Abstract

Some writers have predicted that new technologies mean the 'death of distance', allowing suitably skilled economies to converge with high income countries. This paper evaluates this claim. It argues that geography matters for international income inequalities, and that new technologies will change, but not abolish this dependence. Some activities may become more entrenched in high income countries than they are at present. Others - where information can be readily codified and digitized - will relocate, but typically only to a subset of lower income countries. These countries will benefit, but other countries will continue to experience the costs of remoteness.

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Geography and International Inequalities: the Impact of New Technologies

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1. Introduction

New communications and information technologies (ICT) offer many benefits to developing countries. Costs of establishing communications networks have been slashed, and with that comes the prospect of better provision of education, health care, and a host of other services. Some writers go further, arguing that ICT offers the 'death of distance'. In the words of Frances Cairncross (2001), p16,

> 'To allow communications to work their magic, poor countries will need sound regulations, open markets, and, above all, widely available education. Where these are available, countries with good communications will be indistinguishable. They will all have access to services of world class quality. They will be able to join a world club of traders, electronically linked, and to operate as though geography has no meaning. This equality of access will be one of the great prizes of the death of distance.'

The objective of this paper is to evaluate this claim. At present, we shall argue in this paper, geography matters a great deal for economic interaction and for the spatial distribution of income. How will new technologies change this, and what will they do for the location of economic activity and for international inequalities? What are the prospects that ICT will lead to the death of distance?

The conceptual framework for addressing this question is based on the profitability of production in different countries, knowing that a change that increases profitability will tend to attract firms and bid up wage rates. The profitability of a location is determined by many forces: labour costs and efficiencies, the social infrastructure of the economy, and also geography -- location relative to sources of supply and relative to markets. The fact that firms tend to locate close to their markets creates a force for international inequality. Established economic centres offer large markets, attracting firms and hence supporting high wages -- which in turn supports the large market size. Pulling in the opposite direction are international wage differentials (or primary factor costs more generally). Obviously, the lower are primary factor prices, other things being equal, the more profitable is production in the country, a force for international equality.

The trade-off between these forces provides a simple relationship between costs of distance and international inequalities. We will show in section 2 that there are international wage gradients, with wages falling as a function of remoteness from markets. In so far as new technologies reduce the costs of distance they might be expected to flatten these gradients and reduce international inequalities. If trade were to become perfectly free -- the limiting case of textbook international economics -- distance would be dead, goods markets perfectly integrated and factor price equalisation would hold. Perfectly free international trade means that similar factors get paid the same price, regardless of their location, although per capita income levels may differ as individuals own different amounts of human and physical capital.

This view of the effects of ICT is misleading, for at least two reasons. First, new technologies will have a mixed and complex effect on the costs of distance. Some activities can be digitized and supplied from a distance, but most cannot. Second, geography determines firms' profitability not only via ease of access of markets, but also via access to a cluster of related activities. The propensity of economic activity to cluster is widely documented (for example Porter 1990), and attributed to a range of different forces. One is the development of dense local networks of suppliers of specialised goods and services for industry. A second is development of local labour markets with specialist skills, probably arising because of the training activities of other firms in the industry. A third is the benefit of being close to research centres and to the knowledge spillovers that firms derive from proximity to other firms: 'the mysteries of the trade become no mystery; but are, as it were, in the air' (Marshall 1890). Finally, it may simply be easier to manage and monitor activities in an established centre where firms have local knowledge and can benchmark their performance on that of other firms in the same location.

How does new technology change these clustering forces? Some are likely to be weakened by ICT. For example, proximity may come to matter less for the flow of knowledge between firms and for the supply of business services (at least, to the extent that the relevant knowledge can be codified and digitized). But other clustering forces – such as those arising from labour market skills -- are likely to be unaffected. The overall effects of ICT on location and international inequalities must therefore take into account the fact that distance may die for some of the functions involved in some industries, while remaining important for many other functions and activities. Thus, some activities will no longer need to be close to consumers and will go in search of lower cost locations, but low costs depend on wages, social infrastructure, and access to the benefits of a cluster of related activities. Consequently some activities may tend to move to lower wage countries, while others become more deeply entrenched in high wage economies.

These effects are illustrated by the experience of previous communications revolutions. The transport revolutions of the nineteenth century did not lead to the dispersion of economic activity, but instead to its concentration – in relatively few countries, and within those countries in large and often highly specialised cities. Lower transport costs reduced the value of being close to consumers who could instead be supplied from cities in which production exploited the advantages of increasing returns to scale and agglomeration externalities. So too with new technologies, we might expect to see changes in economic geography of the world economy, but not necessarily changes towards the 'integrated equilibrium' view of the death of distance.

The remainder of the paper develops the argument in three main stages. First, we show that geography matters greatly for many economic interactions; these interactions – be they trade, investment, or knowledge transfers – are overwhelmingly local, falling off sharply with distance. We also argue that the costs that cause interactions to fall off across space have major implications for the world income distribution. Using measures of distance based on the intensity of economic interaction between countries we show that distance can account for a large part of international inequalities. Poor countries are poor, in part, because distance inhibits their access to the markets and suppliers of established economic centres.

We then turn to the effects of information and communications technologies (ICT) on the costs of international transactions. To do this requires that we look more deeply at why distance is costly, and we divide these costs into four main elements. Search costs (the costs of identifying a potential trading partner). Direct shipping costs. Control and management costs. And finally, the cost of time involved in shipping to and communicating with distant locations. ICT reduces some of these costs for some activities, but we argue that its effects are ambiguous, and can in some cases increase the value of proximity, rather than reduce it.

Finally, we turn to the likely effects of these cost changes on the location of activity and hence on wages and income levels. Will existing centres of economic activity deconcentrate, with activities relocating to lower wage economies? This will occur for some activities, but for others the concentration in central regions may well be reinforced. Furthermore, activities that do relocate will tend to cluster in relatively few new locations. Thus, new technologies may change the pattern of inequalities in the world economy, but not necessarily reduce them. In this way it may be like previous rounds of infrastructure development, such as canals, railways and road networks, that permitted deagglomeration of some industrial activities, but probably reinforced rather than diminished centralising tendencies (Leamer and Storper, 2000).

2. Does distance matter?

2.1 Distance and economic interactions.

Almost all economic interactions fall off very rapidly with distance. We look at some of the reasons for this later, but first simply outline the facts. The standard framework for quantifying the effect of distance on economic interactions is the gravity model, which relates interactions between a pair of countries to their economic mass and to a measure of the cost of the interaction between them. This framework has been applied in a number of different contexts, most of all to trade flows. Thus, if y_{ij} is the value of exports from country i to country j, then the gravity relationship takes the form,

$$y_{ij} = s_i m_j t_{ij}^{\theta} \tag{1}$$

where s_i denotes exporter (supplier) country characteristics, m_j denotes importer country characteristics, and t_{ij} is a set of 'between-country' factors measuring the costs of trade between the countries. This between-country term is typically proxied by distance, and perhaps also by further between-country characteristics such as sharing a common border, a common language, history, or treaty relationship. Exporter and importer country characteristics can be modelled in detail, including income, area, population, and geographical features such as being landlocked. However, if the researcher's main interest is the between-country term, t_{ij}, then s_i and m_j can simply take the form of dummy variables whose values are estimated for each country.

Extensive data permits the gravity trade model to be estimated on the bilateral trade flows of one hundred or more countries. Studies find that the elasticity of trade flows with respect to distance is around -0.9 to -1.5. It is important to realise quite how steep the decline in trade volumes implied by this relationship is. Table 1 expresses trade volumes at different distances, relative to their value at 1000km; if $\theta = -1.25$, then by 4000km volumes are down by 82% and by 8000km down by 93%.

Similar methodologies have been used to study other sorts of economic interactions. Portes and Rey (1999) study cross-border equity transactions (using data for 14 countries accounting for around 87% of global equity market capitalisation, 1989-96). Their main measure of country mass is stock market capitalisation, and their baseline specification gives an elasticity of transactions with respect to distance of -0.85. This indicates again how – controlling for the characteristics of the countries – distance matters. Other authors have studied foreign direct investment flows. Data limitations mean that the set of countries is once again quite small, and the estimated gravity coefficient is smaller, although still highly significant; for example, Di Mauro, (2000) finds an elasticity of FDI flows with respect to distance of -0.42. The effect of distance on technology flows has been studied by Keller (2001) who looks at the dependence of total factor productivity (TFP) on R&D stocks (i.e. cumulated R&D expenditures), for 12 industries in the G-7 countries, 1971-95. The R&D stocks include both the own country stock, and foreign country stocks weighted by distance.[1] Both own and foreign country stocks are significant determinants of each countries' TFP and so too is the distance effect, with R&D stocks in distant economies having much weaker effects on TFP than do R&D stocks in closer economies. The final column in table 1 illustrates his results by computing the spillover effects of R&D in more distant economies relative to an economy 1000km away; the attenuation due to distance is once again dramatic.[2]

Table 1: Economic interactions and distance.

