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Dynamic Gains from Trade

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DYNAMIC GAINS FROM TRADE

OECD Trade Policy Working Paper No. 43

by

Hildegunn Nordas, Sébastien Miroudot and Przemyslaw Kowalski

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ABSTRACT

The post world war II era has been characterized by unprecedented growth in the world economy and progressive reduction in barriers to international trade and investment. The objective of this study is to assess to what extent the observed growth and deepening international economic integration are related. It begins by discussing the concept of dynamic gains from trade. Narrowly defined, dynamic gains are trade-related changes in the long-run rate of productivity growth. Although there is no conclusive evidence that trade has dynamic effects in this narrow sense, there is robust evidence that open economies are richer and more productive than closed economies. The studies that most convincingly establish this link find that an increase in the share of trade in GDP of one percentage point raises the income level by between 0.9 and 3%. The study identifies four possible channels through which trade and foreign direct investment affect productivity levels and growth rates: i) better resource allocation, ii) deepening specialization, iii) higher return to investment in capital and R&D and iv) technology spillovers. Strictly speaking, only technology spillovers have an impact on the long-run productivity growth rate, but quantifying such spillovers and their impact has proved difficult. The study also discusses the performance of applied general equilibrium models in quantifying gains from trade and concludes with suggestions on further research in order to improve such models.

Keywords: Productivity growth, international trade, FDI, applied general equilibrium models.

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TABLE OF CONTENTS

Tables

Figures

Boxes

EXECUTIVE SUMMARY

The post world war II era has been characterized by unprecedented growth in the world economy and progressive reduction in barriers to international trade and investment. The objective of this study is to assess to what extent the observed growth and deepening international economic integration are related. It begins by discussing the concept of dynamic gains from trade. Narrowly defined, dynamic gains are trade-related changes in the long-run rate of productivity growth. Although there is no conclusive evidence that trade has dynamic effects in this narrow sense, there is robust evidence that open economies are richer and more productive than closed economies. The studies that most convincingly establish this link find that an increase in the share of trade in GDP of one percentage point raises the income level by between 0.9 and 3%.

Quantitative assessments of productivity gains from trade require models that capture the channels through which trade policy affects trade, foreign direct investment (FDI) and productivity or at least they should incorporate a good estimate of the relation between trade and productivity at the aggregate level. This study identifies four possible channels through which trade and foreign direct investment affect productivity levels and growth rates:

Productivity effects of trade by channel

Channel of productivity gain	Level/Growth effect
Better resource allocation	Level
Deepening specializaton	Level
Higher return to investment (capita and or R&D)	Level – long adjustment period
Technology spillovers	Growth

Each of these channels is discussed separately focusing on the empirical evidence.

There is ample firm-level evidence on the gains from **deeper division of labour.** Firms improve their productivity through specializing in a narrow set of core activities while sourcing a broad range of inputs from other firms locally and abroad. This has resulted in a sharp rise in trade in intermediate inputs. Economy-wide empirical analysis of this effect is, however, scant. Nevertheless a few studies are reported and they all find a significant relation between productivity and diversity of intermediate inputs in manufacturing sectors that produce differentiated products. Applied models often do not fully capture the gains from specialization and therefore underestimate the gains from trade.

One of the most robust empirical linkages between trade and productivity is through **the investment channel**. This is an indirect link as the rate of investment affects productivity while trade affects the rate of investment. Trade can raise the return on investment through a more efficient allocation of resources - including capital -, economies of scale, competition and often lower cost of investment goods. In addition investment is a source of technology transfers with technology embodied in traded capital goods.

The study discusses foreign direct investment as a possible source of increases in productivity levels separately. Many observers report that multinational companies bring technology and management to the host countries. Although local suppliers and competitors (including spin-offs) could learn from the foreign investors, either through market-based cooperation or spillovers, the empirical evidence is mixed. The productivity effect depends on the motivation for the investment, the market conditions in the host economy and the technology gap between host country and the multinational company. If the gap is too big, the probability of technology spillovers is low.

Empirical evidence on the **impact of trade on R&D** is scant. Trade and FDI enhance competition and thus incentives to innovate. Competition also lowers the price-cost margin of innovating firms, while trade extends the market and the volume of sales on which the margin is earned. The net effect differs between sectors and countries. The lowest margins are found in science-based industries and the highest in information-intensive industries. Finally, it appears that rapid technological progress and productivity improvements can take place in all sectors. What matters for productivity is more how things are produced than what is produced. The fear that productivity gains from trade will only accrue on countries that have comparative advantage in high-technology industries is thus not supported by empirical evidence.

Innovations can also be traded directly through licensing. This opens the possibility of a specialized R&D sector separated from production. OECD countries have a comparative advantage for R&D services and net exports of such services have increased sharply for the major OECD countries. R&D is subject to economies of scale and trade has helped obtaining scale through specialization.

Sustained productivity growth requires technological development. Hence for trade to have a sustained impact on productivity growth, it must foster **technology transfers**. Technology is embodied in traded capital goods and intermediate goods and services, and there is also the possibility that trade and FDI cause technology spillovers. Such spillovers are unintentional flows of knowledge that travels with goods, services, capital and labour and are absorbed by trading partners in a way that improves their productivity. On this the evidence is mixed. The most robust finding is that there are learning effects of this nature from imports, while for exports and FDI there are reports of technology spillovers for specific sectors and countries, while no general conclusive evidence is found.

The study finally discusses how dynamic gains are dealt with in the applied trade modelling literature. Most of the models used for trade policy analysis are static in nature and are widely believed to underestimate gains from trade liberalization. Some models contain dynamic features as "add-ons" but the term 'dynamic' in the modelling literature has been used more broadly than in theoretical analyses that link trade and growth theory. One sub-group of dynamic models introduces a time dimension where the adjustment process to the trade policy shock is distributed over a certain time period, thus spreading the static gains over time. Another approach is to impose a link between productivity and openness from the literature on the model (so called off-line calculations). Adding dynamic effects in this way typically more than doubles the productivity effect of trade (e.g. from 0.2 to 3% of GDP in one study and from $287 to $461 billions in another). Finally some applied models have introduced a link between trade, investment and savings and are solved for each time period in a time-consistent way.

All these modelling approaches suffer from the problem that the extent to which dynamic gains from trade exists, their nature and the channels through which they work are not well understood. Dynamic effects are therefore introduced as exogenously imposed conditions rather than being an integrated part of the model structure. Therefore it is concluded that more research into the channels of dynamic gains is required in order to improve the way in which dynamic gains are modelled. Further empirical work into estimating trade-productivity linkages would be particularly beneficial.

In summary, the literature on dynamic gains remains nascent. Theory predicts that trade and FDI enhances productivity growth through technology diffusion, particularly to countries and firms behind the technology frontier. However, dynamic gains are not easy to quantify.

There are a number of avenues for further work on this important topic. Much theoretical and empirical research needs to be done in order to better understand the channels through which trade and FDI affect productivity. This research can then be incorporated into applied trade models. Further research could therefore aim at improving the modelling of:

- The gains from product diversity;
- The relation between trade and technology. For instance: does trade affect the level and allocation of R&D expenditure?
- The relation between trade, financial markets and productivity growth;
- The relations between trade policy and trade flows. Particularly in developing countries it is important to understand how complementary policy measures may enhance the supply side response to trade liberalization.

There is therefore considerable work to be done to increase our understanding of the theory and empirics of the impacts of trade on productivity. But the extent of the challenge should not be used as an excuse not to invest further resources in this cutting edge work.

DYNAMIC GAINS FROM TRADE

Liberalism typically comes as a package [Clemens and Williamson, 2004 p. 6]

1. Introduction

1. In the long run the rate of economic growth makes an enormous difference to income levels and standards of living. A comparison of Ghana and Korea illustrates this well. In 1955 Ghana was the richer of the two with a GDP per capita at $370 compared to Korea's $300. However while Korea embarked on a rapid industrialization and development path, Ghana experienced pedestrian growth and development. The average annual growth rate of GDP per capita was about 8.5% and 3% respectively between 1955 and 2000. By the year 2000 Korea had long since joined the OECD, while Ghana remained a low-income country, and Korea's GDP per capita was more than 10 times higher than Ghana's (at about $15 000 as compared to Ghana's $1 375).[1]

2. Economic growth is probably the most important factor behind the development of human welfare. Thus, understanding why growth rates differ among countries is one of the key challenges for economic research. To quote a Nobel Laureate in economics, Robert Lucas: Once one starts to reflect on what causes the difference in growth rates between countries, it is difficult to think of anything else. The objective of this study is to trace out the possible relationship between economic growth and deeper international integration. The key aims of the study are to:

- Define dynamic gains from trade and explain how they relate to productivity;
- Identify the channels through which dynamic gains may accrue;
- Summarise existing empirical literature on these channels and their impact on productivity growth and levels;
- Discuss to what extent dynamic gains can be measured and predicted, with a focus on applied general equilibrium modelling.

We will distinguish between the possible impact of trade on the *rate of productivity growth* and on the *productivity level.* Usually the former is associated with dynamic gains while the latter is associated with static gains (See Box 1).

Gains from trade and gains from trade liberalization are not always the same thing

3. In the debate on the gains from trade a distinction has been made between the impact of *trade* and the impact of *trade policy* on productivity and its growth rate. This may at first glance be a question

[1] The data on real GDP per capita are from the Penn World Tables version 6.1 and are adjusted for differences in purchasing power.

merely of academic interest, but in fact the relation between trade policy and trade is not always straight forward and well understood. Some countries are for instance "naturally" open because of location and endowments of resources, while others are less so. Second, there has been an at times heated debate on to what extent trade liberalization is good, bad or irrelevant for growth, even when observers agree that trade is good for growth. This debate has moved in the direction of a consensus:

- Trade, income and productivity levels are positively and strongly correlated;
- The direction of causality most likely goes from trade to income levels;
- There is no conclusive evidence of a positive and causal link between trade liberalization and productivity levels or productivity growth;
- There is no conclusive evidence of a positive link between protection and productivity growth or productivity levels.

4. The lack of evidence of a link between trade liberalization and productivity growth may sound discouraging for proponents of trade liberalization and may lead one to think that the lack of progress in multilateral trade negotiations will not make that much of a difference. Such sentiments are not warranted, however. This study will argue that the sheer complexity of the growth process makes it difficult to pin down a robust and causal relationship between any single policy variable and aggregate productivity growth. This applies to all policy variables, not only trade policy.

5. Productivity growth depends on accumulation of factors of production such as human and physical capital. In addition and more importantly productivity growth depends on the way production is organized. Behind these easily measurable factors lie deeper causes including the quality of institutions such as education, the financial sector and perhaps above all the security of property rights and enforcement of contracts. Such institutional factors are persistent and they are affected by exposure to foreign suppliers, customers, investors and ideas in ways that are difficult to pin down empirically and which have developed over a long period of time. And as already mentioned, the evidence points to a positive and causal relation between a country's productivity *level* and its openness to trade.[2]

6. In the long run economic growth amounts to growth in total factor productivity. Therefore, Section 2 starts with a discussion of the sources of economic growth with the purpose of identifying the channels through which trade and foreign direct investment may affect productivity growth. Having identified these channels, each subsequent section is devoted to one channel of possible dynamic gains from trade, focusing on recent empirical evidence. Section 3 discusses the most obvious and direct possible link between trade and productivity growth, namely deepening international specialization. A related question is whether trade-induced specialization may lock in an industrial structure that is good for growth in countries with comparative advantage in high-technology sectors and bad for growth in countries with comparative advantage in low-technology sectors. This question is discussed in section 4 while sections 5 and 6 address the relation between trade and accumulation of assets, focusing on capital and research and development (R&D) respectively. Section 7 discusses the relation between trade, FDI and technology transfers. It distinguishes between technology transfers that result from conscious decisions by investors and trading partners, and technology spillovers which are benign side-effects of trade and FDI activities. Section 8 discusses what it takes to model dynamic gains from trade and presents recent models and the results of their policy simulations. Section 9 summarizes, suggests areas for future research and concludes.

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2 See Alcalá and Ciccone (2004) for recent empirical evidence.

Box 1 Gains from trade – static and dynamic

Trade can affect productivity in four distinct ways:

A shift in the *average productivity level* for the economy as a whole. This happens when trade liberalization leads to a shift of labour and capital towards the sectors with the highest productivity level, giving them higher weights in the average for the economy as a whole. The productivity level of each sector need not be affected.

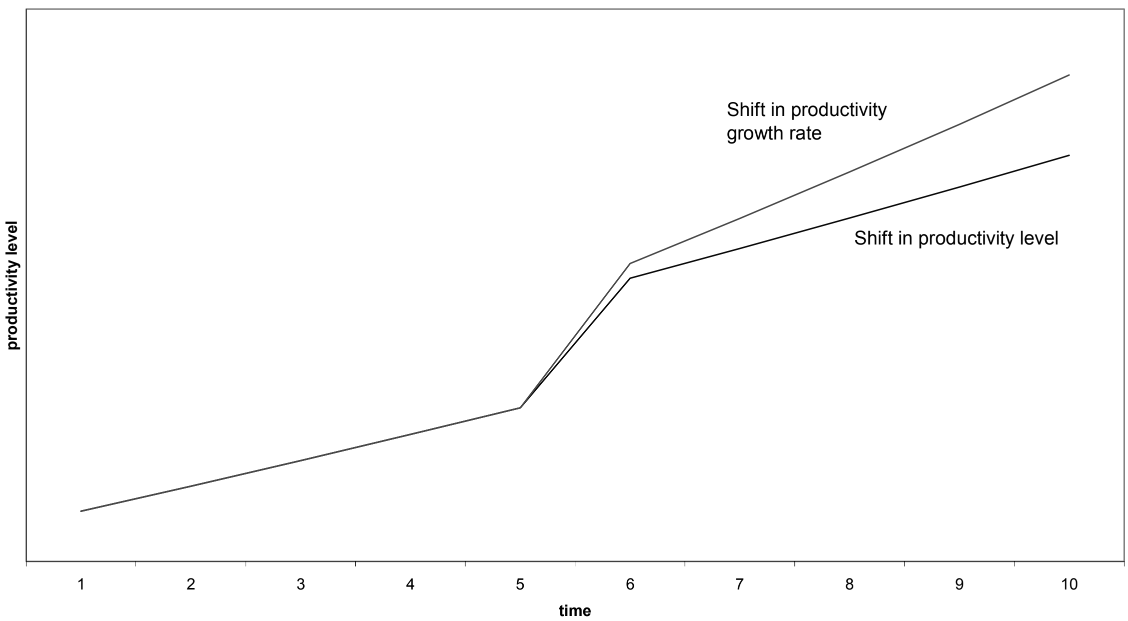
A shift in the productivity *level* in each sector. This happens when trade liberalization leads to deeper specialization, capital deepening and improved scale economies in each sector (or firm). This will of course also raise the average productivity level for the economy as a whole.

A shift in the *average productivity growth rate* for the economy as a whole. This happens when trade liberalization leads to a shift of labour and capital towards the sectors with the highest productivity growth rates, giving them higher weights in the average for the economy as a whole. The productivity growth rate of each sector need not be affected.

A shift in the *productivity growth rate* for each sector. This can follow trade liberalization when trade brings technology spillovers for instance if there are scale economies in transforming knowledge into productive assets.

