - \frac{q_2^{F,II}}{q_2^{H,II}} = \frac{Sg(2a + 3(c^* - c))}{(a - 2c^* + c)(a - 2c + c^*)} > 0 \qquad (7)$$

and hence, in relative (and also in absolute) terms, firm *1* is more oriented towards export than firm *2*. This pattern of size and export orientation of firms is similar to the conclusions of models based on monopolistic competition in the 'new new' trade theory.

Asymmetrical market presence

The analysis above has paid no attention to long-run conditions of entry and exit on the markets. If only two firms should be active in the longer term, each firm should have non-negative profit in contrast to potential firms. We assume that this basic assumption is fulfilled. However, it does not follow from this that each firm will be active in the foreign market. Each firm will only have presence in the foreign market if the operating profit from the foreign market is sufficient to cover the fixed market access costs. If one of the firms is deterred from operating in the foreign market and the other stays, the market structure of the foreign market will be monopoly.

Market presence in the foreign market depends among other things on the size of variable trade costs. For each technology configuration of the two firms, a critical value of variable trade costs, $\hat{g}$, exists, given by the condition that the firm with the lowest operating profit in the foreign market exactly can cover the fixed market access costs. If the variable trade costs exceed this critical value, one of the firms will drop out leaving the market to the other as monopolist. [9]

The results reported in *Table 1* allow for calculation of the critical value of variable trade costs ($\hat{g}$) for the alternative technology configurations; specialized, specialized (*s,s*); specialized, non-specialized (*s,ns*), and non-specialized, non-specialized (*ns,ns*), respectively:

$$\hat{g}_{s,s} = (a-c) - 3\sqrt{\frac{m}{S}}$$

$$\hat{g}_{s,ns} = (a-c^*) - (c^* - c) - 3\sqrt{\frac{m}{S}} \qquad (8)$$

$$\hat{g}_{ns,ns} = (a-c^*) - 3\sqrt{\frac{m}{S}}$$

As $c^*<c$, we have $\hat{g}_{ns,ns} < \hat{g}_{s,ns} < \hat{g}_{s,s}$, i.e. the probability of exit of one of the firms from the foreign market is highest in case of the symmetric non-specialized technology configuration. For obvious reasons, all three critical values decrease for increasing market access costs, or put it differently, the results in *Table 1* for a duopoly on both markets only hold for moderate market access costs and limited variable trade costs.

For substantial market access costs, the actual value of trade costs g may exceed one or more of the critical values of $\hat{g}$ ($\hat{g}_{s,s}, \hat{g}_{s,ns}, \hat{g}_{ns,ns}$). In this case, the variable trade costs influence the technology choice in a more complex way, because the market structure in the foreign market influences the technology choice. This will be discussed more in detail in the following section.

[9] If, contrary to the assumptions above, one of the producers was located in the home country and the other in the foreign country, the domestic producer will provide his home market and the smallest market may develop into a monopoly.

3. Market integration

Market integration may materialize through a decrease of per unit trade costs g and/or by a decrease of fixed market access costs m. A decrease in per unit trade costs, g, may be a result of a real costs reduction (e.g. transportation costs) or a tariff or non-tariff reduction through bilateral (multilateral) trade negotiation. A decrease of the market access costs may follow from smoothing the legal procedures for being allowed to operate on the foreign market. Lower regulatory barriers through WTO measures against non-tariff barriers or EU initiatives like the Single Market Program are examples. Market integration may trigger strategic changes of one or of both firms' choice of technologies, as well as their decisions on whether or not to operate in the foreign market.

Technology change

Let us first look at the effects of a decrease of variable unit trade costs, g, and assume that both producers find it profitable to operate both in the home and the foreign markets. The effects of a decrease of g follow straightforwardly from the previous section on Nash-equilibrium, see *Figure 1*. If both companies initially use non-specialized technology (g is initially above g_{max}), a decrease in trade costs may in some cases induce one or both of the producers to shifts to specialized technology (move from IV to II/III or I in *Table 1*). Similarly, in cases of initially mixed technologies (g is initially above g_{min}, but below g_{max}) a decrease in trade costs may induce the producer with a non-specialized technology to shift to a specialized technology (move from II/ III to I in *Table 1*).