(Flows relative to their magnitude at 1000km)

	Trade (θ = -1.25)	Equity flows (θ = -0.85)	FDI (θ = -0.42)	Technology
1000km	1	1	1	1
2000km	0.42	0.55	0.75	0.65
4000km	0.18	0.31	0.56	0.28
8000km	0.07	0.17	0.42	0.05

2.2. Distance and real income.

The previous sub-section made the point that distance matters greatly for economic interactions. How does this feed into the distribution of income across countries? A number of mechanisms might be at work, including the effects of investment flows and technology transfers. Here, to illustrate effects, we concentrate just on the way in which trade flows – and the implicit trade costs demonstrated by the gravity model – can generate international income gradients.

The effect of distance on factor prices is easily seen through a simple example. Suppose that country 1 represents the high income countries, from which country 2, a developing country, imports intermediate goods and to which it exports manufactures. The cost of producing manufactures in country 1 is given by $c(w_1, r_1, q)$ where w_1 and r_1 are the unit costs of labour and capital and q the cost of intermediate goods.[3] The developing country has to import the intermediate good, and imports are subject to 'trade costs' at proportionate rate t.[4] These 'trade costs' consist of a number of different elements that we discuss in detail in section 3. Trade costs at rate t mean that the price of intermediates in country 2 is tq, so country 2 units costs are $c(w_2, r_2, tq)$, given its factor prices, w_2 and r_2.[5] It sells in the developed country market, but faces trade cost factor t in shipping to this market. In order to compete with production in country 1, the following equation must therefore hold

$$c(w_1, r_1, q) \;=\; t\,c(w_2, r_2, tq). \tag{2}$$

Figure 1 illustrates country 2 wages (expressed as a proportion of country 1 wages) as a function of trade costs, computed from this relationship with the assumption that $r_2 = r_1$. It can be thought of as illustrating the wage gradient for different countries at increasing distances (increasing trade costs) from the centre. In all cases illustrated two thirds of value added is labour and one third capital. In the upper line there are no intermediate goods, while in the middle line intermediates account for 25% of country 1 costs, and in the bottom line 50% of country 1 costs. The point to note from the figure is how rapidly wages get squeezed at more remote locations with higher trade costs. Thus if trade costs are 30% of the value of output (t = 1.3) and intermediate inputs are 50% of costs (bottom curve) then wages drop to around one tenth of their level in the centre. Trade costs of 30% are not that high (the median cif/fob ratio for all countries reporting bilateral trade is 1.28). Furthermore, if the price of capital were higher in more remote locations ($r_2 > r_1$) then wages would be depressed still further.

Figure 1 suggests the theoretical importance of distance for international inequalities. To establish the importance of this relationship in fact we must generalise it to many countries and to the full set of trade relationships between them. Instead of simple measures of transport costs we define the 'market-access' of country i, $MA_i = \sum_j m_j t_{ij}^{\theta}$. Recall that m_j measures the economic mass of an importer country, and t_{ij}^{θ} the rate at which its effect falls off with distance. MA_i is therefore a measure of country i's access to demand from all countries. It provides a generalisation of the old idea of 'market potential' (Harris 1954), which takes GDP as economic mass and the reciprocal of distance as the measure of spatial decay. Analogously, we define the 'supplier-access' of country i as $SA_i = \sum_j s_j t_{ij}^{\theta}$. s_j represents economic characteristics of exporting countries, such as manufacturing output, and we can use SA_i to measure country i's access to suppliers of intermediate goods. Thus, a high value of SA_i means that country i is close to exporting countries so has relatively cheap access to intermediate goods.

Using these concepts we can now express the rate of return to production in country i as a function of the wage in the country and its market and supplier access:

$$r_i = R\left(w_i, \sum_j m_j t_{ij}^{\theta}, \sum_j s_j t_{ij}^{\theta}\right) = R\left(w_i, MA_i, SA_i\right) \tag{3}$$

Suppose that economic activity locates in a manner that equalises the rate of return across countries. Equations (3) then form a set of equations linking each country's wage to its market and supplier access, so generates an estimating equation of the form,

$$w_i = \alpha + \varphi_1 MA_i + \varphi_2 SA_i + u_i. \qquad (4)$$

The final term, u_i, is an error term to which we assign, for the moment, all other influences on wages. Redding and Venables (2000) estimate this relationship using a cross-section of data on 101 developed and developing countries.[6] A two-stage procedure is followed. At the first stage a gravity trade model (equation 1) is estimated to give estimates of m_j, s_i and θ, from which measures of market-access and supplier-access can be constructed for each country. The full specification of market-access and supplier-access requires that each country's own market (and supply) is included, as well as the effect of all foreign markets (suppliers). In this paper we discuss only the foreign market (foreign supplier) effects, so work with foreign market-access and foreign supplier-access, defined as $FMA_i = \sum_{j \neq i} m_j t_{ij}^{\theta}$ and $FSA_i = \sum_{j \neq i} s_j t_{ij}^{\theta}$; Redding and Venables deal with the full case.

At the second stage, equation (4) is econometrically estimated. Before looking at regression results it is instructive to look at the scatter plot given in Figure 2. The horizontal axis is log of foreign market access (FMA), and the vertical axis gives the log of GDP per capita, used as a proxy for manufacturing wages.[7] The figure presents evidence of the importance of market-access in determining wages – the empirical analogue of figure 1. Clearly, there is a strong positive association between FMA and per capita income. There are outliers such as Australia, New Zealand, Japan, the USA, Singapore and Hong Kong. For two of these, this is explicable in terms of their own size: the sheer population mass of the US and Japan mean that domestic market and supplier access are extremely important relative to foreign access. Looking at the rest of the sample, the relationship holds within regions as well as between them. Thus, there is a European wage gradient lying from the core countries down through Spain and Portugal (ESP and PRT) to Greece (GRC). There is an East European gradient, lying below the West European, indicating that these countries have lower per capita income than their location alone would justify. Similar gradients can be pulled out for other regions.

The results of using this data to estimate equation (4) are given in table 2. Column (1) presents the results using foreign market-access alone. The estimated coefficient is positive and highly statistically significant and the variable explains about 35% of the cross-country variation in income per capita. Column (2) uses foreign supplier-access alone, with similar effect. The theoretical specification says that we should include both market-access and supplier-access, and column (3) does this, although separately identifying the coefficients on these two variables is difficult given the high degree of correlation between them. However, the theory suggests a restriction across the two coefficients based on the relative shares of labour and intermediates in costs, and column (3) presents estimates based on the assumption that the intermediate share of costs is 50% higher than the labour share. Once again, results are highly significant, with the measures explaining 36% of the variation in the cross-country income distribution.

Of course, we do not claim that geography is the only cause of cross-country variations in income, and the final column of Table 2 includes other variables, particularly those used by Sachs and his coauthors[8]. Endowments of hydrocarbons per capita have a positive and significant effect, as would be expected, while the proportion of land in the tropics is negative although insignificant. Former socialist rule and involvement in external wars have negative and significant effects. Sachs has argued that Malaria can have a pervasive productivity reducing effect, and the variable measuring the presence of Malaria (a dummy variable taking value one in countries where Malaria is endemic) has a significant negative and quantitatively important effect. Together with the foreign market-access measure these variables explain around two-thirds of the cross country variation in per capita income. From the current perspective, the main point is that the foreign market-access measure remains highly significant, making the point that distance matters for per capita income, as suggested by the theory.