The difference between a shift in the productivity level and the productivity growth rate is illustrated in the figure below. Trade liberalisation takes place in year 5. With a shift in the growth rate both the height and the slope of the productivity curve change, while with a change in the productivity level only the height changes. A significant shift in the productivity level that takes a long time to materialize is probably the most common outcome and it is often difficult to distinguish empirically from changes in the growth rate.

Static and dynamic gains from trade



Measures of productivity

The most commonly used measures of productivity are labour productivity and total factor productivity (TFP). Labour productivity is simply measured as the value of output per hour of labour input. Total factor productivity measures output relative to the employment of all primary factors of production. The table below illustrates the difference by a simple stylised example with two factors of production. The comparison is most meaningful when looking at changes over time.

Comparing labour productivity and TFP, a stylised example

	Period1	**Period 2**	**Period 3**
Output	100	105	112
Capital stock employed	400	410	425
Labour employed	75	75	75
Change in labour productivity %		5%	6.67%
Change in total factor productivity %*		4.2%	5.5%

** Using the stylised fact that capital accounts for a third of factor use.*

The change in labour productivity only takes into account the increase in output per worker, while total factor productivity also takes into account the capital deepening that has taken place between the periods. Therefore, the change in TFP growth is smaller than the change in labour productivity.

2. What are the sources of economic growth and what is the role of trade?

7. The ultimate source of long-run economic growth is the continuous expansion of our knowledge base. However, in order for knowledge to generate economic growth it must be transformed into productive assets such as enhanced skills, better machines, and better ways of organizing production. As we will see in this study, trade and deeper international engagement can contribute to both the expansion of the knowledge base and its transformation into productive assets.

Knowledge and technology may flow with trade and FDI

8. Behind the technology-frontier growth takes place mainly through *adoption* of the knowledge created by the frontrunners. However, technology diffusion is not automatic and requires considerable R&D efforts in order to match foreign technology with domestic productive assets, i.e. increasing absorption capacity. Trade can stimulate the process in several ways. Trade facilitates the transmission of knowledge embodied in traded capital and intermediate goods. Suffice to mention almost universal access to computers and software for which prices have kept falling for decades, largely thanks to the international production networks characterising this sector.[3] Trade in services as well as FDI can be important for the transmission of knowledge embodied in people and in organizations, while licenses allow firms behind the technology frontier to use foreign companies' state-of-the-art technology. Finally, knowledge travels with goods, services and investment as a benign unintended side-effect of trade and investment flows. But the extent to which such potential technology spillovers materialize depends on the recipient's stock of human capital, which is the most important determinant of absorption capacity.

9. The growth effect of R&D expenditure and the linkage to trade depend on two key questions. The first is whether R&D productivity rises or declines with the stock of knowledge. Put differently is it easier or more difficult to make new innovations the more innovations have already been made? There are sensible arguments supporting both possibilities. Big general purpose technology innovations such as the

3 See for instance Jorgenson (2001) for an estimate of long-run quality-adjusted price trends (so-called hedonic prices) in computer hardware and software.

microprocessor probably made it easer to develop a host of complementary innovations. However, as the stock of complementary innovations rise, it might become increasingly difficult to come up with additional, genuinely useful innovations. The empirical evidence so far indicates that for the economy as a whole R&D productivity does not increase with the stock of knowledge. It has for instance been found that the share of engineers and researchers in total employment has increased steadily in the post World War II period in major OECD countries, without raising the productivity growth rate (Jones, 1995a; 1995b).

10. The second question relates to what is the relevant stock of knowledge – national, regional or global – that domestic researchers can draw on? And how exactly do researchers benefit from previous research? As argued by an observer as early as 1935; in large economies there are more mouths to eat an innovation and more eyes to find it, while the cost of finding it is the same (Gilfillian, 1935 reported in Young 1998). If trade allows foreign mouths and eyes to be part of the equation, trade could lead to productivity growth.

11. To what extent trade expands the reach of technology transfers and spillovers is an empirical question which will be discussed in depth in section 7. Suffice it to mention here that foreign technology accounts for the bulk of domestic productivity growth in most countries and the more so the smaller the country. Further there is evidence that technology travels with imports, although the magnitude of the spillovers is still not firmly established (Keller, 2004). In contrast there is no conclusive evidence that firms learn foreign technology through exports. This does not mean that such spillovers do not exist, but if they do, they have yet to be proven. Finally, technology is found to travel with FDI, at least in high-technology industries, but it is uncertain to what extent technology spills over to other industries than those of the foreign investor. In any case technology diffusion is not automatic, but requires a minimum level of absorption capacity which is gained through local investment in human capital and R&D. Technology also appears to be localized rather than global as technology diffusion falls off sharply with distance.[4]

No pain, no gain

12. Trade liberalization tend to induce the most productive firms to expand, while the least productive firms exit the market, leaving the average productivity level in the liberalized sector higher (Melitz, 2003; Melitz and Ottaviano, 2005). Gains from trade liberalization depend on the speed and extent to which resources are reallocated to industries and activities for which the country in question has a comparative advantage. Obviously, reallocations means that jobs are created, but also that jobs are destructed and the latter has at times induced popular resentment to trade liberalization.

13. Human capital plays an important role in the adjustment to trade liberalization. Thus, generic knowledge acquired through education enhances the ability of workers to move rapidly between industries or between jobs within an industry. A higher level of relevant education thus facilitates adjustments and keeps down adjustment costs.[5] It has been argued that this kind of interaction between trade and education has been an important driving force for the rise of the Asian newly industrial countries (Kim and Kim, 2000).

Specialization is not a source of endogenous growth, but nevertheless an important source of gains in productivity levels

14. Gains from specialization or division of labour was already noted by Adam Smith in his famous description of the pin factory, while Ford managed to make cars affordable to ordinary people through

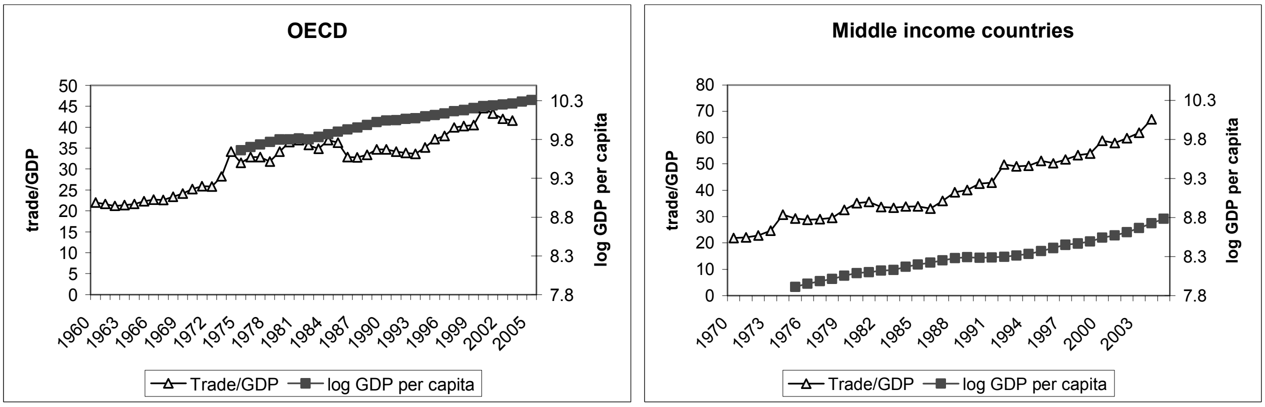
4 See Keller (2004) for an excellent stocktaking of our knowledge of international technology diffusion.

5 See also Box 1 above.

extensive specialization within the firm. With more complicated production processes, further specialization had to take place *between* firms rather than within firms. While for instance the original T-Ford consisted of about 700 components, a passenger car today consists of more than 3000 components which in turn are made from a large number of parts including an increasing share of advanced electronics components. This complexity can not effectively be kept within the firm which is why firms tend to specialize in a narrow range of products and activities while sourcing most inputs from each other. In the presence of economies of scale, the degree of specialization is determined by the extent of the market, which brings trade into the picture. Trade extends markets and larger markets can accommodate a broader variety of specialized firms and thus allow for a deeper division of labour. This is one of the reasons why small countries tend to have a higher trade to GDP ratio than large countries.[6]

15. A deeper division of labour has been one of the most important driving forces behind the increase in world trade relative to world output since World War II, a period of gradual reduction of political as well as technical trade barriers. Figure 1 depicts trade in goods and services as a share of output during the period 1960 – 2003 (the latest available year) for the OECD countries and the period 1970-2003 for middle income countries. The (log of) GDP per capita in constant 2000 U.S. dollars purchasing parity is also depicted in the figure. The ratio of trade to GDP doubled from about 24% in 1965 to about 48% in 2003 for the world economy as a whole. The OECD countries have increased their trade to GDP ratio in line with the world average, while middle income countries have experienced a sharper rise both in trade/GDP and GDP per capita. GDP per capita in OECD countries increased by 90% from 1975 to 2005, while the corresponding figure in middle income countries was 138%.

Figure 1. Trade share of output and GDP per capita growth



Source: World Bank; World Development Indicators

16. In addition to the expansion of world trade, many companies chose to service foreign markets through foreign direct investment (FDI). In fact, sales of foreign affiliates by far outpace cross-border trade both in goods and services. An indicator of the growing importance of FDI is the fact that foreign capital inflows quadrupled as a share of world gross fixed capital formation between 1980 and 2003, from 2% in 1980 to more than 8% in 2003.[7]

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6 McDermott (2002) argues that trade and large domestic markets are substitutes.

7 Calculated by authors from UNCTAD data on FDI flows and World Bank (WDI) data on gross fixed capital formation. The latest year for which data on global gross fixed capital formation is available is 2003.

17. At first when trade costs were relatively high, countries specialized in broad sectors according to comparative advantage and goods were classified as exportable, importable or non-tradable. As trade costs came down, countries at similar income levels started to specialize *within* sectors trading different varieties or brands of the same goods, e.g. different car models, different computer brands and so on. Recently, international division of labour has been further deepened through the slicing up of the production process into parts, modules and services which are produced in different countries and assembled close to the final market. Such vertical specialization has fuelled the most recent spurt in the trade/GDP ratio (Yi, 2003). It represents a continuation of a long-run trend and can be understood and analysed within a standard trade policy analysis framework focusing on trade in intermediate inputs. Finally, the non-tradable category has been shrinking as more sectors, including services, are exposed to international competition.

18. Access to better, cheaper and a broader variety of inputs that go with deeper division of labour clearly improves productivity (see Box 2). Whether it also raises the rate of productivity *growth* is less clear. What appears to be the strongest hypothesis at this point is that productivity improves with the degree of specialization, but at a diminishing rate. This means that the degree of specialization is an important determinant of the income and productivity *level,* but not their long-run growth rates.[8] Nevertheless, the effect of deepening specialization can be significant during the transition to a higher income level. Furthermore, there may be new spurts in specialization from time to time as indicated in Figure 1, followed by temporary increases in productivity growth. If such spurts are frequent and the transition period relatively long, it may be difficult to distinguish between shifts in productivity growth and productivity levels when the time horizon of the analysis is a couple of decades or less, which is usually the case.

19. Accepting that deepening specialization has a level effect on productivity, but not a growth effect in the long run, we need to look elsewhere for trade-related sources of sustained growth. Recent research has shed some light on this by representing specialization as a two-dimensional process. Specialization is extended horizontally by splitting up the production process into specialized components/activities and vertically by improving the quality of each component/activity. The horizontal dimension has been found to have a level effect on productivity, while the vertical dimension has been found to have a potential growth effect (Young, 1998; Segerstrom, 1999). This raises the question whether R&D expenditure is optimally allocated between the search for new varieties and the search for improved quality. Whether and how trade and FDI affect this allocation is an area of research where very little, if anything, has been done so far.

8 In this respect deepening of specialization is similar to capital deepening, which also has an effect on income level, but not long-run growth (see Box 2).

Box 2. Growth theory in a nutshell

The first modern growth theory was developed by Robert Solow (1956) and can be summarized in a simple macroeconomic product function:

$$Y = AL^{\alpha} K^{1-\alpha} \qquad (1)$$

L represents labour inputs, K capital inputs and A is a parameter that reflects the level of technology or total factor productivity. This production function has the property that a proportional increase in labour and capital inputs, say by 10%, increases output by 10%. An increase in capital while holding labour input constant (capital deepening) increases output, but at a diminishing rate as the stock of capital per worker increases. Eventually the capital stock reaches a level where investors will only replace depreciating capital in the absence of technological progress. Capital deepening has nevertheless been an important source of (transitional) output growth in emerging economies where the capital per worker ratio was initially low. However, the only source of sustained growth in this model is technology or total factor productivity represented by A, which is an exogenous variable. The Solow model thus describes the long-run (steady-state) growth path and it does so pretty well, but it does not explain it. That being the case the theory also had little to offer in terms of policy implications.

Empirical research following Solow's work aimed at quantifying the contribution of labour, capital investment and technological progress to observed growth. The contribution of technological progress was typically found to be around 50% and it was then coined a measure of our (considerable) ignorance on economic growth.

Subsequent research aimed at *explaining* technological progress and to explore how policy could stimulate growth. Technically speaking the challenge was to endogenize developments in A in the macro production function, which is why the new growth theory was coined endogenous growth theory. A host of models that either explicitly included R&D or assumed that capital investments exhibited externalities in the form of contributing to a common knowledge base were developed.

A stylized version of the model with externalities from investment in (physical or human) capital is as follows:

$A = K^{\beta}$, consequently $Y = L^{\alpha} K^{1-\alpha+\beta}$ (2)

The major difference between equations (1) and (2) is that the return to capital investment will not necessarily diminish (depending on the size of β relative to α) as the stock of capital per worker increases. Furthermore, since investors do not take the impact of their investments on the total stock of knowledge into account, they will invest less than the social optimum, and there is a role for government policy in stimulating investment. An important externality explored in the literature is learning-by-doing. This idea has formed the justification for infant industry protection and trade and industrial policy measures that promote industries in which learning-by-doing is faster (a high β).[1]

An alternative way of modelling technological progress is to look at it as a result of deliberate investment in R&D. Firms will only have incentives to invest in R&D if they can earn a positive net profit in order to recover their R&D expenditure. Consequently perfectly competitive markets have to be abandoned as an analytical framework. The output of R&D is a flow of blueprints that investors can transform into productive assets. A version of R&D-driven growth models that is particularly relevant for the analysis of the relation between trade and productivity growth is the group of models that makes out the result of R&D as blueprints for new and/or better intermediate inputs. The simplest version of this approach is:

$H = \lambda(\gamma) + \varepsilon x$ and $Y = \left(\sum (\gamma_i x_i)^{\sigma}\right)^{1/\sigma} = N^{1/\sigma} \gamma x$ (3)

Production takes place through three activities. First, intermediate inputs are developed through R&D. The cost of this activity is signified by *λ(γ)* in the first equation which represents the cost of developing and producing intermediate inputs. The R&D activity constitutes an up-front fixed cost that is born independently of subsequent production and it is a function of the quality or technological content of the product to be developed. Obviously the quality needs to be better than already existing intermediate products. Second, the intermediate input is produced at a unit cost of *ε* and the volume is denoted by *x*. Finally the inputs are assembled into final output *Y*. Again γ denotes quality and *x* denotes quantity of each input. The inputs are assumed to enter the production function symmetrically such that final output is a function of the number of inputs (*N*) and the quality-adjusted quantity of each input *(γx)*.