Firm size and internationalization

In the case of mixed technologies before and after market integration, market integration also changes the relative firm size (and market shares) and their export intensities. While the absolute difference in size of firms is independent of variable trade costs (see (6)), market integration increases the relative size (and market share) of the firm with the low fixed cost technology. The disadvantage of having high marginal costs of production decreases with better access to the foreign market, and hence the relative export orientation of the low fixed cost technology firm increases with increasing market integration (see (7)).

Welfare

The analysis of market integration and technology choice also provides some conclusions on welfare of the home country and the foreign country. For the home country, social welfare is made up by consumer surplus in the home market and total producer surplus, which consists of operating profit in the two markets minus total fixed costs (fixed production costs plus market access costs). For the foreign country, the contribution to social welfare of the market consists of the consumer surplus exclusively, as we disregard production in this industry in the foreign country. The expressions for all elements of social welfare in the two countries are reported in the Appendix.

If the variable unit trade cost g gradually is reduced from a relatively high level to a low level, the two firms will go through three stages of technologies, starting from a stage with a uniform low fixed cost technology, to a stage of mixed technologies of low variable and fixed costs and a final stage of uniform low variable cost technology. For decreases of g in the intervals, where technology is unchanged, consumer and producer surplus in the home country is unaffected. In the foreign market, the producers' profit increases monotonically with the decrease of g. Total welfare in the home country, W^H, therefore increases monotonically with the decrease of g.[10] The welfare impact in the foreign country, W^F, only relates to consumer surplus. A part of the lower variable trade costs translates to the foreign consumers through a lower price, so welfare of the foreign country therefore also increases monotonically with the decrease of g.

If a decrease of g triggers a shift of technology, consumer surplus jumps discontinuously upwards in both countries in the wake of the drop in prices. The shift of technology affects the two producers' profit differently, and the two producers may therefore have opposing views on trade liberalization. A marginal decrease of g, which induces one of the producers to shift to a specialized technology, leaves this producer's profit

[10] The following analysis only deals with real trade costs i.e. there are no public budget effects.

approximately unchanged as the increase of his operating profit is offset by higher fixed production costs. The other producer, which does not change technology, suffers a loss because he meets a more fierce competition in both markets due to the competitor's increased efficiency of variable input. A marginal decrease of g therefore unambiguously reduces total profit of the two producers, and the overall welfare effect in home country of market integration is therefore ambiguous.

The simple linear structure of the model allows for a calculation of the welfare effect in the home country in the two cases, where the technology changes from symmetric, non-specialized technology to asymmetric specialized technology ($\Delta W^H(g_{max})$) and from asymmetric specialized technology to symmetric specialized technology ($\Delta W^H(g_{min})$), respectively. In general, the welfare effects also depend on the market sizes of the two countries (as do g_{max} and g_{min}). If the market size of the foreign country is relatively small, i.e. S is close to zero, the main source to a loss of producer surplus is in the home market, and it is therefore less likely that the overall welfare effect is negative. In the special case where the two countries are symmetric in size (S=1), the welfare effects in the home country in the two cases of technology changes are:[11]

$$\Delta W^H(g_{\max}) = \frac{1}{18}(c^* - c)\left(4(a-c) + 9(c^* - c) - 9\frac{(f - f^*)}{(c^* - c)}\right) \tag{9}$$

and

$$\Delta W^H(g_{\min}) = \frac{1}{18}(c^* - c)\left(4(a-c) - 13(c^* - c) - 9\frac{(f - f^*)}{(c^* - c)}\right) < 0 \tag{10}$$