Table 2: GDP per capita, market and supplier access[(a)]

ln(*GDP per capita*)	(1)[(b)]	(2)[(b)]	(3)[(b)]	(5)[(b)]
Obs	101	101	101	99
Year	1996	1996	1996	1996
ln(FMA_i)	0.476		0.319	0.277
	[0.076]			*[0.063]*
ln(FSA_i)		0.532	0.182	
		[0.114]	*[0.040]*	
ln(Hydrocarbons per capita)				0.026
				[0.016]
Fraction Land in Geog. Tropics				-0.139
				[0.253]
Prevalence of Malaria				-1.496
				[0.268]
Socialist Rule 1950-95				-0.743
				[0.156]
External War 1960-85				-0.344
				[0.170]
Estimation	OLS	OLS	OLS	OLS
R^2	0.346	0.377	0.361	0.671
F(·)	52.76	57.05	54.60	55.63
Prob>F	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

3. What determines distance costs and how are they changing?

We argued above that geography is an important determinant of per capita income. Despite the presence of large cross-country wage differences it is not profitable for firms to relocate, moving away from markets and suppliers. We now look in more detail at the determinants of the costs of distance and at the effects of new technologies on these costs. This can best be addressed through the following thought experiment. A firm is considering where to source its supplies from, or where to locate its own production. How is the decision to outsource to a low wage economy deterred by distance, and how might ICT mitigate this deterrent effect?

We divide the distance effects into four main elements. First, making any sort of trade involves finding a trading partner, a process of search and matching which turns on the availability of information. Second, inputs and outputs have to be transported. We show how these depend on country and commodity characteristics and present some evidence on how they are changing; in 'weightless' activities new technologies set these costs essentially at zero, but we argue that such activities amount to only a few percent of total expenditure. Third, the supply chain has to be managed; for outsourced supply this involves a process of information exchange and monitoring, and for own investment it involves management of the entire project. The final component of the costs of distance is time. New technologies often speed up aspects of the production and management process, but we argue that this might either increase or decrease the benefits of proximity and costs of distance.

3.1 Searching and matching

A major reason why transactions fall off with distance is that we simply know less about what potential trades can be made with people on the other side of the earth than we do about potential trades with our neighbours. Relatively little is known about the magnitude of these information barriers, although attempts to establish their existence have been made by a number of researchers. For example, Rauch and Trindada (1999) use a gravity trade model to show how ethnic Chinese networks seem to increase trade volumes.

It seems likely that new technologies -- the internet in particular -- significantly reduce search and matching costs. The internet means that distance ceases to be important in advertising (by either suppliers and purchasers) and business-to-business exchanges facilitate search and matching across space. From my desktop a search engine will produce 'about 10,300' matches for the search string garment+export+china+ltd, at least the first ten of which are trading houses or Chinese firms offering supply. The most heavily researched examples of searching and matching through the internet have a national rather than international focus. For example, in the US automobile market in 1999 more than 40% of buyers used the internet to seek out price and model information -- although only 3% of sales were made on the internet.[9] This example makes a point which many dotcom companies have discovered, and which is surely even more true in an international context. The internet is excellent for acquiring information, but information is a necessary but by no means a sufficient condition for completing a trade.

3.2 Moving inputs and outputs

An international transaction requires that outputs and traded inputs be moved across space. This can be done by different modes -- surface, air, or for some activities, digitally. How large are these costs, and in what ways -- and for how large a share of trade -- do we expect new technologies to reduce them?

Data on shipping costs indicates that there is a very wide dispersion of transport costs across commodities and across countries. Thus, for the US in 1994, freight expenditure was only 3.8% of the value of imports, but equivalent numbers for Brazil and Paraguay are 7.3% and 13.3% (Hummels 1999a, from customs data). These values incorporate the fact that most trade is with countries that are close, and in goods that have relatively low transport costs. Looking at transport costs unweighted by trade volumes gives much higher numbers; thus, the median cif/fob ratio, across all country pairs for which data is available, is 1.28 (implying 28% transport and insurance costs). Looking across commodities, an unweighted average of freight rates is typically 2 to 3 times higher than the trade weighted average rate.

Estimates of the determinants of transport costs are given in Hummels (1999b) and Limao and Venables (2001). These studies typically find elasticities of transport costs with respect to distance of between 0.2 and 0.3. Limao and Venables find that sharing a common border substantially reduces transport costs, overland distance is around 7 times more expensive than sea distance, and being landlocked increases transport costs by approximately 50%. Infrastructure quality (as measured by a composite of index of transport and communications networks) is important; for example, while the median cif/fob ratio is 1.28, the predicted value of this ratio for a pair of countries with infrastructure quality at the 75th percentile rises to 1.40.

How are transport costs changing through time? Figure 3 documents the evolution of the costs of ocean shipping, air freight, and transmission of digitized information. There are three main points to notice. First, the costs of sea transport declined during the 1940s and 50s, but since then there has been no trend decline, although there have been substantial fluctuations driven largely by oil prices. This seems superficially surprising, but less so when one sees that the variable reported is the shipping cost relative to a goods price index. Thus, there has been technical progress in shipping, but it has been no faster than the average in the rest of the economy. Second, the cost of airfreight fell more and continued to fall for a longer period, but this too has essentially bottomed out from the 1980s onwards. The third series is a measure of the cost of transmitting digitized information. Evidently, this has experienced the most dramatic fall, and can now be regarded as being close to zero. From the standpoint of investigating international inequalities the important question is: what share of world expenditure is now ‘weightless’ and can be digitized and transmitted at close to zero cost?

This question is very hard to answer, because it is typically particular economic functions that can be digitized, rather than whole production sectors that are the basis for data collection. There are numerous examples of activities that have been digitized and relocated. Airline ticketing services and the back-room operations of banks are standard ones. Call centres, transcription of medical notes, architectural drawings, and cartoons and computer graphics for the film industry are further possibilities.

One way to try and get a quantitative estimate is to look sectorally, in which case the numbers look rather small. Figures are available for US household consumption of ICT-based products and services. By 1998 50 per cent of Americans already had a personal computer and 30 per cent were regular Internet users. But total consumption of ICT-based products and services, including voice telephony, was only 2.4 per cent of consumer expenditure, of which a very large part is ultimately devoted to upkeep of the network, a largely non-tradeable activity (Turner, 2001). On the supply side, the US Bureau of Labor Statistics foresee ICT industry employment growing from 3.7 per cent of the US total in 1998 to 4.9 per cent in 2008, with the increase concentrated almost entirely in computer processing and software services (Turner, 2001). The OECD estimates that all software and computer related services accounted to 2.7 per cent of US GDP in 1996, and half that in other OECD countries studied. Software products and computer services combined accounted for just 0.8 per cent of US exports in 1996 (OECD 1998).

Other sectors contain functions that are ‘IT enabled’. In banking it is estimated that some 17-24 per cent of the cost base of banks can be outsourced, (Economist May 5th 2001), a share that seems quite low for an activity that is fundamentally weightless.

Another way to get a feel for the magnitude of these activities is to look at the recent experience of the highly successful Indian software and IT-enabled services sectors. The total output of software and related services in 2000 was around $8bill with exports of $4bill. IT enabled services – call centres ('customer interaction centres'), medical transcriptions, finance and accounting services – had exports to the US of $0.26bill, predicted to grow to $4bill by 2005 (Economist May 5th 2001). These are substantial size activities, compared to total Indian exports of $45bill in 2000, but are less than 1 per cent of total US imports of around $950billion.

Although it is difficult to quantify the share of the economy that is, or is likely to become, weightless, one fundamental point can be made. As activities are codified and digitized, so not only can they be moved costlessly through space, but also they are typically subject to very large productivity increases and price reductions. Thus, the effect of ICT on, say, airline ticketing, has been primarily to replace labour by computer equipment, and only secondarily to allow remaining workers to be employed in India rather than the US or Europe. (Technology that can capture voice or handwriting will make Indian medical transcription obsolete). This suggests that even if more activities become weightless the share of world expenditure and employment attributable to these activities will remain small -- perhaps as little as a few percent of world GDP.

3.3 Monitoring and management

Recent years have seen rapid growth of both outsourcing and foreign direct investment (FDI), with the associated development of production networks or production chains.[10] FDI has grown faster than either income or trade. The growth of production networks has been studied by a number of researchers. One way to measure its growth is by looking at trade in components, and Yeats (1998) estimates that 30% of world trade in manufactures is trade in components rather than final products. Hummels, Ishii and Yi (2001) chart trade flows that cross borders multiple times, as when a country imports a component and then re-exports it embodied in some downstream product. They find that (for 10 OECD countries), the share of imported value added in exports rose by one third between 1970 and 1990, reaching 21% of export value.