The model has two sources of productivity improvements. First, productivity in the assembly activity improves with deepening division of labour as represented by the number of inputs, *N*. In other words, the deeper the degree of specialization, the higher is productivity. However, assuming that $\sigma > 1$, productivity increases with the number of inputs at a decreasing rate (the first derivative of *Y* with respect to N is positive, the second derivative is negative). Thus, in the long run an increase in N has a level effect, not a growth effect. Note that the impact of increased specialization in this model is analogous to the impact of capital deepening in the Solow model – it has a level effect but not a long-run growth effect.

The second source of productivity gains is the quality of each input. The rate of productivity growth is proportional to the rate of quality improvements in perpetuity, analogous to the rate of technological progress in the Solow model. What generates endogenous, sustained growth in this model is thus the R&D expenditure that is devoted to improving the quality of existing inputs (as opposed to developing a new variety) (Young, 1998). In order to generate endogenous growth in these quality-ladder models, one needs to superimpose the assumption that λ is a falling function of γ, i.e. that it is easier to make further quality improvements the higher the quality already in place. Finally, trade affects the productivity growth rate only if there are international technology spillovers; i.e. if γ refers to an international stock of knowledge which can be accessed through trade and FDI.

1. This model is compatible with competitive markets since equation (1) applies to production at the firm level while equation (2) only applies to the macro level. This type of model was first developed by Paul Romer (1990; 1994) and provided a new impetus to research on economic growth.

The empirical evidence supports the tenet that trade is good for productivity….

20. A simple approach to empirical analysis of the relation between productivity growth and trade is to regress total factor productivity growth (the growth of A in equation 1 in Box 2) on trade, controlling for other relevant factors such as measures of human capital accumulation, the initial level of GDP per capita (which is a proxy for the initial stock of technology) and a host of other variables.[9] The majority of these studies do find a positive relation between trade and economic growth or between trade and income level. In fact, among all the variables that are included in such regressions, openness to trade is among the ones most robustly linked to economic growth (Sala-i-Martin, 1997). However, a closer scrutiny of the results reveals that the relation between trade and growth in most successful studies refers to actual trade volumes rather than to trade policy measures. A seminal paper that focuses on the impact of trade and income using a more sophisticated methodology for dealing with the direction of causality, finds a large, but only moderately statistically significant impact of trade on income levels. The estimates of the impact on GDP per capita from a one percentage point increase in the trade to GDP ratio range from 0.9 to 3% increase in GDP per capita.[10]

….but under which conditions trade liberalization improves productivity is not well understood

21. There are also some studies that find a strong relation between trade policy and growth, but these have been criticized for using policy variables that are more related to sound macroeconomic management than to trade policy (Rodrik and Rodriguez, 2000). One of the problems with establishing a relation

9 As long as the process is poorly understood, it can be useful not to impose too much structure on the regressions. However, there are now so many studies using the same core data set while adding one new variable to the regression that the usefulness of further studies along the same lines is diminishing. Furthermore, so-called meta analysis of existing studies find that very few of the variables included in the literature are robust to variations in the time period analysed, the sample of countries included and the control variables applied.

10 Frankel and Romer (1999) use instrumental variables where the instrument is trade as predicted from a country's geographical characteristics.

between trade policy and productivity is the scarcity of good time series data on trade barriers. For this reason it can even be difficult to establish empirically a plausible relation between trade flows, tariffs and non-tariff barriers. Tariffs are for instance usually left out of gravity regressions on the determinants of bilateral trade. One would argue that if it is difficult to establish a robust empirical link between trade flows and trade barriers it is not surprising that it is more difficult still to establish a link between economic growth and trade policy. This problem can be solved with better data on trade barriers.

22. In conclusion there is robust evidence of a link between productivity levels and trade as measured by (exports + imports)/GDP, but a causal and robust link between *trade liberalization*, as measured by changes in tariff restrictions or non-tariff barriers, and productivity growth is yet to be established. To put this finding into context, no policy variables have so far been found to have a robust impact on productivity growth at the macroeconomic level. Those who argue that there is no conclusive evidence that trade liberalization causes growth are thus right, but when they go on to suggest alternative growth-promoting trade policy measures, they fall prey to their own critique. This chapter has identified the possible channels through which trade may affect productivity growth, as summarized in Table 1.

Table 1. Productivity effects of trade by channel

Channel of productivity gain	Level/Growth effect
Better resource allocation	Level
Deepening specializaton	Level
Higher return to investment (capita and or R&D)	Level – long adjustment period
Technology spillovers	Growth

23. We now turn to empirical evidence of the importance of each of the identified channels.

3. Gains from specialization

24. The most interesting recent research on the gains from specialization focuses on trade in intermediate inputs and the variety of such inputs available to individual producers. It has been shown in theory that trade in intermediate goods can yield higher welfare gains than trade in final goods (Markusen, 1989; Feenstra, 1996). This is because a trade-induced broadening of the variety of intermediate inputs or lower costs of each input can have the same effect as capital deepening or technological progress, depending on the technology applied for producing final goods (see Box 2). Outsourcing of labour-intensive activities to low-cost countries has a similar impact as skills-biased technological change; it raises the level of productivity, reduces demand for unskilled labour and in the long run enhances the incentives to invest in human capital.

Increased product variety through trade could raise TFP and welfare significantly

25. Empirical research on the productivity impact of trade in intermediate inputs is quite demanding in terms of data requirements since data on numbers or varieties of intermediate inputs are not readily available. Therefore proxies have to be constructed. One approach has been to develop indices of the number of varieties for a benchmark year and then study the increase in the number of varieties in a trade model that incorporates trade in differentiated intermediate goods and services. Rutherford and Tarr (2002) simulated the impact of reducing tariffs from 20% to 10% in a dynamic model that had a transition period from the policy intervention to the long-run steady state equilibrium of 54 years. They found that the GDP growth rate would increase from 2.0% on average per annum before the tariff reform to 2.1% per annum on average during the transition period after which it would return to 2%. The engine of growth in the model is expanding variety which reduces production costs and increases the return to capital. This is a

stylized example of a representative small open economy built on as realistic assumptions as possible. The results of this exercise are compatible with the finding that expanding variety affects the productivity level, but not the long-run growth rate. Finally the length of the adjustment period is worth noticing. It is as much as 54 years in this model and it illustrates the argument made in the introduction that a change in the productivity level in practise can often not be easily distinguished from a change in the long-run growth rate. Furthermore, for practical policy purposes the distinction may not be important.

Product variety and TFP is significantly and positively correlated with TFP in manufacturing

26. Another approach to measuring product variety for trade analysis is to count the number product categories in which a country trades. This approach has been followed by Feenstra et al. (1999) who studied the relationship between product variety and total factor productivity in South Korea and Taiwan and by Funke and Ruhwedel (2001) who analyzed 14 OECD countries. The former looks at to what extent product variety can explain the difference in total factor productivity growth between South Korea and Taiwan in 16 industries of which 9 were secondary industries producing differentiated outputs. The authors found that product variety had a positive impact on TFP in seven out of these nine secondary industries and none of the primary industries and argues that the result supports the theory of expanding variety as a source of productivity growth. The data analysed were for a 16-year period between 1975 and 1991. Funke and Ruhwedel (2001) find that the index of product variety that they developed is significantly correlated with TFP growth in manufacturing. A 1% increase in product variety increases TFP (relative to the U.S.) by 0.7, 0.8 and 2.5% respectively for exports, imports and total trade. The study spans the period 1990-96.

27. It is noticed that both these econometric studies are careful to emphasize that they find a positive and significant *correlation* between product variety and productivity, but they do not claim to have established a causal relationship. Thus, more research is needed in this area in order to establish whether there is a causal relationship.

Gains from product variety are not fully captured in applied models

28. The expansion of trade relative to GDP can largely be explained by deepening specialization as argued above. Furthermore, it has been found that big economies export a wider set of goods rather than larger quantities of each good (Hummels and Klenow, 2005). Both these observations suggest that expanding variety is an important phenomenon in international trade. Most applied models that simulate the gains from trade liberalization, however, assign one variety to each country in each sector. Therefore, gains from diversification of the export base or expanding the range of trading partners are not captured in these models.[11] If there is indeed a causal relationship between product variety and productivity, such gains, whether they have a level effect or growth effect, are not fully captured in these models. In other words, the static gains from trade are probably significantly larger than what is captured in most applied general equilibrium models. These are discussed in more depth in section 8.

4. Do productivity gains from trade depend on specialization in high-technology industries?

29. It has long been a concern that specializing in mature sectors with slow productivity growth could lead to a widening technology gap towards countries that specialize in high-technology sectors. Margins are low in mature sectors and leave little resources for R&D and growth goes the argument. Worse, in a free trade regime such a pattern of specialization could be locked in leaving countries that

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11 Some models allow for expanding variety within existing sectoral trade flows, but few, if any, capture new trade flows.

specialize in mature sectors further and further behind. Therefore there is a role for trade and industrial policy to foster sectors with higher productivity growth, it is contended.

30. The infant industry argument implies that there are dynamic gains from protection. The argument is clear enough in theory and has been discussed since the early 19th century. In the presence of dynamic learning effects that are external to firms (e.g. learning by doing at industry level), then there is a productivity and welfare gain from protecting the industry provided that protection is temporary, the industry becomes viable after the protection period and the net benefits provided by the industry exceed the temporary cost of protection.[12] In practice, however, it has turned out that protection tends to become permanent and that the cost of protection exceeds the benefits. A relatively recent survey of the determinants of manufacturing sector performance in developing countries argues that learning by doing is a complement to rather than a substitute for access to international technology and that the case for infant industry protection is weak judging from the empirical evidence (Tybout, 2000).

31. In spite of few documented success stories, the infant industry protection argument remains popular. It can even be argued that it is built into the WTO architecture that allows developing countries special and differential treatment partly on the ground that they need more time to develop their industries behind protective trade barriers. The rationale for infant industry protection argument rests on four assumptions:

- Sectors differ systematically in terms of productivity growth and productivity levels;
- The ranking of sectors according to productivity growth and productivity levels is constant over time;
- Patterns of specialization are persistent;
- There are no cross-border, cross-sectoral technology spillovers.

There is a large variation in productivity levels and growth rates between sectors…

32. These assumptions can be verified empirically and we will discuss each of them. The first assumption is generally verified. A recent study from the United Kingdom for instance finds large variation in productivity growth among manufacturing sectors during the period 1971-92 (Cameron at al., 2005). The other assumptions are, however, more doubtful.

…But the ranking of industries by productivity changes over time

33. The already mentioned study from the United Kingdom finds substantial changes in the ranking of industries according to total factor productivity growth as well as levels (relative to the U.S.) even during the relatively short period from 1971 to 1992. Thus, in 1970 the sector that came closest to the U.S productivity level was Machinery, while in 1992 it was Rubber and Plastics. The largest productivity gap in 1970 was in the Paper and Printing industry, while the largest gap in 1992 was in Wood Products.

34. A database that includes measures of total factor productivity (TFP) growth rates for U.S. manufacturing industries (SIC 4-digit level) during the period 1958-1996 also documents sectoral shifts in

12 See Melitz (2005) for a recent discussion. This paper comes up with a rather unorthodox policy implication arguing that quotas are often the better policy measure for infant industry protection. The reason is that an import quota would become less binding as the protected industry embarks on the learning curve. This solves the policy problem of scaling back protection over time.

the rate of growth of total factor productivity. The base year for comparing productivity growth rates is 1987 when the productivity level index is set to unity for all sectors. The 5 fastest-growing sectors between 1960 and 1987 were all in the electronics and computer industries, while the five sectors with the fastest rate of TFP decline were mainly in the low-technology sectors such as food processing and basic metal industries. However, the sector with the second to largest fall in TFP between 1960 and 1987 was production of oil and gas field equipment, a relatively high-technology sector.

35. Turning to the period from 1987 to 1996, electronics and computer industries continued to pose the highest TFP growth, but it is also noticeable that footwear (SIC 3149) ranked fourth among the highest TFP-growth sectors, while a high-technology sector such as pharmaceuticals (SIC 2834) had the third largest fall in TFP during the same period. The ranking of sectors according to TFP-growth rates has clearly changed during the period 1960-1996 as indicated in Table 1. The table should be read as follows: The TFP level of Computer storage devices increased 20.8-fold between 1960 and 1987; while the TFP level in Semiconductors and related services increased 8.2-fold from 1987 to 1996.

Table 2. The 10 manufacturing sectors with fastest growing TFP, 1960-87 and 1987-96, USA

	1960-87			1987-96	
SIC	**Name**	**TFP**	**SIC**	**Name**	**TFP**
3572	Computer storage devices	20.8	3674	Semiconductors and related services	8.2
3571	Electronic computers	20.2	3571	Electronic computers	2.9
3577	Computer peripheral equipment not elsewhere classified	19.7	3577	Computer peripheral equipment not elsewhere classified	2.1
3575	Computer terminals	15.7	3149	Footwear except rubber, not elsewhere classified	1.7
3695	Magnetic and optical recording media	5.6	3575	Computer terminals	1.7
3674	Semiconductors and related services	5.0	3661	Telephone and telegraph apparatus	1.6
3578	Calculating and accounting machines, except electronic computers	3.4	3572	Computer storage devices	1.5
3826	Laboratory analytical instruments	3.0	2121	Cigars	1.5
3827	Optical instruments and lenses	3.0	2381	Dress and work gloves, except knit and all-leather	1.5
2833	Medicinal chemicals and botanical products	2.9	2253	Knit outwear mills	1.4

Source: Calculated from Bartelsman *et al* (2000)

How you do it matters more than what you do

36. Although specialization in computers and related products clearly has contributed to higher productivity growth in the U.S. economy, it is also clear that it is possible for low-technology sectors to perform well in terms of productivity growth. Furthermore, it is likely that increased import competition has contributed to the productivity surge in the clothing and footwear sectors. As has been pointed out by several authors, the same product can be produced with different technologies and there can be high-technology segments within most sectors. Thus, the evidence points in the direction that what matters for productivity levels and growth rates are more how things are produced than what is produced.

Patterns of specialization appear not to be locked in by trade

37. Second, we look for evidence on whether the pattern of specialization is persistent in countries, and thus whether trade can lock in an unfavourable pattern of specialization. The empirical literature on this is relatively scarce, but the evidence points in the direction that patterns of specialization do change over time. Redding (2002) for instance finds that over time horizons of 10 years or more, patterns of specialization do change. The most important determinants of such changes are found to be a country's relative factor endowments. This finding implies that if a country over time has a high rate of capital

investment, its pattern of specialization will gradually change towards capital-intensive sectors. By the same token, if a country invests a lot in education, its pattern of specialization would gradually shift towards skills-intensive industries or skills-intensive activities within industries. Ito and Fukao (2004) find evidence that this has happened in Japan. They also find that the shift has been most profound *within* sectors where companies have focused on more skills-intensive *activities* while outsourcing the less skills-intensive activities to neighbouring countries such as China and ASEAN.