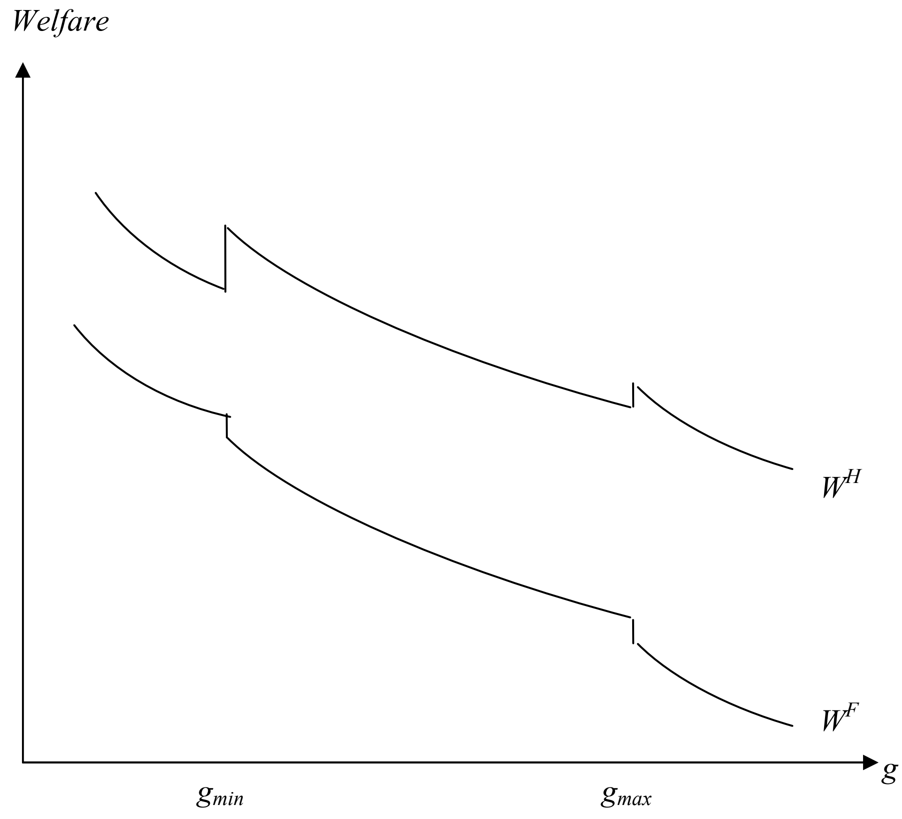
The technological restructuring may reduce welfare in the home country in both cases if the establishment of specialized technology demands substantial extra fixed production costs. Comparing the two expressions (9) and (10), we have that $\Delta W^H(g_{mim}) < \Delta W^H(g_{max})$, i.e. the risk of a negative welfare effect in the home country of market integration is largest, when the technology configuration changes from asymmetry to symmetry compared with the change from symmetry to asymmetry. The intuition behind this result is that in case of initial asymmetry, the specialized producer has the largest market shares

[11] See the Appendix.

in both markets. The specialized producer therefore incurs a relatively big loss in profit, when the non-specialized producer restructure by switching to a specialized technology. In the appendix, it is shown that in case technology changes from asymmetry to symmetry, the welfare effect in the home country is unconditionally negative (S=1).

Figure 2 illustrates the results in the interesting case where $\Delta W^H(g_{min})$ and $\Delta W^H(g_{max})$ both are negative and hence the technological restructuring triggered by market integration reduces welfare in the home country. However, a negative welfare effect may only appear, when the variable trade costs decline moderately. If a substantial reduction of trade costs takes place, the welfare effect will be positive.

Figure 2: Welfare and variable trade costs: Both firms export



Note: W^H and W^F are welfare in country H and F, respectively.

In the Appendix, it is shown that global welfare will always increase, when market integration triggers a technology change from homogeneity to heterogeneity. Hence, a restructuring to firm heterogeneity has positive social qualities. For the case where market integration triggers a technological change from heterogeneity to homogeneity world welfare will always fall. So, in a process of market integration firms are switching technologies to heterogeneity too late and to homogeneity too early, from a social point of view.