Both FDI and outsourcing involve, in somewhat different ways, a fragmentation of the structure of the firm, as production is split into geographically and/or organisationally different units. From the international perspective this fragmentation offers the benefits of being able to move particular stages of the production process to the lowest cost locations – labour intensive parts to low wage economies, and so on. However, as well as involving potentially costly shipping of parts and components it also creates formidable management challenges. Product specification and other information has to be transferred, and production schedules and quality standards have to be monitored. Do new technologies reduce the costs of doing this?

To the extent that pertinent information is 'codifiable' the answer is likely to be yes. The use of ICT for business-to-business trade is well documented, although this is reported to often reduce the number of suppliers a firm uses, rather than increase it.[11] In mass production of standardized products designs can be relatively easily codified; the production process is routine, daily or hourly production runs can be reported and quality data can be monitored. Dell Computers offers the classic example of the use of new technologies to outsource to order, getting components from suppliers at short notice. However, it is instructive that Dell's business practises, while held up as a model, has not been widely emulated (Economist April 12th 2001). It works because PCs are made almost entirely from standard parts, available from many sources; there is no need to order special components in advance and consumer customization of PCs is within very narrow limits -- speed and memory, but not colour or trim. The product range and set of options is vastly less complex than a motor car.

In many activities then, the pertinent information cannot be codified so easily. There are two sorts of reasons for this. One is the inherent complexity of the activity. For example, frequent design changes and a process of ongoing product design and improvement (involving both marketing and production engineering) may require a level of interaction that -- to date -- can only be achieved by face-to-face contact.

The second reason is to do with the fact that contracts are incomplete, and people on either side of the contract (or in different positions within a single firm) have their own objectives. It is typically expensive or impossible to ensure that their incentives can be shaped to be compatible with meeting the objectives of the firm. This issue has been the subject of a large economics literature. Part of the literature has its origins in analysis of the boundaries of the firm (Coase, 1937), asking what transactions are best done within the firm, and what by the market. Following Williamson (1975, 1985) this is typically modelled as a trade-off between efficiency gains of using specialist suppliers (or suppliers in locations with a comparative advantage or low labour costs) and the problems encountered in writing (enforceable) contracts with them. Another part of the literature looks at the problems of incentives in organisations, asking how employees can be induced to meet their firm's objectives.[12]

While new technologies may reduce the costs of monitoring, it seems unlikely that these problems of incomplete contracts are amenable to a technological fix. What evidence is there? On the one hand, there is the fact that in recent years there has been a dramatic increase in the outsourcing of activities to specialist suppliers, suggesting that difficulties in writing contracts and monitoring performance have been reduced. On the other hand, a number of empirical studies point to the continuing importance, despite new technologies, of regular face-to-face contact. Thus, Gaspar and Glaeser (1998) argue that telephones are likely to be complements, not substitutes, for face-to-face contact as they increase the overall amount of business interaction. They suggest that, as a consequence, telephones have historically promoted the development of cities. The evidence on business travel suggests that as electronic communications have increased so too has travel, again indicating the importance of face-to-face contact. Leamer and Storper (2000) draw the distinction between 'conversational' transactions (that can be done at a distance by ICT) and 'handshake' transactions that require face-to-face contact. New technologies allow dispersion of activities that only require 'conversational' transactions, but might also increase the complexity of production and design process, and hence increase the proportion of activities that require 'handshake' communication.

Overall then, it seems that there are some relatively straightforward activities where knowledge can be codified, new technologies will make management from a distance easier, and relocation of the activity to lower wage regions might be expected. But monitoring, control, and information exchange in more complex activities still requires a degree of contact that involves proximity and face-to-face meetings. Perhaps nowhere is this more evident than in design and development of the new technologies themselves.

3.4 The costs of time in transit

We now turn to the final element of shipping costs -- the cost of time in transit. New technologies provide radical opportunities for speeding up parts of the overall supply process. There are several ways this can occur. One is simply that basic information -- product specifications, orders and invoices -- can be transmitted and processed more rapidly. Another is that information about uncertain aspects of the supply process can be discovered and transmitted sooner. For example, retailers' electronic stock control can provide manufacturers with real time information about sales and hence about changes in fashion and overall expenditure levels. For intermediate goods, improved stock controls and lean production techniques allow manufacturers to detect and identify defects in supplies more rapidly. These changes pose the interesting question: if some elements of the supply process become quicker, what does this do to the marginal value of time saved (or marginal cost of delay) in other parts of the process? In particular, if one part of the process that takes time is the physical shipment of goods, then will time saving technical changes encourage firms to move production closer to markets, or allow them to move further away?

The importance of the costs of time in transit is highlighted by recent work by Hummels (2000), who analyses data on some 25 million observations of shipments into the US, some by air and some by sea (imports classified at the 10-digit commodity level by exporter country and district of entry to the US for 25 years). Given data on the costs of each mode and the shipping times from different countries he is able to estimate the implicit value of time saved by using air transport. The numbers are quite large. The cost of an extra day's travel is (from estimates on imports as a whole) around 0.3% of the value shipped. For manufacturing sectors, the number goes up to 0.5%, costs that are around 30 times larger than the interest charge on the value of the goods. One implication of these figures is that transport costs have fallen much more through time than suggested by looking at freight charges alone. The share of US imports going by air freight rose from zero to 30% between 1950 to 1998, and containerization approximately doubled the speed of ocean shipping; these giving a reduction in shipping time of 26 days, equivalent to a shipping cost reduction worth 12-13% of the value of goods traded.

Given the magnitude of these costs, how might a time-saving technology influence the location of production? To answer this question it is worth writing down a very simple economic model. Production of a good can take place in one of many locations, and the distance of each of these locations from the place where the product is sold is δ. Production requires one unit of labour, so has unit cost equal to the wage. Wages are lower in more remote locations – for the reasons outlined in section 2.2 above – and we write this relationship $w(\delta)$, where $w'(\delta) < 0$, (as in figure 1). The full supply process and delivery to market takes time $T(\delta, z)$, which is increasing in distance to market and in a technology parameter, z, so $T_\delta(\delta, z) > 0$ and $T_z(\delta, z) > 0$, where a subscript denotes a partial derivative. The proportion of earnings lost due to delay is $\varphi(T)$, $\varphi'(T) > 0$. Thus, if the price is p, profits per unit are,

$$\pi = p\left[1 - \varphi\left(T(\delta, z)\right)\right] - w(\delta). \tag{5}$$

Firms choose where to produce, trading off the loss of earnings due to delay against the lower wages they have to pay in more remote regions. The profit maximising choice of δ is characterised by first order condition,

$$\pi_\delta = -p\varphi'\left(T(\delta, z)\right)T_\delta(\delta, z) - w'(\delta) = 0. \tag{6}$$

The final term is the lower wage costs from moving to a more remote location, and the first term is the effect of this extra distance on time, $T_\delta(\delta, z)$, times the marginal cost of delay, $p\varphi'$.

Suppose that there is a technological change, dz, that directly reduces the time taken in the supply process. We want to know whether this technical change induces firms to move closer to the centre or further way. Totally differentiating the first order condition for location choice gives

$$\left[\frac{\pi_{\delta\delta}}{\varphi' T_\delta T_z}\right]\frac{d\delta}{dz} = \left[\frac{\varphi''}{\varphi'} + \frac{T_{\delta z}}{T_\delta T_z}\right] \tag{7}$$

The term in square brackets on the left hand side is negative ($\pi_{\delta\delta}$ must be negative as the second order condition for profit maximisation) so a time saving technical change causes production to move towards the centre ($d\delta/dz$ positive) if the right hand side is negative. We look at the two terms on the right hand side in turn.

The first term, φ''/φ', measures how the marginal cost of time changes as T increases. The case where this is negative is illustrated by the solid (concave) curve in figure 4. In this case a technical improvement which reduces T increases the marginal value of a further reduction in T, so will encourage firms to move production closer to the centre. This is in fact the normal case that arises because of discounting (at rate r, so $\varphi = 1 - \exp(-rT)$).