38. Finally, as further discussed in section 7, there is evidence of technology spillovers across sectors and international borders. These are particularly likely to be found in international production networks where lead firms have an interest in helping their suppliers to produce the right quality as effectively as possible. If there are cross-sectoral technology spillovers, then the productivity gap between trading partners will not widen (Nordås, 2000).

39. These results suggest that the fears of being locked into an unfavourable pattern of specialization in a free trade scenario are exaggerated. Admittedly the empirical evidence so far only covers a few countries, but it strongly suggests that if a country wishes to specialize in higher value added sectors, it needs to invest in human and physical capital as well as R&D. If it does, comparative advantage will shift and so will industrial structure and trade patterns. The fear that productivity gains from trade will only accrue on the countries that have comparative advantage in high-technology sectors and whose firms are competitive in these sectors is not supported by empirical evidence.

Are clusters a new impetus for a more active trade and industrial policy?

40. The existence of so-called clusters or industrial agglomeration has been another argument for fostering certain sectors in order to improve productivity and competitiveness.[13] If a sector has strong backward and forward linkages to other sectors, its establishment could induce investments in related sectors that could reduce the cost and improve productivity of all firms involved as the number of firms in the cluster expands. This is essentially the gains from specialization through expanding variety argument discussed in sections 2 and 3 adding technology spillovers and the pooling of skills. The argument rests on the assumption that proximity is important for reaping the benefit from forward and backward linkages and spillovers. Clusters became a hot topic in the early 1990s following Michael Porter's (1990) work.[14] A large body of empirical research has assessed the importance of clusters and to what extent trade policy measures could be used to foster them.[15]

41. The existence of clusters is of course beyond doubt but the trade policy consequences are not clear. It appears that clusters form in most sectors, and are based on a location's natural or acquired comparative advantage. Subsidizing or protecting the core industries in a cluster do not necessarily yield the desired result of creating backward and forward linkages. Furthermore, it appears that attempts to duplicate successful clusters, for instance Silicon Valley, has been successful only when they build on existing local comparative advantage. Thus, a recent study finds that it is beneficial for a country to specialize in a sector subject to clustering only if it has a (potential) comparative advantage for this sector. Furthermore, price-distorting trade policy measures are unlikely to have the desired effect, particularly if the targeted industry can adopt several types of technology, some of which may have few externalities and

13 Clusters are a geographical concentration of firms that are vertically and horizontally related through buyer-supplier relationships and drawing on the same pool of skills and supporting infrastructure and related services.

14 In an international trade and growth context, the cluster-argument was explored by Krugman and Venables (1995) who found that the world economy organizes into commodity-producing relatively poor countries and more prosperous countries hosting industrial clusters at intermediate levels of trade costs, while at very high or very low trade costs this pattern disappears.

15 See Rosenthal and Strange (2004) for a review.

clustering effects. A better policy according to this study is to support agglomeration forces directly by reducing transaction costs and for developing countries perhaps attracting FDI in sectors that produce key inputs (Rodriguez-Clare, 2006). Key sectors could for instance be services that provide essential inputs to all sectors (see Box 3).

If clusters are needed for technology spillovers, the prospect for international technology spillovers looks bleak!

42. Whichever trade policy implications one might draw from the cluster literature, the very existence of agglomeration forces creating geographically concentrated clusters are discouraging from the point of view of dynamic gains from trade. We recall that the most likely sources of dynamic gains from trade are knowledge and technology spillovers and access to a broader variety of inputs. If such spillovers are localized in scope to the extent suggested in the cluster literature, dynamic gains from technology spillovers are less likely, particularly in trade among distant trading partners.

Box 3. Dynamic gains from trade and key services sectors

Two services sectors have attracted attention as possible engines of economic growth – the financial sector and more recently telecommunications. Both sectors provide inputs to all other sectors in the economy and in addition they provide essential inputs in the conduct of international trade. For both sectors the literature suggests that there is a positive relation between trade openness and performance of the sector.

A study of a large number of banks in 80 countries over the period 1988-1995 found that foreign presence in domestic banking markets had significant impacts on the domestic market (Claessens et al., 2001). First, it was found that foreign banks had lower interest margins, lower profits and lower overhead expenses than domestic banks in developed countries, suggesting that they have more effective operations. Second, it was found that the presence of foreign banks reduced the profitability, non-interest income and overall expenses for domestic banks, suggesting that they become more efficient too. Third, it was found that the impact on domestic banks occurred very soon after the entry of the foreign bank. Provided that the foreign bank entry does not squeeze margins in local banks to the extent that the financial system becomes less stable, financial sector liberalization was found to improve the performance of the financial sector in developed countries. In developing countries, in contrast, foreign banks had higher margins and profits than local banks, a feature that is attributed to lighter regulation and less competition facing foreign banks in developing countries. Nevertheless foreign banks provide access to international financial markets and new products in developing countries (Clarke et al., 2005).

Other studies have found that financial development has a positive impact on economic growth (Levine et. al., 2000; Edison et al., 2002). Thus, if trade liberalization improves the performance of the financial sector and improvements in the financial sector have a positive impact on economic growth, there are indirect dynamic gains from trade liberalization in the financial services sector. However, although the studies on the linkages between financial sector development and growth are rigorous and well documented, financial development is not among the variables that are robustly associated with growth in the meta-analysis referred to in section 2 of this study.

A host of studies have analysed the impact of liberalization, internal and external, on the performance of the telecommunication sector, and all find a large and significant impact (OECD, 2006). Röller and Waverman (2001) find that telephone density has a relatively large impact on economic growth in the OECD countries during the period 1970-90. But again one should be cautious and factor in the possibility that this might have been a temporary effect during a period of rapid developments in the telecommunication sector.

43. Summing up this section, endowments of human, physical, infrastructural and institutional capital determine what is being produced in a country and by which technology. The most effective policy measures aiming at stimulating productivity gains from trade are strengthening human, infrastructural and institutional capital accumulation rather than protecting high-technology industries or engineering clusters.

5. What are the relations between trade and investment?

44. Although the role of capital accumulation has been downplayed in new growth theory, it still holds a central place in the growth process. Levine and Renelt (1992) find that only two variables are robustly related to growth in cross-country growth regressions. They show that there is a positive and robust correlation between growth and the share of investment in GDP and between the investment share and the ratio of international trade to GDP. It illustrates both the importance of capital accumulation in growth and the interactions between trade and investment. Trade can affect the returns to capital in several ways and is thus expected to have an influence on growth through the way it alters capital accumulation. Foreign direct investment, although generally representing a small share of total investment, has been found to have also a positive impact on capital accumulation. In this section of the paper, we examine the links between trade, investment and productivity.

Trade liberalisation moves capital where it is the most efficient and increases the aggregate level of productivity of the economy

45. Trade liberalisation shifts capital towards sectors with the highest productivity, where the country has a comparative advantage. Capital will be more efficient in these sectors and the overall economy has its productivity level increased. This reallocation of capital is encouraged by the pro-competitive impact of trade liberalisation. When the economy opens to trade and foreign companies enter the domestic market, the least productive domestic firms are forced to exit. Not only do firms compete on the product markets but also to have access to the best resources on factor markets (Melitz, 2003). Studying the productivity of Chilean manufacturing plants during the trade liberalisation period of the 1970s and early 1980s, Pavcnik (2002) shows that exiting plants are on average about 8% less productive than surviving firms. This reshuffling of resources increases the aggregate industry-level productivity in the export and import-competing sectors. In Pavcnik's empirical study, the aggregate productivity is found to increase by 25.4% in the export-oriented sector and by 31.9% in the import competing sectors over a period of seven years. By comparison, the gain was 6% in the nontraded goods sectors. This shift of resources does not always imply that firms have to close down. They can also switch to more productive industries (Bernard, Jensen and Schott, 2006).

Trade liberalisation can encourage capital-deepening

46. At the level of each sector, there are several mechanisms that link trade liberalisation to capital deepening[16]. First, trade liberalisation helps countries to better exploit scale economies. Through trade, open countries have access to larger markets for their exports and can specialise in products with increasing returns to scale in capital-intensive sectors. Scale economies are generally found in sectors with high capital costs where production becomes efficient if fixed costs can be spread on a sufficient number of units of output. The extent of the market has thus an impact on the level of investment. When a country opens to trade, the entry of new firms on export markets is likely to induce large fixed investments (Wacziarg, 2001).

47. Trade liberalisation then facilitates the importation of cheaper foreign-produced intermediate goods and services. It also tends to lower the price of capital goods and services in the domestic economy and to increase the efficiency of capital. The relative price of investment goods (that is, relative to the price

16 . The factor proportions theory of international trade predicts that under free trade a country abundant in capital exports capital intensive goods, while a labour-abundant country exports labour-intensive goods. This result is known as the Heckscher-Ohlin theorem. It should be however stressed that it is the relative factor intensity that matters here. Both countries can become more capital-intensive in their export sectors while the capital abundant country has still exports *relatively* more capital intensive.

of other goods in the economy) is negatively correlated with investment rates, as established by Restuccia and Urrutia (2001) in a cross-section of countries. Trade liberalisation leads to a relative price change that favours capital-intensive goods.

48. Lastly, there are also several competitive effects that reinforce the mechanisms describe above and encourage firms to increase their capital intensity and their productivity. A higher degree of competition means lower prices because price-cost margins are lower. It leads to an increased output for a diminished number of firms after the exit of the least productive firms. These firms are in competition on larger markets and are more capital-intensive (Bernard et al., 2006). More competition in the capital goods and services sector is similar to the mechanism described before where cheaper foreign-produced capital goods (and services) lower the price of capital. Last but not least, competition in the financial intermediation sector is also likely to improve capital accumulation. Trade in financial services can improve the efficiency of capital allocation and puts competitive pressures on domestic banks to lower their costs (see Box 3).

Capital goods that embody foreign technology have an important role in increasing productivity

49. Capital goods can embody foreign technologies and in this case the gain in productivity is similar to an increase in total factor productivity and can be described as "investment-specific technological change" (Greenwood, Hercowitz, and Krusell, 1997). This gain is not sizeable without investment and without trade liberalisation in capital goods, as the production of capital equipment is concentrated in a very limited number of R&D intensive countries. According to Sakellaris and Wilson (2004), embodied technological change could account for as much as two-thirds of TFP growth in US manufacturing plants.

50. Lee (1995) provides empirical evidence that the ratio of imported capital to domestically produced inputs is associated with higher per capita growth rates. Eaton and Kortum (2001) estimate that about 12% of cross-country productivity differences can be explained by barriers to trade in capital goods that inhibit the diffusion of embodied technological change.

Has capital accumulation a long-run effect on growth?

51. By changing the return on investment, trade liberalisation can lead to a higher investment rate and hence a higher growth rate in the transition that follows trade liberalisation. But is it a temporary effect or can investment have an impact on long-run growth? The accumulation is transient if the increase in the stock of capital diminishes the returns but it can be permanent in the absence of diminishing returns. Endogenous growth theories have investigated several cases of long-run returns to capital that are constant, for example when trade results in a higher efficiency in producing capital-goods or as a consequence of increased competition in the knowledge-creation sector (Grossman and Helpman, 1991). Caselli (2005) presents evidence of such a long-run effect of capital accumulation on growth. However, it should be kept in mind that the debate is more theoretical than practical as "long run growth" is a theoretical concept and a very long transition to the steady state could be similar to a "long term" outcome.

52. These mechanisms of investment-led growth where investment has been encouraged by trade are less studied in the literature as compared to knowledge spillovers and the impact of FDI on productivity growth. However, it should be stressed that when investment is controlled for, there is almost no additional impact of trade on growth (it is a result often stressed in studies on the robustness of growth regressions that the investment variable captures most of the positive effect attributed to trade indicators when investment is not controlled for). Moreover, productivity gains from trade not related to investment but to knowledge spillovers are difficult to track down (see section 6). As trade influences the accumulation of capital, trade liberalisation can have a dynamic effect on output and welfare. It can be theoretically established in the framework of neoclassical growth theory as an impact on the steady state level of capital,

as well as in new growth theories as an impact on long-run growth. These results suggest that a key area of future research into dynamic gains should focus on the relationship between investment and productivity.

Trade can enhance the productivity gains from FDI[17]

53. Foreign direct investment is a form of long term movement of capital that complements (or sometimes substitutes for) the domestic accumulation of capital. Although FDI could increase the rate of investment in the domestic economy, thus participating in the dynamic gains previously described, the share of FDI in total investment is typically small. The reason why FDI is specifically studied in the literature on trade and growth is that there could be a complementary relationship between trade and FDI with a potential positive impact on productivity[18].

54. Bhagwati was the first in 1973 to introduce the idea that the trade regime conditions the gains from FDI in host countries. He advanced the hypothesis that the growth impact of FDI was higher in the case of export-promotion policies than for import-substitution policies. Since this seminal work, theories have been refined and evidence has been accumulated that indeed trade policies influence the gains from FDI. However, it should be made clear at the outset of the analysis that the relationship is not as simple as it may seem with open trade policies leading to productivity-enhancing FDI and protectionist policies preventing countries from reaping the benefits of FDI. Theories have circumscribed specific cases where trade and FDI could worsen the productivity of domestic firms.

55. The question of the gains from FDI is mostly an empirical question as FDI can be found to have a positive or a negative impact on the productivity of domestic firms. For example, Girma and Görg (2004) in an empirical study on UK manufacturing establishments highlight that the effect of foreign acquisition on productivity differs between sectors. They find that FDI in the electronics sector has reduced productivity whereas it has increased productivity in the food sector.

56. Firstly, trade and FDI can positively impact the level of productivity of domestic firms. Trade liberalisation can influence the type of FDI attracted in the domestic economy. Trade together with investment liberalisation encourages resource-seeking and efficiency-seeking investment with foreign firms rationalising production and maximising scale economies. High trade barriers would on the contrary encourage tariff-jumping FDI with foreign companies investing rather than exporting to get around trade barriers. Such investment is likely to result in foreign companies producing only for the domestic market and trying to gain market power (as foreign firms benefit from the trade protectionist policies once they are established in the host economy).

57. The reduction of barriers to trade and the entry of foreign firms in the host economy also increase the level of competition in domestic markets and lower the price-cost margins of domestic producers[19]. As discussed before, it can either drive domestic firms out of the market or force them to restructure and to increase their productivity. In both cases, the sector productivity is increased but domestic firms may or may not stay in the market. And in the case they stay in the market, their productivity can also be reduced

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17 Only the gains that are not related to knowledge and technology diffusion are discussed in this section. The linkages between trade, FDI and technology transfer are explored in section 6.

18 In classical trade theory, trade and FDI are regarded as substitutes. From an empirical point of view, they are indeed substitutes when one looks at the data at a sufficient level of disaggregation (Swenson, 2004). However, FDI in a four-digit industry is complementary to trade in another four-digit industry (see Markusen, 2002). The complementary relationship which is described in this section is of a different nature. It assumes that trade liberalisation and FDI will together have a positive impact on domestic productivity.

19 An assumption is that the entry of foreign firms and exit of domestic producers do not result in a more concentrated market. But this should not be the case when both trade and FDI are liberalised.

if there are firm-level scale economies and important fixed cost and domestic companies have a smaller share of the market. The impact of competition will also depend on the difference in the initial productivity levels. When foreign firms and foreign products enter a sector that is technologically “backward” they are more likely to drive out domestic firms, whereas the effect of competition in sectors where productivity levels are close will enable domestic firms to catch up.