The reason why there are asymmetrical changes in world welfare at g_{max} and g_{min} is related to both a larger gain in efficiency $((c^*-c)\cdot q)$ and larger gain from reduced oligopoly distortion $((p-c^*)\Delta Q)$, when technologies are switching from symmetrical non-specialized to asymmetrical technologies relative to a switch from asymmetrical to specialized technologies. The larger efficiency gain at g_{max} is related to the fact that the switching firm gets a market share above 50% on which the efficiency gain is measured. At g_{min}, the firm switching from the inefficient non-specialized technology to the efficient specialized technology moves from a market share below 50% to exactly 50%. Some of this efficiency gain is therefore a transfer from the first firm that switched to the efficient technology, and this efficiency is therefore not a net gain to society. The smaller gain from reduced oligopoly distortion at g_{min} simply related to the fact the same change in price and quantity at g_{max} and g_{min} gives a smaller gain at the lower price that is at g_{min}.

Market structure

If market access costs are substantial so one of the firms may be absent in the foreign market, market integration may influence both the technology choice and the market structure. Most relevant in a foreign trade context is the case, where $g > \hat{g}_{ns,ns} > g_{max}$, i.e the trade costs only allow for one producer to operate in the foreign market. Although the variable cost structure would have indicated a non-specialized technology for both producers, the position of the producer with the monopoly in the foreign market may induce him to choose the specialized technology. This outcome is especially likely if g and $\hat{g}_{ns,ns}$ both are close to g_{max}. Market integration in the case where g falls below

$\hat{g}_{ns,ns}$ may therefore trigger a simultaneous technological restructuring and change of market structure. The reason is that the entry of the other firm will reduce the previous monopolist's sale at this market to a level where the non-specialized technology is optimal.

For the home country, the restructuring will give a welfare loss, both because of less consumer surplus as well as less producer surplus. The technology switch to a symmetric non-specialized technology raises the price level in home country making an inroad in consumer's surplus. Operating profit will also decrease in the home country due to higher variable costs. In the foreign market, the previous monopolist will suffer a loss in profit and the entrant will only be able just to cover the market access costs by operating profit in this market. The total profit for the two producers therefore decreases. For the foreign country, the welfare effect is uncertain, since the positive welfare effect of intensified competition is reduced by the costs increase, so the net change of welfare in the market is uncertain. For large cost increases (c*-c), the net welfare effect may therefore be negative.

4. Conclusions

The analysis in this paper rests on two main assumptions. First, the firms face a set of technologies based on a trade-off between marginal production costs and fixed costs. Higher fixed production costs are associated with lower marginal production costs because the capital equipment may be specialized in various degrees. Second, markets are of limited size and this constrains the number of firms which may operate without loss on markets with oligopoly.

Combining market size with blueprints of technologies illustrates that firms may diversify their technologies in market equilibrium. In case of technology heterogeneity, a firm with low marginal production costs is more export-oriented compared with firms with high marginal production costs. This pattern of export orientation is similar to one of the main conclusions in the 'new new' trade theory based on exogenous productivity differences in models where monopolistic competition prevails. The model in our paper also allows for conclusions on impacts of market integration on technology. Lowering unit variable trade costs may induce a shift towards more efficient technologies with respect to marginal production costs. However, the consequences for welfare are ambiguous. Only large trade costs reductions improve with certainty welfare, at a global scale as well as for each country. Similar to the conclusions in the 'new new' trade theory, the model in this paper may allow for cases, where not all producers are exporting, i.e. one of the producers provides one of the markets as monopolist. It is shown that in such cases trade liberalization may trigger simultaneously a change of technology and market structure from monopoly to duopoly, i.e. the non-exporting firm starts to export.

Compared to other models with endogenous firm heterogeneity, one of the virtues of the model presented in this paper is its parsimony**:** Main results from the 'new new' trade theory are presented within the simplest theoretical framework without being dependent on the assumption of monopolistic competition.

There are obvious routes for extending the analysis. The model may be extended to introduce more than two firms, e.g. by assuming producers in both countries resulting in intra-industry trade. However, such an extension will not change the fundamental conclusion of this paper that market integration may trigger changes in technology and affect the size of firms and their export behaviour.[12] The degree of realism may also be extended by letting products in the model be differentiated and by introducing uncertainty in the choice of technologies.