In addition to discounting there are other reasons to believe that φ''/φ' is negative. For example, suppose that the firm produces a fashion sensitive product, and under the old retail stock-control technology it was impossible to detect consumer response to this season's fashion until after it was too late to change production for this season. The firm produced all its stock in advance but expected to have to discount them by factor ψ; thus, the cost of delay is that instead of receiving price p per unit, it receives only $p[1 - \psi]$ (the dashed horizontal line on figure 4). Under the new retail stock-control technology the firm can learn about fashion instantaneously, redesign, and sell without discounting. However, if production and shipping takes T and the length of the season is T_0 (with sales occurring at a constant rate during the season) then the cost of time is $\varphi(T) = \psi T/T_0$, given by the dashed line between 0 and T_0. The shorter is T the higher the proportion of the season in which the firm does not have to discount. (So for example, if $T = T_0/2$ then ½ of the sales are discounted, and the average receipts are $p[1 - \psi/2]$). The dashed line corresponds to a case where $\varphi''/\varphi' < 0$, so the firm moves production *closer* to the market to exploit the advantage of the more rapid market information.[13]

An example of this is the highly successful Spanish clothing chain, Zara (Economist, May 19th 2001). It uses real time sales data, can make a new product line in three weeks (compared to the industry average of nine months) and only commits 15% of production at the start of the season (industry average 60%). It also does almost all its manufacturing (starting with basic fabric dyeing through the full manufacturing process) in house in Spain, with most of the sewing done by 400 local cooperatives (compared to the extensive outsourcing of other firms in the industry). Other examples could arise in intermediate goods supply, where instead of making it quicker to detect new fashions, new technology might make it easier to detect faults; the supplier would then want to move production closer and cut delivery times so that fewer faulty items were in the delivery chain.

Returning to the model, the second term in equation (7) gives a quite different reason why firms may relocate their production, arising because of direct complementarity between technology and distance in the journey time. This is best understood through a few examples.

Suppose that T depends on activities that happen in sequence – say transmitting information, followed by production and shipping -- and that the technical change only affects the first of these. Since activities are in sequence, the total time is the sum of the parts, $T(\delta, z) = T^{z}(z) + T^{\delta}(\delta)$, where the first term is the time of information transmission, and the second the time in shipping. In this case there is no interaction between the technical change and the time taken in shipping, so $T_{\delta z}$ is zero. Conversely, suppose that the processes are in parallel, so the time is set by the slowest part of the process, i.e. $T(\delta, z) = \max[\, T^{z}(z), T^{\delta}(\delta)]$. Generally, we might imagine the situation to be between these cases, and this is illustrated by the curved iso-time line in figure 5. Increasing the time taken in information transmission reduces the effect of moving further out on total time taken, so $T_{\delta z} < 0$. In this case then, we once again expect to see that the technical improvement encourages activity to move closer to the centre, rather than further away.

Evidence on the phenomena outlined here comes from study of just-in-time technologies, where new technologies have allowed much improved stock control and ordering, and a consequent movement of suppliers towards their customers. In a study of the location of suppliers to the US automobile industry Klier (1999) finds that 70-80% of suppliers are located within one days drive of the assembly plant, although even closer location is limited by the fact that many suppliers serve several assembly plants. He also finds evidence that the concentration of supplier plants around assembly plants has increased since 1980, a timing that he points out is consistent with the introduction of just-in-time production methods. The leader in the application of just-in-time techniques is Toyota, whose independent suppliers are on average only 59 miles away from its assembly plants, to which they make eight deliveries a day. By contrast, General Motor's suppliers in North America are an average of 427 miles away from the plants they serve and make fewer than two deliveries a day. As a result, Toyota and its suppliers maintain inventories that are one-fourth of General Motor's, when measured as a percentage of sales (Fortune, Dec 8th 1997).

4. Where will activities move?

The previous section suggests that ICT will change the costs of distance in quite different ways for different types of activity. For many activities both face-to-face contact and proximity to markets or a cluster of related activities will remain important. These are activities where complexity makes it difficult to codify information and write complete contracts, where uncertainty makes rapid response to changing circumstances important, or where transport costs remain important. Other sorts of activities can be fully digitized (the 'weightless' activities) or may be sufficiently simple that information flows required in production control and monitoring can be codified and implemented remotely.

Activities in the former group are likely to remain spatially concentrated, and at least two reasons suggest that their concentration might increase. One is the existence of complementarities in the value of time, as outlined above. The other derives from the possibility of spatially separating these activities from more routine parts of the supply process. For example, suppose that financial services require both 'front-room' operations (that tend to cluster together) and 'back-room' operations (that are intensive in medium skilled labour and office space). If the front and back-room operations have to be located together, then the overall clustering force might be quite weak – firms that are not in London, Tokyo or New York lose out on the benefits of being in a cluster, but at least have the benefits of cheaper labour and office space. But once the back-room operations can be separated from the front-room, then the agglomeration forces on the latter become overwhelming. All these activities will therefore be further concentrated by new technologies. It is therefore perhaps to be expected that financial services – in some ways a prime example of a weightless activity – are in fact enormously concentrated in a few centres, with no prospect of technology causing the dissolution of these centres.

What about the more routine and codifiable activities? These now have the possibility of moving out of established centres, but where will they go? One possibility is that they spread rather evenly through many locations, bringing modest increases in labour demand in many countries. An alternative is that relocation takes these industries to rather few countries, and this is what we expect to see if there is some propensity for these activities to cluster. The propensity may be quite weak – the point is simply that as activities leave established centres in search of lower wage locations, it is likely that a location that has some similar activities will look more attractive than one that has none.

The effects of trade cost reductions in a world where manufacturing is internationally mobile but subject to some clustering forces can be illustrated by developing a variant of the 'new economic geography' models of Fujita, Krugman and Venables (1999). Suppose that there are many countries, arranged in a linear world with a well defined centre and pair of peripheries. Each country is identical (apart from in its location) being endowed with the same quantity of two factors of production (labour and land). There are two production activities, one of which we call 'agriculture', although it can be interpreted as a wider aggregate of all the perfectly competitive sectors of the economy; this sector uses labour, land and manufactures to produce a perfectly tradeable output. The other sector is manufacturing, in which firms operating with increasing returns to scale produce in a monopolistically competitive market structure; these firms use labour and manufactures to produce manufactures.

This structure has within it forward and backwards linkages, as manufacturing firms use inputs from other manufacturing firms and supply outputs to other manufacturing firms. These linkages encourage agglomeration, so that typically manufacturing operates only in the central locations, while peripheral locations are specialised in agriculture. The wage implications of this are illustrated on figure 6. At an initial position with high trade costs the low wage countries have agriculture only, as do a corresponding set of countries on the other side of the centre (concealed in the diagram). Wages in these countries are much lower than those in industrialised countries, and wages peak in the central region that has the best market access and best supplier access.

The effects of trade cost reduction can be seen by moving to the right along the figure. At lower trade costs it becomes profitable for some firms to relocate to lower wage economies, but (a) these are the countries that are relatively close to the centre and (b) as these countries attract industry so a process of cumulative causation commences. Forward and backwards linkages between firms in the country mean that there is rapid 'take-off' of these countries, as indicated by the steepness of the wage gradient. The bold line AA illustrates the wage path of a country located midway between centre and edge as transport costs fall. This country is initially in 'the periphery' with no manufacturing and low wages, but lower trade costs cause manufacturing to spread out of the centre, industrialising this country and causing the rapid wage growth illustrated.

The point of this example is then, that even for activities that can relocate from established centres, the presence of (weak) agglomeration forces means that they will move to just a subset of possible new locations. As a consequence some countries will experience a rapid increase in labour demand and wages, while others remain in the periphery, essentially untouched by the process. New technologies change the pattern of inequalities in the world economy, but do not uniformly decrease them.

The predictions of this theoretical model seem to be broadly in line with what we know about recent sectoral relocations. Much software production has left the US – but to concentrate largely in Ireland and Bangalore. At a broader level, there has been growth of production networks, with components production outsourced to lower wage countries, but this growth of vertical specialisation and parts and components trade is concentrated in a few countries neighbouring existing centres – in Asia, Europe and America.

The growth of trade in production networks and its geographical concentration are illustrated in Table 3, which looks at countries' exports of telecommunications equipment (both final equipment and parts and components), a set of commodities for which there has been rapid growth of outsourcing to lower wage countries. The 68 countries in the sample are divided according to their initial (1983-85) per capita incomes, and we see (bottom row) that the share of low income countries in world trade in telecoms equipment rose from 5% in the early 1980s to 19% in the late 1990s. The body of the table gives the number of countries in each income group classified according to the share of telecoms in their exports. The point to note is the skewness of this distribution: telecoms equipment production and trade has become very important for just a few low income countries (for one country it accounts for more than 10% of total exports, another between 6.6 and 10%) while for the vast majority it remains unimportant. This pattern is repeated in other sectors, generally with the same set of countries being the main exporters.