58. Although empirical evidence is not always conclusive, there is an array of evidence pointing to potential productivity gains from trade and FDI in an economy that opens to trade. And it is important to take into account the gains which are not related to technology transfer to fully understand the relation between trade and FDI.

6. What are the relations between trade and R&D?

59. This section discusses the third channel identified earlier; the relation between trade and investment in R&D. It starts by discussing the possible relation between trade and incentives to invest in R&D under the assumption that innovating firms sell products that embody their innovations. Second, it discusses trade and incentives to invest in R&D when the innovation itself is the product that is sold to the market, including in international markets, e.g. through licensing. Section 7 below discusses the relation between technology spillovers and trade, but to the extent that technology spillovers affect local investment in R&D, it is also addressed in the current section.

Private R&D expenditure is motivated by expected profits

60. Private firms engage in R&D in order to develop new products or processes, motivated by expected profits. Innovators are rewarded with a temporary monopoly for the new product or lower costs of production than their competitors, depending on whether the innovation is a product or a process. The expected profit from the innovation depends on market conditions such as the size and competitiveness of the market, and how well intellectual property rights are protected.

61. Roughly speaking competitiveness determines the mark-up over (marginal) costs that the innovating firm can charge, protection of intellectual property rights determines for how long the firm can charge this mark-up while the size of the market determines how many units the mark-up can be earned on at each point in time. In addition the market size is also a factor in determining for how long the innovator can charge a premium in the market. The larger the market, the more competitors and the more likely it is that one of them will come up with a new innovation that makes the existing state-of-the-art obsolescent. This point refers to so-called Schumpetarian creative destruction.

Trade leads to lower margins, but higher volume – the net effect on profits is uncertain

62. A recent British study (Greenhalgh and Rogers, 2006) find empirical evidence that more competitive markets are correlated with a lower return on R&D investments while market size is correlated with a higher return. This study also found that the impact of R&D on market value varies substantially between sectors and attribute this variation to differences in the competitiveness of markets. The results suggest that innovating firms can earn a handsome profit both in relatively small, protected markets and in large, competitive markets - and of course even more profits in large and protected markets. When the domestic market is small to medium size, trade policy involves a trade-off between large margins and small volumes and small margins and large volumes.

Protection of intellectual property rights yields higher margins…

63. The above mentioned British study also provides useful insights into a possible trade-off between protection of intellectual property rights and technology diffusion. The study found relatively large

differences in return to R&D among sectors. The highest return was found in the industries classified as "production-intensive, scale", followed by "information-intensive" sectors, while the lowest return was found in "science based" and "software-related" sectors.[20] They suggest that a possible explanation for the difference between sectors is that technology more easily spills over to competitors in the low-return sectors. Thus, science-based sectors build on research in the public domain e.g. in universities and software may be difficult to protect.

64. Technology spillovers occur when technology flows across sectors and national boundaries as an unintended side-effect of R&D investments or other forms of knowledge accumulation, for instance resulting in early imitation of technology. There is then the possibility that R&D spillovers related to trade and FDI may discourage domestic investments in R&D both in the source country of the spillover and the recipient. In the source country spillovers may undermine the return to investment in R&D. In the recipient country "free-riding" on foreign R&D expenditure could discourage local innovations.[21] Striking a balance between sufficient incentives to innovate and technology diffusion is of great concern to policy makers. Intellectual property rights have been introduced in international trade agreements, including the trade-related intellectual property (TRIPS) in the WTO, in order to balance the interests of the innovators and the economy at large.

65. In the presence of technology spillovers investors will not fully capture the benefit of their R&D investments resulting in underinvestment in R&D compared to the social optimum. The social optimum can be established by subsidizing R&D expenditure, which in fact most countries do. With international trade in R&D (e.g. "blueprints") and international technology spillovers, the effect of subsidies on R&D expenditure and welfare is more complex. Large countries with a strong comparative advantage in R&D could under some circumstances hurt themselves through a negative terms of trade effect if they subsidize R&D (Engers and Mitchell, 2006).

…and the emergence of an international market for innovations

66. The optimal balance between intellectual property protection and technology diffusion may shift in the direction of intellectual property protection if efficient markets for innovations are developed. In that case the innovator can realize the market value of the innovation directly through licensing. When innovations become tradable, R&D and production can be separated and located in different countries where most OECD countries have a comparative advantage for R&D services. Therefore, a development towards an international market for innovations should lead to a shift of resources towards R&D in skills-abundant countries and a rising share of R&D in GDP. Net exports of royalties and license fees for selected OECD countries are depicted in Figure 2 below.

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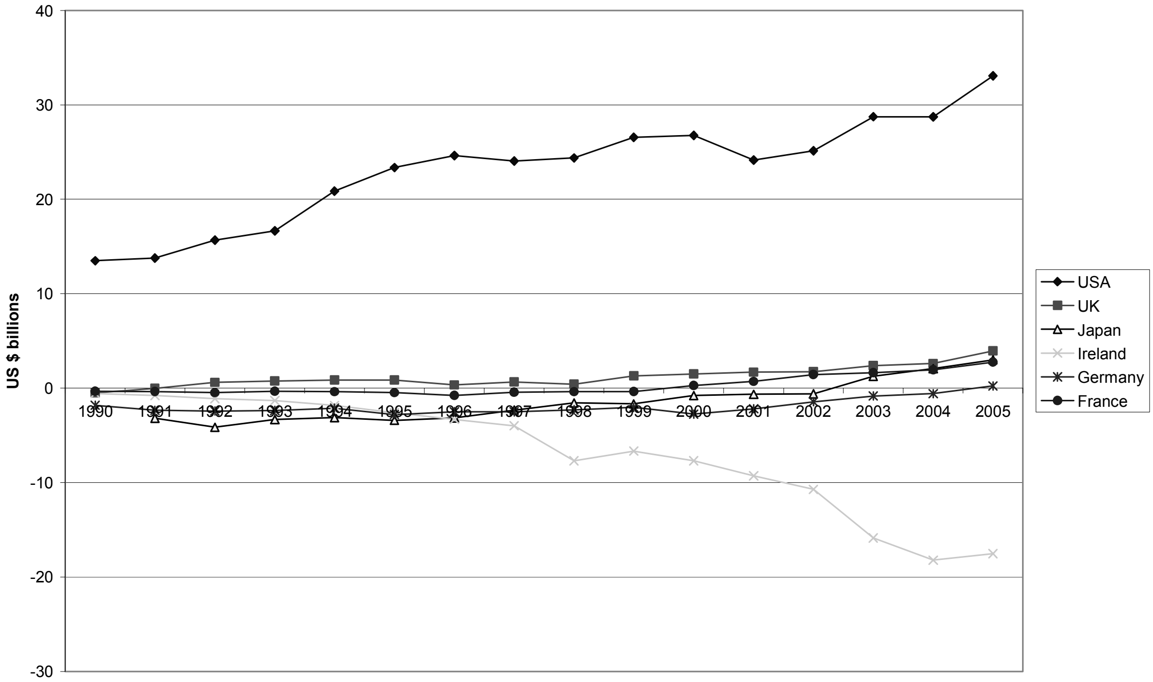
20 This is a classification system developed by Pavitt (1984) and has been widely used in R&D and technology policy analysis. Software firms and information-intensive sectors have been added to Pavitt's original classification and the latter includes services sectors such as finance, retail, communication and publishing.

21 If local R&D expenditure in technology laggards duplicate innovations already made, this may improve global welfare.

Figure 2. Net exports of royalties and license fees, U.S. $ billions



Source: IMF Balance of Payment Statistics

67. The United States is by far the largest net exporter of innovations as measured by royalties and license fees. All the other countries included in the figure were net importers in 1990. However, as the international market for innovations has developed, all except Ireland has become net exporters. The United Kingdom was first to cross the line in 1992 and Germany last in 2005. It is also interesting to note Ireland's substantial deficit in royalties and license fees during a period of stellar growth performance. Technology transfer through the market channel has undoubtedly contributed to its growth. Thus, trade in innovations not only benefit the exporter, it also has substantial advantages for importers.

68. The share of R&D in GDP has indeed increased in the OECD countries from 1.92% in 1981 to 2.26% in 2004.[22] But it has also increased in non-OECD countries. China, for instance still specializes mainly in labour-intensive industries and the country is a large recipient of investments from the OECD countries, mainly in labour-intensive activities. Yet its R&D share of GDP increased from 0.74% in 1991 to 1.23% in 2004. However, as long as the OECD countries are *relatively* abundant in human capital, they will still have a comparative advantage in R&D, and a larger R&D share in GDP in an open international market for innovations.

Financial markets have a key role in private sector R&D

69. We finally note that the workings of the R&D channel depend to a large extent on the depth and efficiency of financial markets, which in turn is affected by the sectors openness to international trade (see Box 3). R&D is an activity in which success is uncertain and in the absence of adequate financial instruments, it can be difficult to fund R&D activities.

22 The data are for the OECD as a whole and come from Source OECD Science and Technology Statistics.

70. To sum up this section, the relation between trade and R&D is complex. On the one hand trade is likely to lower margins and increase the number of imitators – discouraging private investment in R&D. On the other hand, trade provides a larger market from which to recoup R&D expenditure and in addition opens up a large market for licenses – encouraging R&D provided that intellectual property is adequately protected. If the second effect dominates, trade may contribute to a rising share of R&D in countries relatively abundant in human capital. Empirical evidence on the linkage between trade liberalization and R&D is, however, scant.

7. What are the relations between trade, FDI and technology diffusion?

71. We now examine the fourth channel through which dynamic gains can accrue. International technology diffusion through trade has been the focus of much debate in the last decade. Since the work of Rivera-Batiz and Romer (1991) and Grossman and Helpman (1991), a number of theoretical and empirical studies have investigated how trade and FDI can spread technologies between countries and increase productivity in the long-run equilibrium or during transitional dynamics[23]. Although many theoretical linkages have been proposed, the empirical evidence is more elusive, in particular when it comes to the relationship between trade (or FDI) and productivity growth.

In theory, sectors exposed to trade should have a higher total factor productivity through technological spillovers related to trade

72. The economic literature has investigated several sources of linkages between trade and productivity growth through technological spillovers. Although firms involved in international trade should be the direct beneficiaries of technology diffusion, the concept of spillovers imply that other firms in the same sector or even nation-wide can also have a higher productivity because the average stock of knowledge of the sector or of the economy has increased. Knowledge spillovers are externalities. They can be described through three learning effects that can increase total factor productivity:

- "Learning-by-doing" effects are a by-product of ordinary production and measure the role of experience in increasing productivity. Learning-by-doing effects, which have been the cornerstone of the import-substitution trade policies (see section 4), are in fact more likely to be stronger in an open economy because of the higher degree of specialisation resulting from trade. If as a consequence of trade liberalisation, a country specialises in sectors where there are more economies of scale, there will be also more opportunities to learn (Ades and Glaeser, 1999). The gains from specialisation and scale economies described in section 1 can be complemented by technological externalities resulting from learning by doing effects. These technological spillovers increase the productivity of sectors whose production has been enlarged because of trade.

- "Learning-by-importing" effects are the consequence of the exposure to foreign goods and services. Through imports, domestic producers have indirectly access to the foreign stock of knowledge and can draw on this stock to increase their productivity. While all kinds of goods and services can incorporate some form of knowledge that can be diffused through trade, the focus has been on technologies embodied in intermediate goods because these goods generally incorporate the latest technology and are used by domestic companies in their production process. Ethier (1982) was the first to suggest that intermediate goods can be a substitute to technological progress. Through imports of intermediates it is possible to benefit from the knowledge accumulated in partner countries and it can be unnecessary to invest in R&D to develop this same knowledge.

[23] See Keller (2004) for a review.

- "Learning-by-exporting" effects point to a relationship between exports and the productivity of firms. Exporting firms can learn from the expertise of their foreign buyers and are in contact with buyers and competitors using more advanced technologies in foreign markets. They have also strong incentives to be at the technological frontier and to sell cutting edge products. Foreign customers can even be active in diffusing their technologies to new (and cheaper) suppliers, for example to reach the quality standards required.

73. These three learning effects also correspond to three types of interactions between trade and technology. In the case of learning-by-doing, the unique role of trade is to increase the size of markets and the scale of specialisation with positive spillovers on the domestic production of knowledge and accumulation of experience. There is also a potential impact from trade on the composition of production, as specialisation switches from sectors with low technological spillovers (e.g., primary goods) to sectors with important learning-by-doing effects (e.g., low-tech manufacturing goods). In the case of learning-by-importing, it is the foreign technology that is used or imitated. The role of trade is to carry over foreign technologies within the domestic economy or to let domestic firms improve their own technologies or products through "reverse engineering" and imitation. Lastly, while exporting firms can also learn by observing their competitors on international markets, the driving force of "learning-by-exporting" would be the incentives to reach the same efficiency as competitors and hence to adopt their technologies.

A positive relationship between trade and productivity growth can also be expected at the firm level as well as the aggregate level

74. While the interactions described above can certainly increase productivity levels (at least for firms exposed to foreign trade), new growth theories assume that they can also lead to a permanent change in productivity growth. The key mechanism can be represented through the addition of a fourth type of learning effect: "learning-to-learn". While domestic producers are in contact with foreign products or foreign buyers, they can learn how to further increase their productivity not only by using the available technology but by improving their own technologies at a higher rate than before. Another mechanism linking trade and productivity growth at the firm level is the "competitive push" as an incentive to innovate. Firms have incentives to use better inputs and to adopt more rapidly foreign technologies. In that sense, the impact of trade could be on productivity growth rather than just the productivity levels.

75. At the aggregate level, models of economic growth that assume that total factor productivity increases in proportion to the stock of knowledge also predicts a positive relationship between trade and productivity growth if trade enlarges the stock of knowledge. It depends on the assumptions made on knowledge, as an international stock of ideas shared by every country or as a national stock with ideas not crossing borders. In this later case, trade is one way to increase the domestic stock of knowledge and bring about a permanent increase in TFP.

Empirical studies point to non-negligible knowledge spillovers from trade but the specific role of imports in technology diffusion is still debated

76. At the aggregate level, empirical studies point to a positive relationship between trade and TFP growth (see discussion in section 1). It can be explained by the reallocation of production in sectors where the productivity growth rate is higher. Although it can also support theories where trade increases the domestic stock of knowledge and productivity growth is stimulated across all sectors, the recent empirical literature stresses the heterogeneity of TFP levels and growth rates, not only between sectors but also among exporting firms (Bernard and Jones, 1996; Bernard et al., 2003). This literature is sometimes difficult to reconcile with a systematic link between trade and productivity growth.

77. Technology diffusion through imports has been studied in the context of R&D spillovers where the increase of the foreign stock of knowledge has a positive impact on domestic TFP through imports. While Coe and Helpman (1995) have proposed evidence on the positive impact of import-weighted foreign R&D on the productivity of OCED countries, Keller (2004) shows the fragility of the result that can be also obtained with randomly created import shares. An indirect transmission of technology has been studied by Lumenga-Neso, Olarreaga and Schiff (2001) where it is not necessary to import directly from the innovating country to benefit from its R&D as long as trade can take place with third countries which import from the innovating country. The existence of knowledge spillovers is not called into question in these studies but the specific role of imports in the diffusion process is still not fully understood.