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[12] However, the welfare analysis will be complicated by the cross hauling waste of resources as is known from the reciprocal dumping model of Brander and Krugman (1983).

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Appendix

A: The solution of the Cournot model

The Cournot-solution is derived below for the three cases *I*, *II*, and *IV* in *Table 1*. In case *I* and *IV*, the producers are symmetric with marginal production costs at c and $c*$, respectively. In case *II*, the producers are asymmetric, as producer *1* produces with marginal production costs at c and producer *2* with marginal production costs at $c*$. The demand on each of the two markets is given by (1) and trade costs by g per unit sold on the foreign market. Using standard Cournot maximization gives the following set of solutions with q_i, p_i, π_i and CS_i as quantity, consumer price, operating profit and consumer surplus for producer i (i= 1,*2*) in home (*H*) and foreign (*F*) country, respectively:

I: Both producers produce at specialized plants.

$$q_1^{H,I} = q_2^{H,I} = \frac{(a-c)}{3}; q_1^{F,I} = q_2^{F,I} = \frac{S(a-c-g)}{3}$$

$$Q_1^I = (q_1^{H,I} + q_1^{F,I}) = Q_2^I = (q_2^{H,I} + q_2^{F,I}) = \frac{(1+S)(a-c)-Sg}{3}$$

$$p^{H,I} = \frac{(a+2c)}{3}$$

$$p^{F,I} = \frac{(a+2c+2g)}{3}$$

$$\pi_1^{H,I} = \pi_2^{H,I} = \left(\frac{a-c}{3}\right)^2; \pi_1^{F,I} = \pi_2^{F,I} = S\left(\frac{a-c-g}{3}\right)^2$$

$$\pi_1^I = \pi_2^I = \left(\frac{a-c}{3}\right)^2 + S\left(\frac{a-c-g}{3}\right)^2$$

$$CS^{H,I} = ½(a - p_i^{H,I})(q_i^{1,H,I} + q_i^{2,H,I}) = \frac{1}{2}\left(\frac{2a-2c}{3}\right)^2$$

$$CS^{F,I} = ½(a - p^{F,I})(q_1^{F,I} + q_2^{F,I}) = \frac{S}{2}\left(\frac{2a-2c-2g}{3}\right)^2$$

II: Producer 1 produces at a specialized plant; producer 2 produces at a *non-specialized plant.*

$$q_1^{H,II} = \frac{(a-2c+c^*)}{3}; q_1^{F,II} = \frac{S(a-2c+c^*-g)}{3}; Q_1^{II} = (q_1^{H,II} + q_1^{F,II}) = \frac{(1+S)(a-2c+c^*)-Sg}{3}$$

$$q_2^{H,II} = \frac{(a-2c^*+c)}{3}; q_2^{F,II} = \frac{S(a-2c^*+c-g)}{3}; Q_2^{II} = (q_2^{H,II} + q_2^{F,II}) = \frac{(1+S)(a-2c^*+c)-Sg}{3}$$

$$p^{H,II} = \frac{(a+c+c^*)}{3}$$

$$p^{F,II} = \frac{(a+c+c^*+2g)}{3}$$

$$\pi_1^{H,II} = \left(\frac{a-2c+c^*}{3}\right)^2; \pi_1^{F,II} = S\left(\frac{a-2c+c^*-g}{3}\right)^2$$

$$\pi_1^{II} = \left(\frac{a-2c+c^*}{3}\right)^2 + S\left(\frac{a-2c+c^*-g}{3}\right)^2$$

$$\pi_2^{H,II} = \left(\frac{a-2c^*+c}{3}\right)^2; \pi_2^{F,II} = S\left(\frac{a-2c^*+c-g}{3}\right)^2$$

$$\pi_2^{II} = \left(\frac{a-2c^*+c}{3}\right)^2 + S\left(\frac{a-2c^*+c-g}{3}\right)^2$$

$$CS^{H,II} = ½(a - p^{H,II})(q_1^{H,II} + q_2^{H,II}) = \frac{1}{2}\left(\frac{2a - c^* - c}{3}\right)^2$$

$$CS^{F,II} = ½(a - p^{F,II})(q_1^{F,II} + q_2^{F,II}) = \frac{S}{2}\left(\frac{2a - c^* - c - 2g}{3}\right)^2$$