Table 3: Exports of telecommunications equipment, final and parts.

Number of countries classified by per capita income and share of telecoms in exports.

	1983-85			1995-97		
Telecoms as % country's exports	low income	mid income	high income	low income	mid income	high income
<3.33%	36	9	14	32	7	11
3.3%-6.6%	1	1	3	3	4	5
6.6%-10%	0	2	1	1	1	2
>10%	0	0	1	1	0	1
Share of countries in all telecoms exports	0.051	0.117	0.83	0.191	0.112	0.697

5. Conclusions.

Speculating about the implications of new technology is a notoriously risky activity. However, the analysis of the paper suggests several main conclusions. Some activities will become more deeply entrenched in high income countries – and typically in cities in these countries. These activities will generally be complex – knowledge intensive, rapidly changing, and requiring face-to-face communication. But they will also include supply of non-tradeables and of produced goods where shipping is costly or time consuming. Other activities which are more readily transportable and less dependent on face-to-face communications may relocate to lower wage countries, and this will be an important force for development. However, since these activities may cluster together, development is likely to take the form of rapid development by a small number of countries (or regions) rather than a more uniform process of convergence. Although new technologies facilitate the relocation of these activities, the proportion of world GDP that can 'operate as though geography has no meaning' (Cairncross 2001) is likely to be small.

New technologies will not mean the death of distance, but the contribution of these technologies to economic development will nevertheless be important. It will come primarily from allowing individuals greater access to knowledge, education and basic services, not through rewriting the rules of economic geography.

Appendix:

Table A1: Countries in figure 2 and table 2.

1. Albania (ALB)	28. Estonia (EST)	55. Morocco (MAR)	82. Singapore (SGP)
2. Argentina (ARG)	29. Ethiopia (ETH)	56. Moldova (MDA)	83. El Salvador (SLV)
3. Armenia (ARM)	30. Finland (FIN)	57. Madagasc. (MDG)	84. Slovak Rep. (SVK)
4. Australia (AUS)	31. France (FRA)	58. Mexico (MEX)	85. Slovenia (SVN)
5. Austria (AUT)	32. Gabon (GAB)	59. Macedonia (MKD)	86. Sweden (SWE)
6. Bangladesh (BGD)	33. UK (GBR)	60. Mongolia (MNG)	87. Syria (SYR)
7. Bulgaria (BGR)	34. Greece (GRC)	61. Mozambiq. (MOZ)	88. Chad (TCD)
8. Belg./Lux (BLX)	35. Guatemala (GTM)	62. Mauritius (MUS)	89. Thailand (THA)
9. Bolivia (BOL)	36. Hong Kong (HKG)	63. Malawi (MWI)	90. Trinidad/T. (TTO)
10. Brazil (BRA)	37. Honduras (HND)	64. Malaysia (MYS)	91. Tunisia (TUN)
11. C Afr. Rp. (CAF)	38. Croatia (HRV)	65. Nicaragua (NIC)	92. Turkey (TUR)
12. Canada (CAN)	39. Hungary (HUN)	66. Netherlands (NLD)	93. Taiwan (TWN)
13. Switzerl. (CHE),	40. Indonesia (IDN)	67. Norway (NOR)	94. Tanzania (TZA)
14. Chile (CHL)	41. India (IND)	68. Nepal (NPL)	95.Uruguay (URY)
15. China (CHN)	42. Ireland (IRL)	69. New Zeal. (NZL)	96. USA (USA)
16. Cote d'Ivoire (CIV)	43. Israel (ISR)	70. Pakistan (PAK)	97. Venezuela (VEN)
17. Cameroon (CMR)	44. Italy (ITA)	71. Panama (PAN)	98. Yemen (YEM)
18. Congo Rep. (COG)	45. Jamaica (JAM)	72. Peru (PER)	99. South Afr. (ZAF)
19. Colombia (COL)	46. Jordan (JOR)	73. Philippines (PHL)	100. Zambia (ZMB)
20. Costa Rica (CRI)	47. Japan (JPN)	74.Poland (POL)	101. Zimbabwe (ZWE)
21. Czech Rep. (CZE)	48. Kazakhstan (KAZ)	75. Portugal (PRT)	
22. Germany (DEU)	49. Kenya (KEN)	76. Paraguay (PRY)	
23. Denmark (DNK)	50. Kyrgyz Rp. (KGZ)	77. Romania (ROM)	
24. Algeria (DZA)	51. Korea, Rp. (KOR)	78. Russia (RUS)	
25. Ecuador (ECU)	52. Sri Lanka (LKA)	79. Saudi Arab. (SAU)	
26. Egypt (EGY)	53. Lithuania (LTU)	80. Sudan (SDN)	
27. Spain (ESP)	54. Latvia (LVA)	81. Senegal (SEN)	

Notes:

1. Distance weighting according to $\exp(-\theta \text{ distance}_{ij})$

2. To try and identify the channels through which technical knowledge is transmitted Keller investigates not just distance between countries, but also the volume of trade between them, their bilateral FDI holdings, and their language skills (the share of the population in country *i* that speaks the language of country *j*). Adding these variables renders simple geographical distance insignificant; around two-thirds of the difference in bilateral technology diffusion is accounted for by trade patterns, and one sixth each through FDI and language. However, all these variables are themselves declining with distance.

3. Of course, there are many intermediate goods, but here we summarise their prices in a single price index, *q*.

4. This is a trade cost factor, thus $t = 1.2$ means that trade costs are 20% of the value of goods shipped.

5. We assume that technologies are the same in all countries – geography is the only source of difference between countries.

6. They also derive the wage equation and the market access and supplier access from economic fundamentals, based on Fujita, Krugman and Venables (1999).

7. The list of countries is given in the appendix. A similar pattern is observed using data on manufacturing wages per worker. See Redding and Venables (2000) for further details.

8. For example, Gallup and Sachs (1999). We only use variables that can be reasonably regarded as exogenous, so do not have, for example, measures of countries' human or physical capital stocks.

9. Cairncross (2001) p113.

10. A good example of outsourcing is Nortel Networks, a Canadian company that specialises in high-performance communications networks. In 1998 it sold off its production plants to separate companies with whom it now has long term contracts, in order to concentrate on production of the most sophisticated components and on network installation (Cairncross 2001 p150).

11. British Airways expects to reduce the number of suppliers from 14000 to around 2000 as it implements on-line procurement. (Cairncross 2001 p138).

12. See Holmstrom and Roberts (1998) and Gibbons (1998) for surveys of these two areas.

13. The curve is concave, although not strictly concave everywhere.

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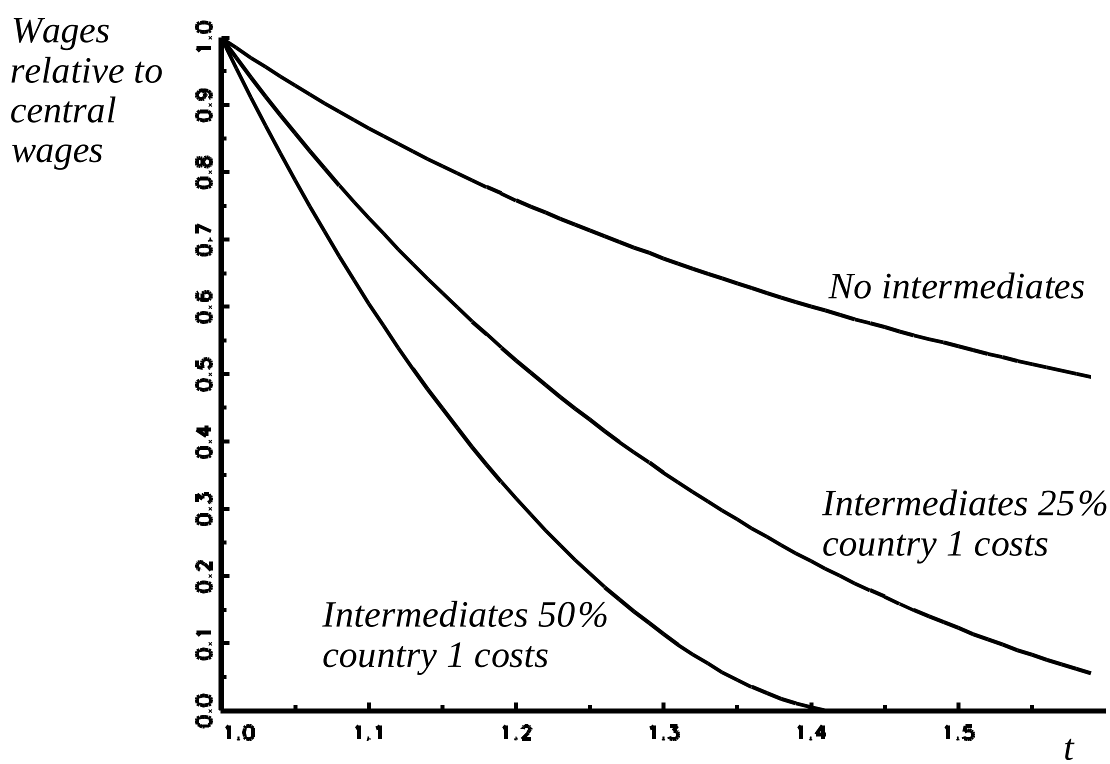