78. The East Asian growth miracle has provided many examples of imports of high tech goods and imitation of developed countries technologies by developing countries that are now the technological leaders in these same technologies. Beyond this anecdotic evidence, Connolly (2003) shows in a sample of developing countries that domestic imitation and innovation are both positively correlated with high technology imports of developed countries. Several studies have also found a positive relationship between imports of capital goods and an increase in the level of TFP. But there is no sign that imports of capital goods also increase the TFP growth rate. For example, Savvides and Zachariadis (2005) show that imports of machinery have no significant effect on the TFP growth rate of the manufacturing sector in a panel of 32 developing countries.

79. Learning by importing is certainly a good candidate as a channel between increased trade and productivity growth. But the fact that imported capital goods are found to be the ones with potential technological spillovers takes us back to the role of trade and investment rather than trade alone in the diffusion of technology.

There is evidence of higher total factor productivity in exporting sectors and firms but it is not clear that trade boosts intra-firm productivity growth

80. Regarding a possible "learning-by-exporting" effect, there is evidence that exporting sectors have a higher *level* of productivity but not always a higher productivity *growth*[24]. Moreover, the causality in this relationship is debated as it could be the result of a selection effect where only the most productive firms are likely to sell on world markets. The fact that productivity growth can be associated with exports is not a sufficient evidence of a causality going from exports to productivity growth as firms can also target world markets when they anticipate improvements in their productivity. All studies highlight that more efficient producers self-select into export markets.

81. At the firm level, there is some evidence that TFP is higher after a firm starts to export, thus suggesting a positive impact of trade on firms' productivity rather than a selection effect. Fernandes and Isgut (2005) find evidence of learning-by-exporting in Colombian manufacturing firms, in particular for young plants that export to high-income developed countries. It is one of the few studies finding a significant relationship between entry in export markets and intra-firm productivity growth rates[25]. Most studies find however that exporting firms have higher TFP levels. For example, Aw et al. (2006) show that export experience leads to higher productivity in the case of Chinese Taipei manufacturing firms. While exporting firms are found to be more productive, exporting firms that have also invested in R&D are even more productive, suggesting a complementary role of exports and investment in R&D.

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24 See Greenaway et al. (2005) for a recent review of empirical studies.

25 Baldwin and Gu (2003) also find that export-market participation is associated with greater productivity growth in Canadian manufacturing firms. They also show that the importance of export markets for productivity growth has increased over time.

82. However, Greenaway et al. (2005) find no conclusive evidence of a productivity difference between exporting and non-exporting firms in Sweden. A possible explanation is that the Swedish economy is so open that almost all firms compete with other firms engaged in export activity or with imports. In the presence of technological spillovers, it is not only the exporting or import-competing firm that should have a higher productivity but all firms in the sector, the region or the economy (depending on the assumption made on the scope of spillovers). Clerides et al. (1998), who have also inconclusive results about a "learning-by-exporting" effect at the firm level, do find evidence of positive regional externalities. In regions where export activity increases, production costs become lower for all firms and not only for exporters.

83. The key point to note from this sub-section is that while there appears to be some correlation between exporting and firm-level productivity levels, it is difficult to identify causation.

FDI, vertical specialisation and outsourcing have changed world production and have created more opportunities for technological diffusion

84. The relationship between trade and technology transfer cannot be fully understood without introducing foreign direct investment and the role of multinational corporations in international trade. Foreign direct investment is generally considered as the main channel of international technology diffusion. The reason is that FDI creates many interactions between foreign and domestic firms that can be opportunities for technology to be diffused. FDI not only places foreign technologies right in the host economy where they can be studied, where domestic workers can learn from them and where they can be used as inputs for domestic production, but FDI also gives incentives for the foreign firm to actively diffuse its technology in order to improve the supply of its inputs or to create a market for its products. The literature[26] usually distinguishes between backward linkages (with domestic suppliers), forward linkages (with customer firms and firms down the production chain) and horizontal linkages (with competing firms). Although it may seem odd for a company to develop linkages with its competitors, it is sometimes a rational strategy to create a market for the final products or for suppliers to reach the appropriate scale economies. A foreign firm may be more interested by exports markets and be pleased with competition in the host economy. Table 3 summarises the different interactions between domestic and foreign companies with potential technological spillovers for the host economy.

85. The specific role of multinational enterprises (MNEs) in technological spillovers from trade and FDI comes from: (1) their more advanced production methods using "frontier technology"; (2) their network of international suppliers, customers and contracting firms, involving contacts with skilled people all over the world with knowledge sharing and international training programs; and (3) their intangible assets that are the source of their value creation (e.g., management and marketing know-how). Recently, the focus has been on the role of vertical specialisation and the fragmentation of world production. Production processes have dramatically changed in the last two decades. A first phenomenon is the apparition of sequential, vertical trading chains with the fragmentation of production across many countries, each specialising in a particular stage of the production sequence. It has been made possible by the reduction in transport and communication costs and trade barriers. Today vertical specialisation explains 21% of world trade (Hummels et al., 2001). It has increased FDI flows and intra-firm trade in a complementary relationship and has encouraged many of the interactions described in Table 2.

[26] See Saggi (2002) for a review.

Table 3. A typology of the interactions between domestic and foreign companies with potential technological spillovers for the host economy

Type of interaction	Backward (with suppliers)	Forward (with clients)	Horizontal (with competitors)
Direct transfer of knowledge	Technology transfer contracts with suppliers Training programs for suppliers Assistance to reach the standard set by the MNE	Training in the use of inputs produced by the MNE Licensing and technology transfer contracts to use the technology of the MNE Externality from the inputs produced by the MNE	Imitation, reverse engineering, demonstration effects
Incentives for local firms to increase their productivity	Competition between suppliers to sell products and services to the MNE. Incentives from the MNE to improve quality, diminsh prices or time to produce	Competition between domestic firms to become a client of the MNE. More advanced technologies required to use the inputs produced by the MNE and requiring a technological upgrade.	Increased competition with foreign firms.
Indirect transfer of knowledge	Labor turnover between the MNE and its suppliers Former employee of the MNe creating its own company as supplier.	Higher productivity through better inputs and services produced by the MNC (embodied technologies) Labor turnover and former employee of the MNE creating a client firm	Labor turnover and former employee of the MNE creating a competing firm.
Scale effects	Scale economies among suppliers from the increased demand of inputs with the entry of MNEs	Productivity gains through cheaper inputs produced by the MNE (scale economies of the MNE transmitted to domestic producers).	Scale economies through new export markets where domestic firms can sell following the example of the MNE

86. A second phenomenon that has changed world trade and has encouraged the diffusion of technologies through trade is the development of international outsourcing. It is closely related to vertical specialisation and the emergence of global value chains as firms have outsourced in foreign countries part of their production process to cut their costs and improve their efficiency. The difference is that international outsourcing creates trade flows instead of FDI flows. It generates services trade when the outsourced activity is performed by another company in another country. There is however a relationship between trade, FDI and outsourcing as most of the companies that provide outsourced services to MNEs are subsidiaries of these MNEs or domestic firms that have benefited of the technological spillovers from these MNEs in their country. The textbook case is business-process outsourcing services in India. The BPO sector in India has developed through FDI of foreign firms (in particular US firms) in information technology sectors. Outsourcing has significantly contributed to the increase in the growth of intermediate inputs trade and thus to the potential technological spillovers from this type of trade. The fragmentation of world production and the new organisational forms of international sourcing have created a more complex trading system where the interactions and technological spillovers presented in Table 2 are more likely to happen. But theories have still to be developed to provide a global assessment of their impact on trade and growth[27].

87. It should be emphasised that most of the technological spillovers from FDI described in Table 2 would not happen without an open trade policy. To begin with, the MNE would maybe not invest in the host economy. If driven by market-seeking motivations, the foreign investment would not translate into the

27 A first assessment of new theoretical and empirical work on trade, FDI and the organisation of firms is provided by Helpman (2006).

same type of interactions because the foreign firm once established would try to benefit from its market power (she would be protected by the high trade barriers that justified its establishment and would not aim at international exports but at extracting rents from the domestic market).

88. Moreover, analysis of FDI and productivity can be confusing as spillovers are often not clearly identified. A spillover effect implies an externality: an increase in the productivity of the domestic firm that is greater than the price paid by the firm to benefit from the new technology (the social value is greater than the private value). It is not always possible to distinguish the spillovers from those productivity gains that are "paid for". A domestic company can employ a former manager of an MNE but there is no "spillover" if the wage paid includes the knowledge externality or if the new employee has no positive influence on knowledge-creation in his new company. It is where the distinction between an increase in the level of productivity and the productivity growth rate matters. The transfer of knowledge needs to be associated with positive externalities if one expects labour mobility to be associated with a higher productivity growth rate[28].

The evidence on FDI and technology diffusion is mixed but hints at potential positive spillovers for domestic firms

89. As with the impact of trade on productivity, empirical studies on FDI and technology diffusion are confronted with a selection bias. Sectors where FDI is important are generally those where productivity is the highest and productivity growth strong. Firms will tend to invest in sectors with the most promising growth rate and will pick the best companies in the host country which are likely to be the most productive. Moreover, with imperfect competition and scale economies, the impact on domestic firms of the entry of foreign companies is twofold. On the one hand, domestic firms can expect productivity gains through technological spillovers. On the other hand, the increased competition from foreign firms diminishes the production of domestic firms and increase their average costs (market-stealing effect). As a consequence, the net impact of FDI on productivity can be either positive or negative and market structure matters.

90. Aitken and Harrison (1999) measure plants productivity in Venezuela and find that technological spillovers from FDI are rather modest. Backward vertical spillovers and horizontal spillovers are found to be significant and robust but there is no evidence of forward vertical spillovers. The spillovers are stronger in companies whose equity is shared between domestic and foreign producers. Javorcik (2004) presents also convincing evidence of backward linkages in a study on Lithuania with firm-level data. But some studies also find a negative impact from FDI on domestic productivity (such as Djankov and Hoekman, 2000). A major limitation in all these studies is however that only the manufacturing sector is analysed, whereas technological spillovers are expected to be important in the services sector which is the largest sector of the economy in all countries.

91. Görg and Strobl (2005) provide evidence of the role of labour turnover in technology transfer. They find that firms run by owners that worked for multinationals in the same industry prior to opening up their own firm have higher productivity growth than other domestic firms. However, there are no positive effects on productivity if the owner formerly worked in a multinational in another industry or received training by multinationals. It goes against the idea of spillovers effects (with productivity increases across sectors) but confirms that technology can diffuse through worker mobility in the same industry.

92. Lastly, the role of FDI in technology diffusion can be analysed through patent citations data to infer technological spillovers. Using such a methodology, Branstetter (2005) highlights how FDI can be a channel of knowledge spillovers, both from investing firms to local firms and from local firms to investing firms in the case of Japanese firms investing in the US.

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28 On the conceptual distinction between knowledge diffusion and true externalities, see Møen (2005).

The relevant question is how can a country maximise the benefits from FDI

93. As illustrated by the studies mentioned in the two last paragraphs, the evidence on FDI and technology transfer is mixed, even when using micro-data that allow analysing the productivity impact of trade and FDI at the firm or plant level. FDI is more likely to generate technology transfer in the following circumstances:

- Technological spillovers are more likely to appear in the context of joint-ventures or companies whose capital is shared between domestic and foreign investors (Aitken and Harrison, 1999; Javorcik, 2004). Again it is the interactions between local and foreign producers or workers that are decisive.

- Export-oriented FDI or efficiency-seeking FDI has been found more often associated with positive spillovers. The type of FDI matters.

- The productivity difference between domestic and foreign firms should not be too wide.

- The host country needs to have certain characteristics that define its "absorptive capability". In particular, the host country needs a sufficient stock of human capital (Borensztein, De Gregorio and Lee, 1998) to benefit from FDI. Social capital, informational networks, the number of students studying abroad are also mentioned as determinants of the absorptive capability.

- The literature also discusses the existence of a threshold effect, where the benefits of FDI can materialise only after a certain amount of foreign capital has been accumulated.

94. An important conclusion of the analysis on trade, FDI and technology diffusion is that it is less the level of capital accumulation that matters than the efficiency gains provided by foreign firms. It suggests that attempts to model dynamic gains from trade and investment should not only look at the importance of trade and investment flows but also at the difference in productivity between foreign and domestic firms in order to assess the degree of potential spillovers (and how these might change as a result of deeper trade and investment relations). Variables such as the stock of human capital or TFP differences between host and home countries seem relevant to be included in the analysis, as well as a decomposition of FDI flows according to the type of investment. Trade barriers should also be assessed in relation to their detrimental effect on the entry of the most productive firms or on the incentives that have foreign firms to diffuse their technology.

95. As endogenous growth theories have stressed the role of knowledge and innovation in increasing the total productivity of factors, they have given a new role to trade and the movement of factors of production as a way to diffuse technology across national borders. Economies of scale and learning-by-doing effects were considered as the main determinants of how trade can affect growth a decade ago. A new paradigm has emerged where what matters is to create the right incentives for firms to increase their productivity. In this new paradigm, trade is no longer explained by disparities in factor endowments. A better assumption seems to be that factor endowments are endogenous (Eicher, 1999), in particular in view of the major changes that transformed world production and trade.

96. The relationship between trade, FDI and technology diffusion have not yet reached a stage where firm conclusions can be drawn from the analysis. However there is already ample evidence that trade and FDI can positively impact productivity. Many countries have reached a higher level of income through the linkages between trade, FDI and technology diffusion described in this section and the interesting empirical question is how they did it rather than to know if there is a systematic link between trade or investment liberalisation and growth.

8. Can we model the dynamic gains from trade liberalization?

In the applied trade modelling literature the interpretation of the term 'dynamic' has been rather broad, if not misleading

97. The notion of 'dynamic gains from trade' has been long present in the applied trade modelling literature concerned with the quantitative estimates of economic gains from trade policy reforms. Nevertheless, the interpretation of the term dynamic has been rather broad, if not confusing. Indeed, the term dynamic has been used to describe:

(i) gains that are additional to the so-called static gains from trade (e.g. additional productivity changes);

(ii) gains estimated with models that allow an analysis of lagged transmissions and adjustments over time as well as

(iii) gains from models that would attempt to represent the impact of trade on increase in the productivity growth rate.

98. Most existing applied evaluations of effects of trade liberalization that have been discussed in policy circles employ the static modelling approach and consider the static gains from trade. According to the definition provided in the Deardorff's Glossary of International Trade (Deardorff, 2001) 'static gains' include the efficiency gains from exploiting comparative advantage, the reduced costs from scale economies, reduction in distortion from imperfect competition, and increased product variety. A corresponding definition by the same author describes 'dynamic gains', somewhat vaguely, as those that 'accrue over time, in addition to the conventional static gains from trade'. Indeed, this definition is not exceptionally illuminating since in reality the so-called static gains also take time to feed through an economic system.