IV: Both producers produce at a non-specialized plant.

$$q_1^{H,IV} = q_2^{H,IV} = \frac{(a-c^*)}{3}; q_1^{F,IV} = q_2^{F,IV} = \frac{S(a-c^*-g)}{3};$$

$$Q_1^{IV} = (q_1^{H,IV} + q_1^{F,IV}) = Q_2^{IV} = (q_2^{H,IV} + q_2^{F,IV}) = \frac{(1+S)(a-c^*)-Sg}{3}$$

$$p^{H,IV} = \frac{(a+2c^*)}{3}$$

$$p^{F,IV} = \frac{(a+2c^*+2g)}{3};$$

$$\pi_1^{H,IV} = \pi_2^{H,IV} = \left(\frac{a-c^*}{3}\right)^2; \pi_1^{F,IV} = \pi_2^{F,IV} = S\left(\frac{a-c^*-g}{3}\right)^2$$

$$\pi_1^{IV} = \pi_2^{IV} = \left(\frac{a-c^*}{3}\right)^2 + S\left(\frac{a-c^*-g}{3}\right)^2$$

$$CS^{H,IV} = ½(a - p_i^{H,IV})(q_1^{H,IV} + q_2^{H,IV}) = \frac{1}{2}\left(\frac{2a-2c^*}{3}\right)^2$$

$$CS^{F,IV} = ½(a - p^{F,IV})(q_1^{F,IV} + q_2^{F,IV}) = \frac{S}{2}\left(\frac{2a-2c^*-2g}{3}\right)^2$$

B. The long-term conditions for two firms operating on both markets

a) *Non-exit condition*

In the *short run*, the companies should have non-negative operating profits on both markets. This is the case if

$$a-2c^*+c-g \geq 0$$

or

$$(c^*+g)+(c^*-c) \leq a.$$

The marginal costs of serving customers in the foreign market from a non-specialized plant (c^*+g) plus the difference in marginal costs between a specialized and a non-specialized plant (c^*-c) should not exceed a specific threshold value given by demand (a).

In the *long run*, total profit of both firms should be non-negative. Inspection of *Table 1* gives the following rankings of operating profits for the two producers

$\pi_1^{II} > \pi_1^{I} > \pi_1^{IV}$

$\pi_2^{I} > \pi_2^{IV} > \pi_2^{II}$

Hence, total profit is non-negative if

$\pi_1^{I} \geq 2(f+m)$ and

$\pi_2^{II} \geq (f^*+2m)$

Using the expressing for operating profits, this condition may be written as:

$$\frac{(a\text{-}c)^2 + S(a-c-g)^2}{9} \geq (f+m)$$

and

$$\frac{(a\text{-}2c^*+c)^2 + S(a-2c^*+c-g)^2}{9} \geq (\frac{f^*}{2}+m)$$

In all alternative cases zero or positive profit is thus only possible if the fixed plant costs plus market access costs are moderate relative to obtainable operating profit.

b) *Non-entry condition*

Potential new firms should not have an incentive to enter. If a new firm enters, the operating profit of the new firm will be lower than the operating profit for any of the incumbent firms in duopoly, because of the intensified competition. To deter potential firms from entering, potential operating profit of the new firm should thus be lower than the total fixed costs irrespective of choice of plant. This is the case if fixed plant and market access costs are substantial relative to operating profit for the two firms in duopoly.

C. The effect of market integration on welfare in the home market, when technologies change (ΔW^H)

a) *From IV to II* ($\Delta W^H(g_{max})$:

For the specific situation where g just passes g_{max}, and one of the firms changes from a non-specialized to a specialized technology, while the other firm continues using the non-specialized technology, the welfare effect for the home country is the sum of the change in consumer surplus plus the change in the operating profit of the non-specialized producer, since the producer changing technology does not have any change in total profit for $g = g_{max}$.