Figure 1: Trade costs and wages

Figure 2 : GDP per capita and FMA

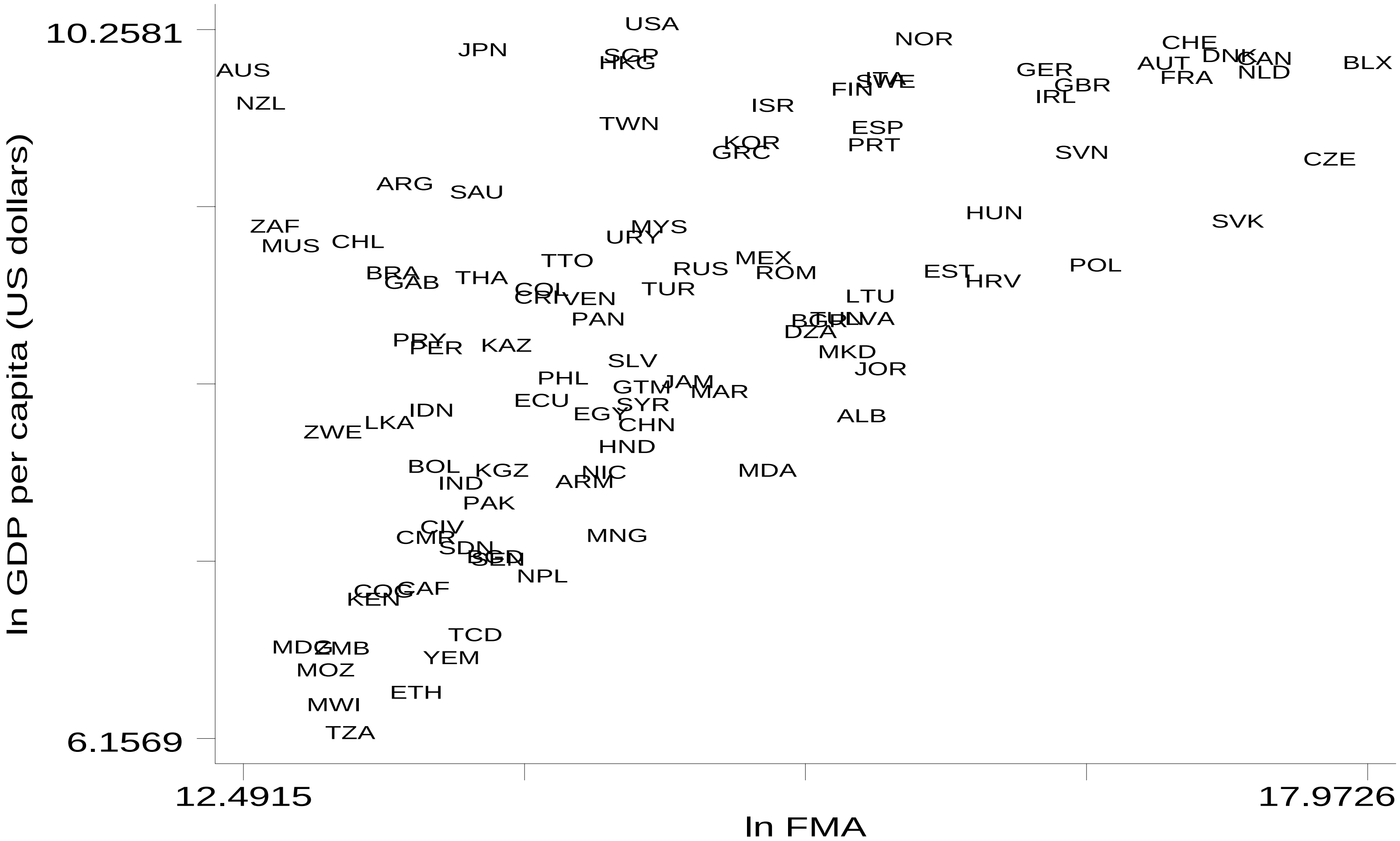
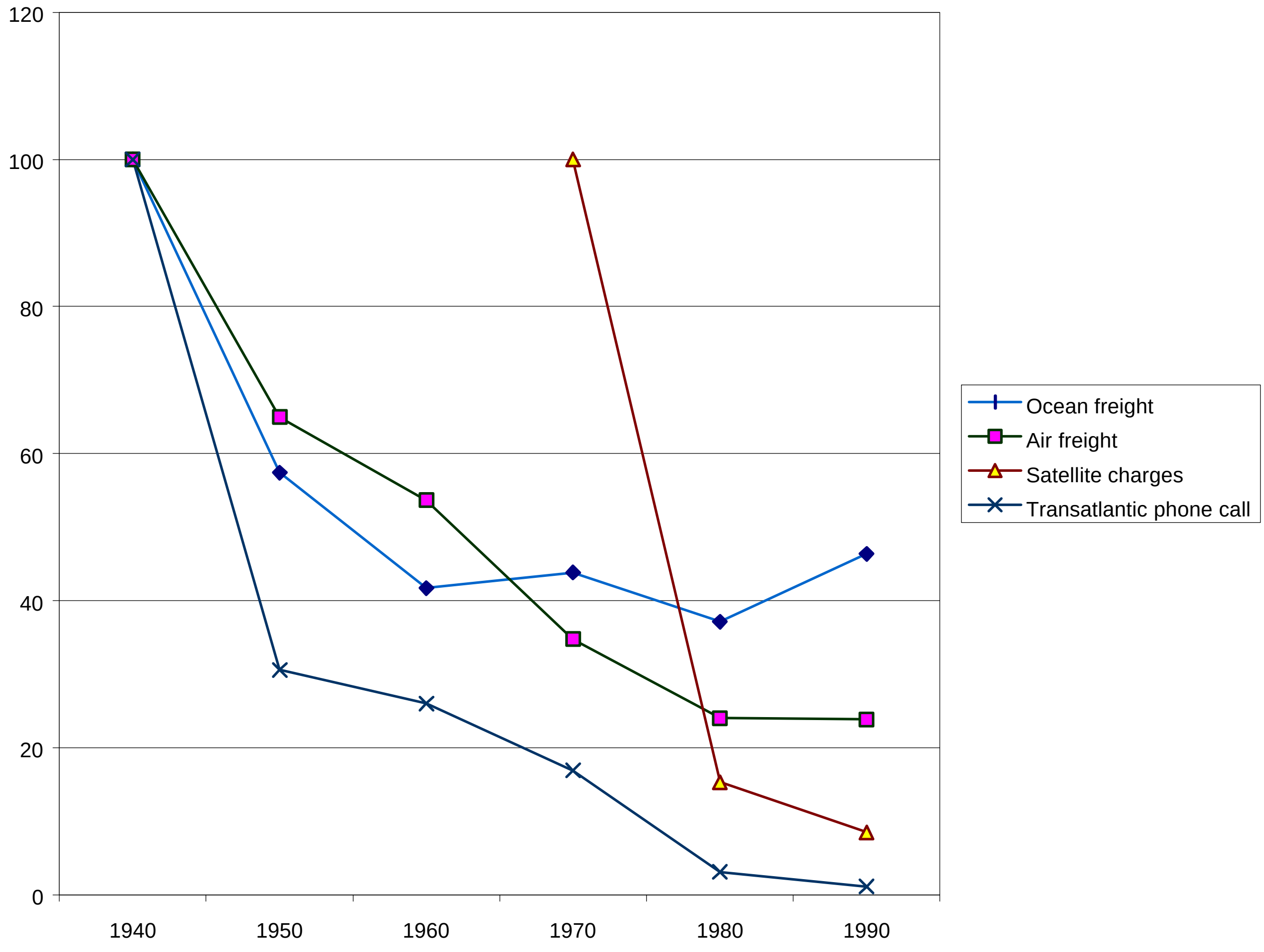