99. It should be pointed out at the outset that the income effects derived from the conventional comparative static analyses of trade liberalization already account for one-off average productivity effects that arise as a result of reallocation of economic activity across sectors with different productivity levels (i.e. allocative efficiency gains). In addition to the static effects of trade policies some existing applied studies consider a variety of the broadly defined dynamic effects such as the interaction of trade liberalisation with capital accumulation or supplementary increases in total factor productivity, which are most frequently implemented as add-ons in 'comparative static' modelling frameworks. What these models really do, however, is to consider one-off changes in levels of productivity (or other exogenous variables) rather than an increase in productivity growth rate that, as discussed in Section 2, is considered to be the only source of sustained long-term growth in modern growth theory. Yet another class of applied trade models—the so called dynamic computable general equilibrium models of trade—allow the analysis of lagged transmissions and adjustment over time without necessarily addressing the connection between openness and productivity. Endogenous trade-related productivity dynamics is almost entirely absent from applied trade modelling literature at this stage.

100. The following sections go into more detail to clarify some the key issues associated with modelling of dynamic gains from trade in selected recent applied trade models (see Annex Table 1) and address their relation to the notion of trade-related productivity gains.

Conventional CGE analysis readily accounts for average productivity increases associated with specialization which generate one-off changes in the level of output

101. The computable general equilibrium (CGE) models that are normally used to evaluate potential gains from various multilateral and regional trade liberalisation scenarios are most frequently concerned with the effects of removal of price-distorting trade policy measures. Most contemporary CGE models are built with a specification of production function where productivity is assumed to be determined exogenously, i.e. with no link to changes in economic structure and policy changes.

102. However, in multi-sector versions of such models reallocation of productive resources across firms or industrial sectors can have an impact on average productivity levels. As pointed out by Jonsson and Subramanian (2001), in this type of models trade policy changes affect allocation of exogenously given resources across different types of economic activity which can have a one-off (positive or negative) effect on a steady-state level of output but not on the rate of output growth. In simple terms, in such models the resource reallocation following a trade policy shock changes the weighting of productivities across sectors and thus the average productivity levels, while leaving the productivity level in each sector or activity unchanged.

103. Most of the recent CGE evaluations of the gains that could be achieved through a conclusion of the Doha Development Agenda readily account for the impacts of resource reallocation on average productivity (e.g. Francois *et al.* 2005; Cernat *et al*., 2002, Dessus *et al*., 1999; Fernandez de Cordoba *et al*., 2004; Lippoldt and Kowalski, 2003; Vanzetti and Fugazza, 2005; Kowalski, 2006, Anderson *et al*., 2006, Polaski, 2006, see also Annex Table 1). While the impact on average productivity is rarely reported as a separate summary statistic the magnitude of average productivity changes induced by reallocation of factors of production can be determined from the figures describing percentage changes to real GDP (since in the absence of factor accumulation in static models, real GDP growth can only come about through productivity changes). One example of estimates of percentage change in real GDP by region and trade liberalization scenario is Kowalski (2006). In this study employing the standard GTAP model of world trade full removal of tariff barriers (with 2001 as the base year) and associated resource reallocation across all trading partners is reported to result in an average productivity increase of 0.35%.[29]

--Off-line productivity effects are sometimes added in comparative static models to account for trade-related productivity gains—

104. Thus, the core results from conventional static CGE assessments of trade liberalization already include the one-off average productivity level effects—in fact these are the main effects underlying the welfare results that are reported in these studies. Nevertheless, it is often acknowledged that, in addition to the resource reallocation effect, trade liberalization is said to have an additional effect on productivity that can be included in a static CGE model projection. The hypothesis of a link between openness and productivity level has been at the center of the sizable literature on the so called export-led growth that attempts to establish the causal link between high growth rates, increasing trade shares in GDP and significant structural changes observed in a number of rapidly industrializing economies post WWII (see e.g. de Melo and Robinson, 1990).

105. As stressed by Ackerman (2005) the productivity effects included in the vast majority of existing modelling exercises are "off-line calculations, not part of the models per se". Because the productivity increase is not determined by the model itself its inclusion requires crucially a separate estimation of the magnitude of the impact of trade liberalization on productivity outside of the employed CGE model and its

29 This is a simple average across all regions that are singled out in the model. In some developing regions average productivity is reported to have increased by as much as 0.79% (see Kowalski, 2006).

implementation as an additional exogenous shock. In other words, most applied models can incorporate trade and productivity linkages but they are "imposed" on the model rather than being determined inside it.

106. One example of such an approach is the study of effects of multilateral tariff liberalization and developing countries by Dessus et al. (1999) that uses a version of the LINKAGE model developed at the OECD (see Annex Table 1). While in the original model productivity is exogenous (determined outside the model) Dessus et al. (1999) adopt an additional assumption that the level of TFP is linked positively to the intensity of trade. The magnitude of this effect is established with a separate econometric model that utilizes information on openness and productivity in 63 countries in the period 1961-95. The estimation results indicate that 10 per cent rise in trade intensity (defined as the ratio of trade volume to output) leads to a 0.9 per cent rise in the level of TFP.

107. As far as the results are concerned, tariff liberalization considered in separation of productivity-enhancing effects is reported to bring about total welfare gains of $82 billion in 1995 prices or approximately 0.2 per cent of world GDP. When the estimated impact of trade on TFP is added to the scenario in order to, as authors put it, calculate dynamic gains from trade, the total welfare gains increase very significantly to around $1200 billion or around 3 per cent of world GDP. Additionally, the increase is most substantial for developing countries. It is clear that in Dessus et al. (1999) the assumption of an additional link between trade and productivity made a big difference in an assessment of gains from multilateral tariff liberalization; in fact this study has come up with one of the highest post-UR estimates of gains from further tariff liberalization.

108. Productivity is also assumed to be influenced by changes in trade in one of the scenarios of the extensively debated World Bank study of effects of multilateral trade reform (Anderson et al., 2006) or the recent study by the Carnegie Endowment (Polaski, 2006). In an associated study one of the co-authors of World Bank simulations acknowledges that the approach adopted in Anderson et. al. (2006) is a short-cut as compared to a genuine endogenous model in which changes in productivity could be influenced by changes in research and development, by technology embodied in imports and by pro-competitive effects of trade (van der Menbrughhe, 2006). In contrast to Dessus et al. (1999) where trade-related productivity changes are implemented at the country level, in Anderson et. al. (2006) trade-related productivity increases are implemented at the sector level and their magnitude is conditioned on the increase in the export-to-output ratio with the elasticity set at one in manufacturing and one-half in agriculture.[30] As van der Menbrughhe (2006) reports the productivity assumption significantly boosts the gains from trade reform particularly for developing countries which, presumably, record more pronounced expansion of trade volumes. At the global level an inclusion of the trade-related-productivity channel in Anderson et al. (2006) almost doubles estimated total gains from full liberalization of world merchandise trade from $287 billion to $461 billion.

--though such an approach has its limitations

109. The marked increases in estimates of benefits of trade liberalization after addition of the productivity effect reported in Dessus et al. (1999) and Anderson et al. (2006) are an indication of a more general predisposition of this type of modelling exercises. Namely, the welfare effects of productivity changes tend to swamp the direct welfare effects of trade policy changes (e.g. tariff reforms). An implication is that results pertaining to overall gains from a trade reform are very sensitive to what one assumes about the relationship between openness and productivity.

30 For comparison, using the data for Thailand in period 1980-95 Rattso and Stokke (2002) estimate the short-run elasticities of productivity with respect to foreign trade to be 0.36 for agriculture and 0.55 for industry

110. Consequently this approach has a number of limitations that all relate to reasonableness of the productivity increase calculations. In some studies simple estimates or rules of thumb are used (e.g. the above-mentioned Anderson et al., 2006 or Polaski, 2006) while in others the relationship between openness and trade is established econometrically (e.g. Dessus et al. 1999). It is often claimed that the existing empirical evidence does not provide a definitive and robust conclusion with respect to existence of trade-related growth effects and that because of this uncertainty they should not be included in the applied trade models simulations (e.g. Hedi Bchir et al, 2002). A more positive conclusion is that there clearly is scope for better understanding and improving the existing estimates of impact of openness on productivity levels.

111. Even if a robust relationship between openness and productivity could be estimated econometrically and added to the CGE simulation they would usually not be consistent with other calculations performed within a CGE model simulation. For example, an econometric estimation of impact of trade on productivity that is later implemented in a CGE model is likely to already include an impact on average productivity level discussed above. If this is the case, an inclusion of an additional productivity shock may cause a problem of double counting of productivity changes. Generally, if the econometric estimation is not based on a reduced form of a structural model that is consistent with the adopted CGE approach, there is no reason why the results should be consistent with other calculations performed within the CGE model. This may need to be more explicitly acknowledged in future econometric work identifying the productivity effects of trade.

112. An early attempt at preventing this kind of inconsistency can be found in de Melo and Robinson (1990) who developed a relatively simple one-country model that incorporates explicit links between exporting and productivity and importing and productivity that arise as a result of export and import externalities. The export externality in de Melo and Robinson (1990) is introduced by linking the amount of composite domestic production to exports. This is an externality since the producers do not see the benefits of exporting beyond the competitively determined level and do not internalize this benefit in their production decision. Government on the other hand is interested in the maximization of the overall income level and internalizes the pro-growth effect of exporting. The import externality is introduced through a link between the import ratio in heavy manufacturing and the productivity of the capital stock. De Melo and Robinson (1990) calibrate the theoretical model so that the initial equilibrium resembles early stages of export-led growth strategy in Korea and consider the optimal policy choices with respect to export subsidies in light and heavy manufacturing and an import subsidy in heavy manufacturing. De Melo and Robinson (1990) conclude that models of this type provide a first step towards endogenizing the major driving forces generating total factor productivity growth to mimic development paths of countries pursuing export-led growth strategies. They find that an incorporation of import and export externalities makes the model better suited to account for the stylized facts of growth and structural changes in these countries.

113. It is also worth adding that a number of comparative static models used currently in applied trade analysis incorporate some dynamic features other than productivity changes. Such is the case with the World Bank Linkage model employed recently by Anderson et al. (2006) or Francois et al. (2003) where exogenous shocks affect investment and therefore the stocks of capital through changing saving rates and prices of capital goods.[31] Van der Menbrughhe (2006) compares the gains from liberalization estimated with the use of 'static dynamic' (i.e. with adjusted capital stocks) and comparative static versions of the Linkage model and shows that the specification where extra savings contribute to capital stocks raise the global gain from merchandise trade reform by around 23%.

31 In a similar, but more conventional, standard GTAP model excess savings are assumed to be spent on capital goods but this spending does not augment the stock of capital employed in production.

Some general equilibrium models of trade that are dubbed 'dynamic' allow the analysis of lagged transmissions and adjustment processes but typically do not address the issue of endogenous productivity growth

114. Even though some dynamic features can be relatively easily incorporated into comparative static modelling frameworks, the analysis of trade liberalization based on such models boils down to comparing the baseline and post-shock equilibria that differ with respect to different assumptions of policy variables or exogenous data. Hence, this type of analysis does not incorporate any time dimension and is incapable of tracing the time path of adjustment of variables of interest. Depending on the focus of a study this may be seen as a drawback but some partisans of static trade models claim that static analysis is all that is needed for assessment of long-term policies such as trade liberalization.

115. The so-called 'dynamic CGE models' allow the analysis of lagged transmissions and adjustment process over time and can be used to trace the accumulation of stock variables (e.g. stock of capital) and the associated changes in production possibilities.

116. In the 'recursive-dynamic models' a recursive sequence of temporary equilibria are specified—in each time period the model is solved for an equilibrium given the exogenous conditions assumed to prevail for that particular period (see e.g. van Tongeren, van Meijl and Surry, 2001). This is achieved either by updating stock variables (such as e.g. capital stock or labour force) exogenously or as a result of updating the equilibrium outcomes of the model simulation in the previous period. The major criticism of recursive-dynamic models is that they do not guarantee time-consistent behaviour; decisions of economic agents modelled within a given period do not account for effects present in other periods.

117. In contrast, in intertemporal general equilibrium models agents behave optimally over time as well as within periods. As van Tongeren, van Meijl and Surry (2001) explain the reason to incorporate intertemporal consistency into trade models is the desire to model savings rate endogenously and to allow the model to generate endogenous growth rates. In this respect the forward-looking general equilibrium models of trade can account for capital deepening and transitional output growth but do not typically address total factor productivity growth which is the only source of sustained growth in modern growth theory (Box2).

118. One example of a recursive-dynamic model is GTAP-Dyn which enhances the standard GTAP treatment of investment and allows for international capital mobility and ownership. One prominent application of this model is a study of China's accession to the WTO by Walmsley and Hertel (2000). In this model international capital flows are determined by differences in expected rates of return to capital across regions that are gradually equalized over time. It is worth stressing that, as in the standard GTAP model, technology is exogenous and the only observed changes concern average productivity levels (see previous section).[32] The dynamic treatment of investment in the model allows Walmsley and Hertel (2000) to study the question of relative timing of tariff liberalization by China and elimination of quotas on textiles and apparel by North America and Europe (see also Annex Table 1).

119. The benefits of accession of China to the WTO have also been studied with the use of an intertemporal CGE model called G-Cubed (McKibbin and Woo, 2002). In this approach the dynamics of adjustment is modeled in a more sophisticated way by specifying forward looking behavior and rational expectations in consumption and investment decisions and by imposing intertemporal budget constraints on households, governments and nations. The dynamic behaviour of the model is driven by gradual asset accumulation and wage adjustment. However, similarly to standard CGE models total factor productivity is an exogenous variable and its evolution over time is determined outside the model. To give an example,

32 GTAP-Dyn can also be used to incorporate additional trade-related productivity gains as exogenous shocks.

the baseline scenario in McKibbin and Woo (2002) (i.e. the scenario that assumes no changes to existing policy regimes) assumes that productivity growth in each sector in each country gradually catches up to the rate of productivity growth in the equivalent sector in the United States with the gap in the growth rates closing at 2% per year. In policy scenarios McKibbin and Woo (2002) assume alternative behaviour of total factor productivity that is linked to FDI flows in order to account for technological spillovers in host economies; in essence the sectoral TFP growth rates in developing countries are assumed to be catching up with the internationally determined ‘natural’ sectoral TFP growth rates and the speed of this process is assumed to depend on changes in FDI flows. In this respect the treatment of productivity is similar to comparative static CGEs where productivity increases are calculated outside the model and added on to the simulation. Hence, in this application of the G-Cubed model incomes may grow at different rates at different points in time as a result of changes in the speed of asset accumulation (determined endogenously) as well as a result of changes in rates of total factor productivity growth (determined exogenously).

Unfortunately, endogenous productivity growth is largely absent from contemporary trade modelling literature and remains a priority for future model development

120. As we have seen in previous sections, the predominant approach in the applied modelling literature that tries to account for the link between openness and productivity is to review the available empirical literature and to incorporate the expected trade-related productivity increase in a comparative static or dynamic equilibrium model as an additional exogenous shock. Even in the existing modelling frameworks this can readily be done at a fairly disaggregated level, i.e. by industrial sector, primary factor of production (e.g. modelling of a rise in labour or land productivity) or intermediate inputs (modelling of increases in technology with which intermediate inputs are used). As already indicated, the limitation of such a strategy is that the extent of productivity increase is determined outside the model and may be inconsistent with its structure. We have also discussed that to correct this shortcoming productivity can in principle be ‘endogenized’ by assuming export and import externalities that explicitly link trade to the *level* of productivity. However, such an approach still does not solve the problem of modelling the impact of openness on productivity *growth*.