The change in consumer surplus is given by the difference in consumer surplus for the non-specialized situation for both firms (*IV*) and the mixed technology case (*II*):

$$\Delta CS^H(g_{\max}) = \frac{1}{18}(c^* - c)(4a - 3c^* - c)$$

Similarly, the change in operating profit for the non-specialized producer (2) is the difference in the operating profit for *IV* and *II*.

$$\Delta \pi_2(g_{max}) = -\frac{1}{9}(c^* - c)\left[(2a - 3c^* + c) + S(2a - 3c^* + c - 2g)\right]$$

For the special case where S=1, the total home market welfare effect is

$$\Delta W^H(g_{max}) = \frac{1}{18}(c^* - c)\left(-4a + 9c^* - 5c + 4g\right)$$

Inserting

$$g = g_{\max} = 2(a - c) - \frac{9}{4}\frac{(f - f^*)}{(c^* - c)}$$

gives

$$\Delta W^H(g_{max}) = \frac{1}{18}(c^* - c)\left(4(a - c^*) + 9(c^* - c) - 9\frac{(f - f^*)}{(c^* - c)}\right)$$

b) *From II to I* ($\Delta W^H(g_{min})$):

Using the same methodology as above, but for the case where technologies are changed from the non-specialized, specialized to the specialized, specialized case (from *II* to *I*), it is the operating profit of firm *1* that changes.

$$\Delta CS^H(g_{\min}) = \frac{1}{18}(c^* - c)(4a - 3c - c^*)$$

$$\Delta \pi_1(g_{\min}) = -\frac{1}{9}(c^* - c)\left[(2a - 3c + c^*) + S(2a - 3c + c^* - 2g)\right]$$

For the special case where S=1, the total home market welfare effect is

$$\Delta W^{H}(g_{\min}) = \frac{1}{18}(c^{*} - c)\left(-4a + 9c - 5c^{*} + 4g\right)$$

Inserting

$$g = g_{\min} = 2(a - c^{*}) - \frac{9}{4}\frac{(f - f^{*})}{(c^{*} - c)}$$

gives

$$\Delta W^{H}(g_{min}) = \frac{1}{18}(c^{*} - c)\left(4(a - c) - 13(c^{*} - c) - 9\frac{(f - f^{*})}{(c^{*} - c)}\right)$$

D. The effect of market integration on world welfare, when technologies change (ΔW^W)

a) *From IV to II* ($\Delta W^W(g_{max})$:

$\Delta W^W(g_{max}) = \Delta W^H(g_{max}) + \Delta W^F(g_{max})$

The change in foreign welfare ($\Delta W^F(g_{max})$) is given by the difference in consumer surplus for the non-specialized situation for both firms (*IV*) and the mixed technology case (*II*):

$$\Delta W^{F}(g_{\max}) = \Delta CS^{F}(g_{\max}) = \frac{S}{18}(c^{*} - c)(4a - 3c^{*} - c - 4g) > 0$$

$\Delta W^H(g_{max})$ is given above.

We get:

$$\Delta W^{W}(g_{\max}) = \frac{(S + 1)}{6}(c^{*} - c)^{2} > 0$$

b) *From II to I* ($\Delta W^W(g_{min})$:

Using the same methodology as above, but for the case where technologies are changed from the non-specialized, specialized to the specialized, specialized case (from *II* to *I*), we get:

$\Delta W^W(g_{min}) = \Delta W^H(g_{min}) + \Delta W^F(g_{min})$

The change in foreign welfare ($\Delta W^F(g_{min})$) is given by the difference in consumer surplus for the non-specialized, specialized and specialized, specialized case (from *II* to *I*):

$$\Delta W^F(g_{\min}) = \Delta CS^F(g_{\min}) = \frac{S}{18}(c^* - c)(4a - c^* - 3c - 4g) > 0$$

$\Delta W^H(g_{min})$ is given above

We get:

$$\Delta W^W(g_{\min}) = -\frac{(S+1)}{6}(c^* - c)^2 < 0$$

Since $\Delta W^W(g_{\min}) < 0$ and $\Delta W^F(g_{min}) > 0$, we have $\Delta W^H(g_{min}) < 0$