Figure 3: Transportation versus Communication Costs, 1940-1990
source: Baldwin and Martin (1999)



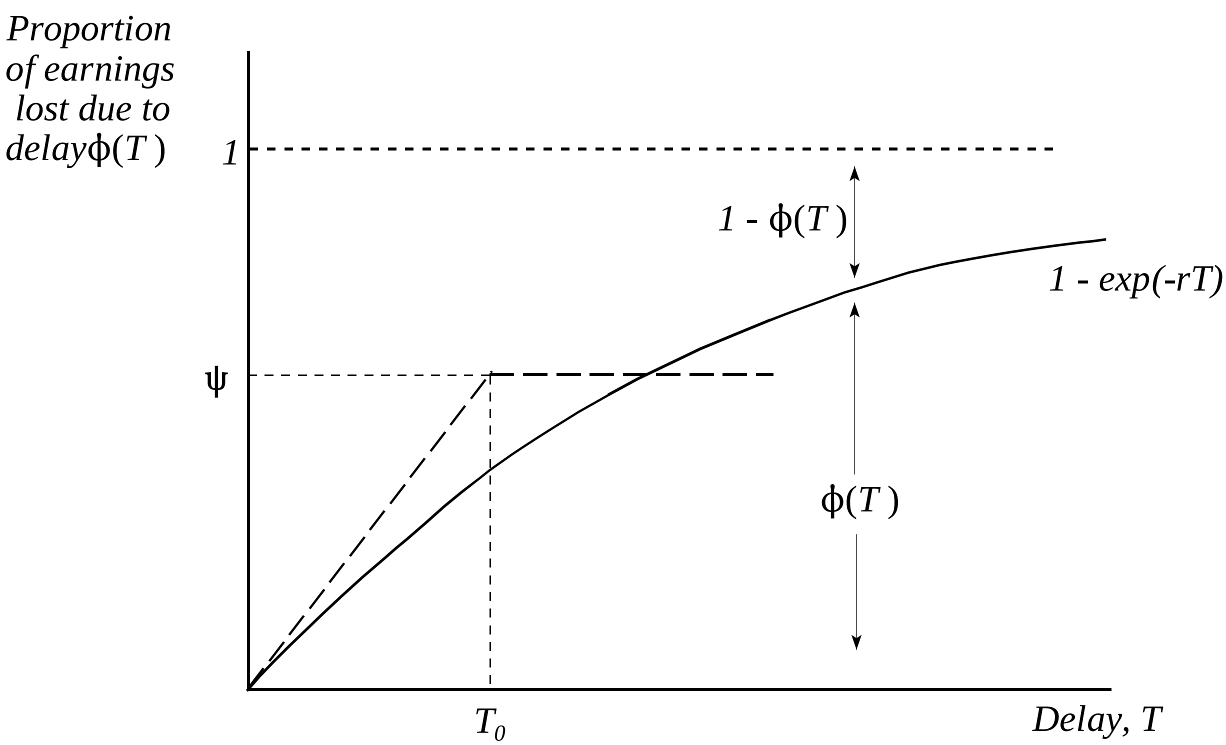


Figure 4: The cost of delay

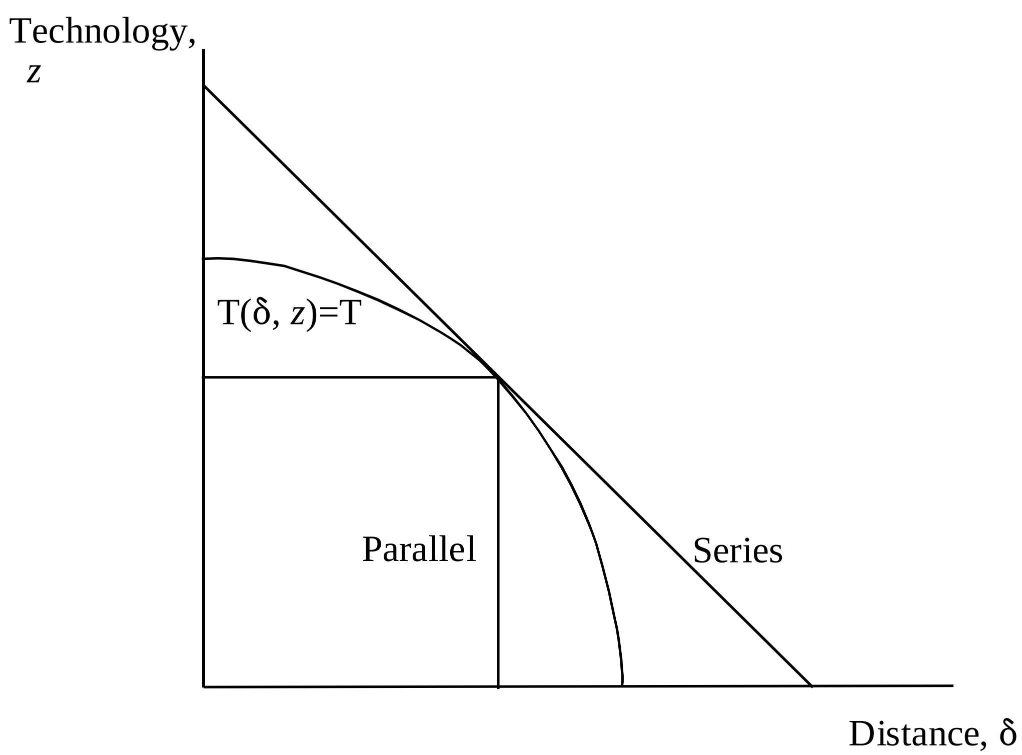


Figure 5: Iso-time lines

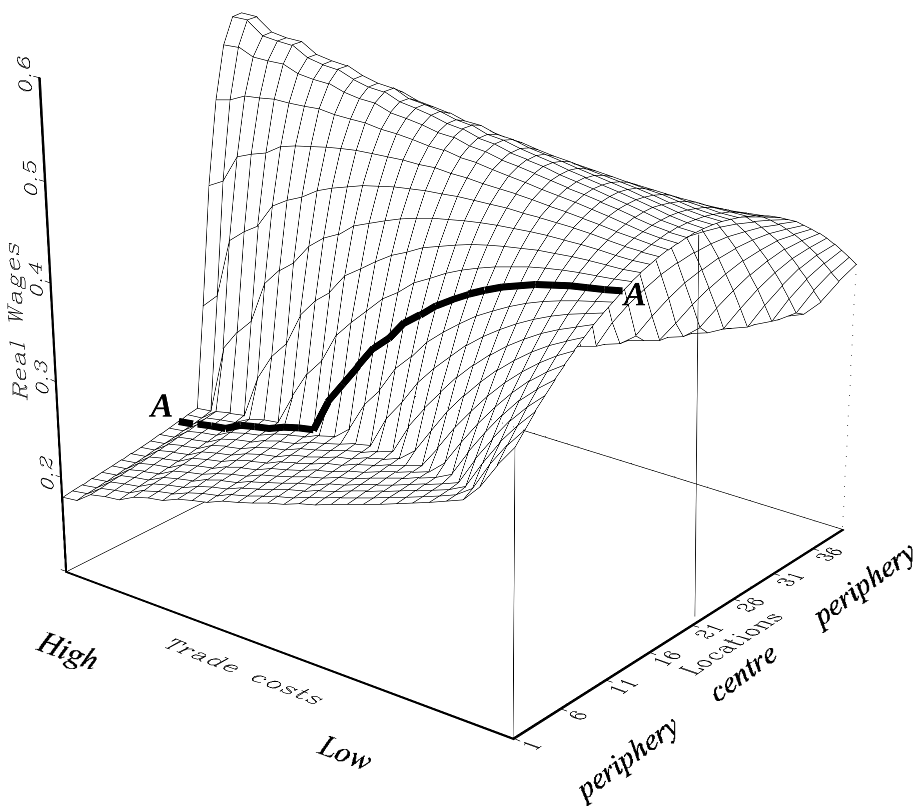


Figure 6: Trade costs and real wages

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