121. Unfortunately, productivity dynamics is largely absent from contemporary applied trade modelling literature.[33] This seems to result from the difficulty of unifying the concepts of specialization and structural change present in multisector comparative static trade models with the concept of balanced growth in literature on long-run economic dynamics. Indeed, Ngai and Pissarides (2004) write that “structural shifts are usually studied in models that do not satisfy the conditions for balanced aggregate growth. Conversely, balanced aggregate growth is normally studied in models that do not allow structural change.”

122. While a number of alternative theories exist on what balanced growth is (Beirwag, 1964), this term is usually used in the modelling literature to describe — quoting Solow and Samuelson (1953) — “a state of affairs in which the output of each commodity increases (or decreases) by a constant percentage per unit of time, the mutual proportions in which commodities are produced remaining constant. The economy changes only in scale, but not in composition.” The condition of balanced growth, when applied to a multisector model, implies that in the dynamic equilibrium sectoral outputs and trade must grow at the same rate and that relative prices and relative factor rewards do not change.

123. In conventional trade models, where often different factor intensities are assumed across sectors, balanced growth conditions place constraints on productivity growth, i.e. productivity growth paths that are

33 One exception is the one country model of trade and growth in Thailand by Diao et al (2002), see Annex Table 1.

consistent with balanced growth are determined by factor intensities and factor supplies. This limits the possibilities of incorporation of trade-related endogenous productivity growth into applied trade models. To give an extreme example, if factor endowments are assumed to be fixed the rates of sectoral TFP growth that are consistent with the balanced growth path must be equal to each other and to the rate of growth of sectoral outputs. Some research is being pursued to determine the properties of utility and production functions that allow coexistence of differences in sectoral TFP growth, balanced aggregate growth path and structural change (e.g. Ngai and Pissarides, 2004). Indeed, it seems that more theoretical research is required on how to reconcile the (possibly endogenous) differences in sectoral TFP growth rates, specialization, structural changes brought about by trade policy changes and balanced growth before endogenous productivity growth becomes a relatively standard feature of applied trade models.

Thorough empirical verification of links between trade and productivity is needed before they are implemented in CGE analyses

124. Overall, the issue of inclusion of trade-related productivity gains in CGE simulations of trade policies is rather delicate. Firstly, CGE models do not test economic theory. Quite to the contrary they use the economic theory to provide quantitative estimates of considered policy changes. As a result, any assumption, be it about the nature of technology transfer or accumulation of productive assets will inevitably be reflected in the estimated gains. This underscores the need for thorough empirical verification of links between trade and productivity before they are implemented in CGE analyses. Secondly, and perhaps even more importantly, the income effects of productivity changes are of an order of a magnitude larger than the effects of the very trade policy changes on which they are predicated. Hence, any uncertainty about the causal link between trade policy and productivity is likely to be yet magnified when it comes to estimates of income effects of such trade policy changes, potentially shedding negative light on modelling approaches to trade policy analysis. This reiterates that a thorough investigation of quantitative estimates of impact of openness and trade policy on productivity may be an avenue for further research that could offer the most immediate and operational gains.

9. Conclusions

125. This study has explored the various channels through which trade and FDI may raise the level of productivity or enhance productivity growth and reviewed the empirical evidence at macro, industry and firm level. It has found a robust relationship between openness to trade and the level of productivity and GDP per capita, even if questions remain about exact magnitudes. However, if dynamic gains from trade are narrowly defined as a sustained long-term increase in the productivity growth rate resulting from trade expansion, then there is not yet any conclusive evidence of dynamic gains.

126. It has been documented that open markets enable firms to operate at an efficient scale, larger markets could make R&D investments more profitable, while exposure to foreign technology and competition could provide incentives to innovate. In addition deepening specialization and technology diffusion are linked to trade and FDI and does at least have an effect on the productivity *level*, while the impact on productivity growth is most likely to be temporary. Technology could travel with trade and FDI as embodied in goods and services and in the form of knowledge spillovers.

127. The probably most important and fundamental source of economic growth is human innovativeness and ideas. The relation between this source of growth and trade is more subtle and difficult to pin down empirically. Creativity and innovativeness appear to thrive in an environment open to new ideas, and is likely to be stimulated by international interaction. The workings of this channel are long-term, multifaceted and not easy to measure, but the economic performance of countries that are closed to foreign influence hints at a large impact.

128. It is fair to say that the empirical evidence on dynamic gains from trade is mixed. At the firm level the relation between productivity and exports appears to be that the most productive firms become exporters and expand at the expense of the lesser productive firms. However, there is no conclusive evidence that firms become more productive from exporting. Still, the increased share of the more productive firms in output raises the average productivity in the liberalized sector, even if each firm's productivity growth is unaffected.

129. At the economy-level the empirical evidence on a causal linkage between openness to trade measured by actual trade flows and productivity levels is strong, suggesting that an increase in openness by one percentage point increases the level of GDP per capita by between 0.9 and 2%. However, it is has not been possible to establish conclusive evidence of a robust link between trade policy and long-run productivity growth rates, and according to economic theory one should expect such a link only if trade policy stimulates technology spillovers. Nevertheless, assuming that trade policy has an impact on trade, and that productivity levels at one point in time are related to productivity growth in earlier periods, the evidence suggests that an open trade policy stand is the trade policy that is most likely to enhance productivity growth.

130. The mechanisms through which trade and FDI affect productivity growth are not fully understood at this stage and models that aim at capturing dynamic effects typically do so by treating these effects as "add-ons" to the standard model structure. As with any economic model, the assumptions imposed on or contained within the model structure determine its outputs. Model estimates of gains from trade therefore differ widely and caution is warranted when interpreting the results. The study has highlighted the importance of further empirical work into the complex relationship between trade, FDI and productivity. A possible first step could be to improve the (exogenous) estimates of the relation between trade and productivity at the sector level as well as the economy level.

131. In conclusion this paper has shown that developing a model that incorporates and endogenizes the impacts of trade and investment policy on productivity growth rates will be a very difficult task which would take several years. However, this does not mean that further research cannot be conducted in the interim aiming at improving existing models and enhancing our understanding of possible dynamic gains from trade. Further research could aim at developing:

- A better understanding of the linkages between services trade and productivity in the goods sector.
- A better understanding of the gains from diversity is necessary in order to improve the performance of existing, static models.
- A better understanding of the relation between trade and technology. For instance does trade affect the allocation and volume of R&D expenditure?
- A better understanding of the relation between trade, financial markets and productivity growth;
- A better understanding of the relation between trade policy and trade flows. Particularly in developing countries it is important to understand better how complementary policy measures may enhance the supply side response to trade liberalization.

These are areas of research at the academic research frontier but they have the potential to make a significant contribution to the trade and growth debate in the future.

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Annex Table 1. Selected studies of trade liberalization, their treatment of trade-related productivity and other dynamic effects

Study	Focus	Model	Data	Dynamic features	Productivity treatment	Selected key findings
Anderson et al. (2006)	Welfare gains from global merchandise trade reform, including tariff reductions and liberalization of agricultural policies	World Bank LINKAGE Model, perfect competition recursive dynamic multicountry multisector	GTAP 6, baseline year 2001, adjusted for recent developments in trade policy and projected to 2015 supplemented by World Bank growth projections	endogenous capital accumulation exogenous population and labor supply exogenous labor-augmenting technological change	exogenous levels assumed to increase in proportion to export-to-output ratio 10% increase in this ratio results in 10% increase in TFP for agricultural sectors and 5 % in manufacturing sectors	Assuming trade has no impact on productivity: - the benefits of moving to global free trade: USD 287 billion in 2015 - gains higher for developed countries in nominal terms but higher for developing countries in relative terms (as % of GDP) -complete removal of protection in agriculture is responsible for two thirds of global welfare gains Assuming trade has an impact on productivity: - the benefits of moving to global free trade: USD 461 billion in 2015 - the gains for developing countries more than double
Kowalski (2006)	Welfare gains from tariff liberalization considering a number of different scenarios for tariff cuts, effects of simple scenarios considering trade facilitation	GTAP, standard, perfect competition comparative static multicountry multisector	GTAP 6, baseline year 2001,adjusted for tariff bindings from WITS	none	exogenous levels not affected by liberalization scenarios	- full removal of tariffs worldwide: USD 42 billion - 1% reduction of trading costs worldwide: USD 120 billion - developing countries: comparatively large proportional effects: on average 0.54% of GDP; developed countries on average 0.08% -results for cuts according to Swiss formula with a coefficient of 5% for developed regions and coefficient of 30% for developing regions: USD 22 billion
Polaski (2006)	Welfare impact of the Doha Round on developing countries; tariff liberalization, reduction of domestic subsidies in agriculture, reduction of agricultural export subsidies	Modified version of Wang (2003), perfect competition comparative static multicountry	GTAP 6, baseline year 2001, plus additional data from national and intergovernmental resources	none	exogenous levels assumed to increase in proportion to imports of capital goods 10% increase in real imports of capital goods – increase of	- the benefits of moving to global free trade: USD 168 billion approximately equivalent to 0.5% of world GDP -the benefits of so-called ‘ plausible Doha scenario’: USD 59 billion or 0.2 of world GDP with 10% of these gains attributed to liberalization in agriculture -developing countries account for approximately 45% of global gains; most developing countries gain form manufacturing liberalization; many poor countries

Study	Focus	Model	Data	Dynamic features	Productivity treatment	Selected key findings
		multisector unusual treatment of clearing in labor market			1% (or less in developed countries) in TFP in given sector	lose from agricultural liberalization
Francois et al. (2003)	Welfare impact s of the Doha Round with a special focus on the Netherlands	Modified version of GTAP, imperfect competition comparative static multicountry multisector	GTAP 5, baseline year 1997, with tariff data from WTO integrated database supplemented by UNCTAD/ World Bank WITS data, original services protection estimates	endogenous capital accumulation in certain sectors	exogenous levels not affected by liberalization scenarios	- the benefits of 100% reduction in agricultural and industrial tariffs, export subsidies, domestic support for agriculture and tariff-equivalent services barriers; reduction in trading costs of 3% of the value of trade: US$367 - 50% reduction in agricultural and industrial tariffs and export subsidies, 50% reduction in domestic support for agriculture, 50% reduction of tariff-equivalent services barriers, reduction in trading costs of 1.5% of the value of trade: US$240
Fernandez de Cordoba et al. (2004)	Welfare, trade, output and revenue effects of different proposals in the non-agricultural market access negotiations in the WTO	GTAP, standard, perfect competition comparative static multicountry multisector	GTAP 5, baseline year 1997, including data on preferential agreements from UNCTAD TRAINS database, additional information on tariff binidings	none	exogenous levels not affected by liberalization scenarios	-free trade scenario: USD$42 billion - results for cuts according to so-called Girard formula range, depending on the ambition, from USD$32-US$41 billion - linear tariff cut of 50% for developed regions and 36% for developing regions: US$28 billion
McKibbin and Woo (2002)	Study of China's accession to the WTO and the consequences on China's neighbours and competitors	G-Cubed Asia Pacific Model, includes FDI activity intertemporal general equilibrium	G-Cubed Asia Pacific Model-specific data, GTAP 4 data for tariffs and World Bank data for baseline projections	endogenous asset accumulation gradual wage adjustment	exogenous levels baseline: productivity growth in each sector catches up to the rate of productivity growth in the equivalent sector in	-when no FDI flows are allowed China's tariff reductions associated with the WTO accession make it better off by approximately 2.5% of GDP above the baseline in the long run -when FDI flows are allowed China's tariff reductions associated with the WTO accession make it better off by approximately 5% of GDP above the baseline in the long run

Study	Focus	Model	Data	Dynamic features	Productivity treatment	Selected key findings
		multicountry multisector			the United States with the gap in the growth rates closing at 2% per year policy scenarios: sectoral TFP growth rates in developing countries are assumed to catch up with internationally determined 'natural' sectoral TFP growth rates; the speed of this process is assumed to depend on changes in FDI flows	-existence of technological spillovers associated with FDI indicates that remarkable increases in China's GDP are accompanied by GDP losses in Thailand, Malaysia, Philippines and Indonesia.
Diao et al. (2002)	Study of Thailand's openness and productivity growth in transition towards long-run balanced growth	Original intertemporal general equilibrium model of a small open economy with endogenous transitory productivity growth Intertemporal general equilibrium one country two sectors: agriculture and Industry (including services)	Calibrated to data from Thailand's Social Accounting Matrix from 1989, interest rate data from the IMF	endogenous productivity growth endogenous capital accumulation	endogenous productivity growth in transition to long-run balanced growth labor-augmenting and land-augmenting productivities related positively to total trade sources of productivity growth studied: learning by doing, technology adoption and international technology spillovers	-model simulations show that endogenous improvements in TFP in transition period generate more capital accumulation and substantially contribute to transitory increase in growth rates -industry and growth would be hurt by protectionism in the short and the long run -over time the effect is driven by the relationship between openness and productivity growth

Study	Focus	Model	Data	Dynamic features	Productivity treatment	Selected key findings
Walmsley and Hertel (2000)	Study of China's accession to the WTO and the issue of timing of tariff liberalization and removal of quotas on imports of textiles and clothing from China by North America and Europe	GTAP-Dyn, perfect competition recursive dynamic multicountry multisector	GTAP 4, baseline year 1995, projected to 2020	endogenous capital stock: international capital flows are determined by differences in expected rates of return to capital across regions that are gradually equalized over time	exogenous level	-delayed removal of quotas results in more negative impacts on China's main competitors in South East Asia -more gradual elimination of quotas leads to a smaller gain in China's real GDP than would occur if quotas were removed concurrently with tariffs in 2005 -reduction of output and employment in European and North American textiles and apparel sectors is more gradual the more gradual the elimination of quotas
Dessus et al. (1999)	Welfare effects of complete elimination of agricultural and industrial tariffs on developing countries	Version of LINKAGE Model developed at OECD, perfect competition, comparative static multicountry multisector	GTAP 4, baseline year 1995, projection year 2010; supplemented by World Bank growth projections and statistics on national savings	exogenous TFP increases	exogenous levels assumed to increase in proportion to trade intensity (ratio of trade volume to output) 10 per cent rise in trade intensity leads to a 0.9 per cent rise in the level of TFP	- complete elimination of agricultural and industrial tariffs in all regions: US$ 82 billion without TFP increase and US$1 212 billion with trade-related TFP increase -Tariff rates reduced by 50% for non-OECD countries and full liberalisation maintained for OECD countries: US$74 billion without TFP increase and US$912 with trade-related TFP increase
De Melo and Robinson (1990)	Modelling of export-led-growth and import-substitution development strategies in newly industrialized countries	Original theoretical model with endogenous productivity level changes introduced through trade externalities comparative static one country	Model calibrated to data characteristic of Korea-like, middle income, semi-industrial economy.	Endogenous TFP level	Endogenous level Introduced through: -a link between composite domestic production and exports (export externality) - a link between the import ratio in heavy manufacturing and the productivity of the capital stock (import externality)	comparative numerical simulations indicate that the model with endogenous productivity growth introduced through externalities captures the pattern of industrialization and TFP change in countries following export-led-growth strategies batter than the standard neoclassical version of the model