ICT: Inflating or Deflating Offshoring?

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Abstract There is a widespread belief that the digital revolution fostered the globalization of production (and will continue to do so). By tracking down firm adjustment in a general equilibrium model, the paper shows that the fraction produced offshore does not necessarily increase though, despite the fact that advances in information and communication technologies (ICT) tend to facilitate the coordination of a fragmented production process. Rather, if, due to technical change, fragmentation of production becomes more effective in reducing costs, the result – though on face of it counterintuitive – becomes ambiguous. Due to its impact on the demand for ICT-related skills and specialization patterns, improvements in ICT may even curb offshoring. The paper identifies crucial parameters in one effect dominating the other.

Keywords: Offshoring, fragmentation, international specialization, service links, technological change

JEL Classification: F12, F16, O33

1. Introduction

The personal computer and the internet, often alluded to as the “digital revolution”, have changed the world.¹ This notion has been popularized and carried to extremes by Pulitzer-prize winning author Thomas L. Friedman in his “The World is Flat” which in 2005 topped the widely acknowledged non-fiction bestseller list of the New York Times. In its 3rd and completely updated and expanded edition (Friedman, 2007), it is still scoring high in the paperback section, obviously reflecting what many people think of as has happened. The book caters to the perception that the information and communication revolution has shrunk the world in the sense that geographical distance matters much less nowadays than it did in the past. The implication of that being, that it does not make a lot of difference whether the competitor sits next door or in China. Thereby, the information and communication technologies (ICT) have intensified the competition or, as Friedman puts it, have leveled the playing field between the industrialized and the emerging economies in particular, thus nourishing the fear of more and more production (and consequently jobs) going offshore, whether it be at arms-length via FDI or in the form of outsourcing to a Foreign supplier.² While most of the scientific community considers this notion as overly exaggerated and is much more cautious when it comes to the word “revolution” in light of the fact that previous waves of globalization were much more intense (at least relative to GDP at those times), most share in the view, that this time things are different in many respects (see Leamer, 2007, for a survey).

Two aspects are emphasized in particular. First, rather than the skill content per se, it seems to be the skill content as combined with the tradability and the potential of the output being digitized that matters for emerging economies gaining market share. Tradability in turn is influenced by ICT. Apparently, while in the 1980s and 1990s the growing competition from Foreign countries primarily affected the low skilled in the US and in Europe, nowadays even some high-skilled work, illustrated by Friedman in terms of the entrepreneur in India eager to export X-ray analysis, software programming, or the filing of tax returns, is being imported from abroad. This casual observation is increasingly backed by theoretical and empirical work according to which it is not just low-skilled labor that is subject to erosion.³ For the US, Alan Blinder (2009) thus quantifies the overall implications as up to 30 to 40 Mio. jobs (blue and white collar)
that are potentially offshorable due to ICT developments. Numbers for Europe (an economy comparable in size to the US) might not be that much different. Rather, there, consequences might be even more pronounced as the ICT-revolution mixes with the EU’s internal integration and the fall of the iron curtain.

Second, much of the growth in international trade has been in intermediates and is thus vertical-specialization related. Chen et al. (2005, p.42), for instance, report that, based on Input-Output tables, the share of imported intermediates in exports rose from 5.9% in 1972 to 12.3% in 1997, in the UK from 20.2% in 1968 to 27.2% in 1998, and in Germany from 18.6% in 1978 to 22.4% in 1995. Hummels et al. (2001), who broaden their focus on 10 OECD countries, come up with a share of 21% as being imported from emerging economies and a growth rate of 30% of vertical specialization-driven trade between 1970 and 1990. Recent estimates by Dean et al. (2008) focusing on Chinese trade in 2002 show a substantial amount of vertical specialization with a foreign content of 25% (average) or 46% (if tracked according to processing and other trade) in aggregate exports. Evidently, this development is by no means confined to just a few OECD-countries. With respect to world trade, Jones et al. (2005), find that in the period 1990 to 2000 (for which data is more reliable than it was in previous periods) trade in parts and components grew on average by 9.1% p.a. whereas world trade rose by 6.5% p.a. and world GDP by just 3.7% p.a. It is certainly not simply the traditional Ricardian pattern of cloth for wine anymore (i.e. horizontal trade in final goods only). Rather, more and more, it seems to be slices of work (or tasks) that move abroad. Without the advances in ICT, which allow the coordination an internationally dispersed production process, this seems to be inconceivable.

Consequently, both aspects are frequently considered as being related. Grossman & Rossi-Hansberg (2008, p.1978), for instance, assume that “[r]evolutionary advances in transportation and communications technology have weakened the link between labor specialization and geographic concentration, [...] The result has been a boom in 'offshoring'.” On a similar account Jones et al. (2005) note that “[t]echnological progress, domestic liberalization and international negotiations all result in lowered prices of service links that encourage increased international fragmentation of production.”

However, although intuitively appealing, advances in ICT need not necessarily imply that the fraction of imports in exports increases, even if those improvements ceteris paribus imply that the management of a fragmented production process tends to become cheaper. Rather, in a general equilibrium context, ICT related technical change might induce opposing forces that outweigh the partial equilibrium effects. Two potential candidates come to mind when it comes to countervailing effects: (i) the increase in the demand for ICT-related skills and (ii) real income effects and their implied effects on the international specialization of production. Hence, it cannot be taken for granted that the trend towards offshoring observed thus far is due to ICT, nor can any trend be extrapolated for sure, even if information processing costs should continue to decline. Consequently, Baldwin (2006, p.7) writes “[u]nderstanding the second unbundling (which has variously been called fragmentation, offshoring, vertical specialization, and slicing up the value chain) may require a new paradigm.”

This becomes particularly evident when considering the difference between the pure division of labor as illustrated by Adam Smith in his famous pin factory example on the one hand and the allocation of the various parts of work across countries on the other hand. In particular the former has been strongly facilitated by the new possibilities ICT opens up, while the latter is also governed by relative prices. The latter will be modified though as supply and demand for business services change due to advances in ICT. Moreover, the fragmentation of production into production blocs is a precondition for parts of production being relocated. By distinguishing these two aspects and by tracking down firm adjustment with respect to fragmentation and offshoring in a general equilibrium framework, this paper shows that advances in ICT indeed have an ambiguous effect on the fraction of production being offshored. Here, offshoring is understood as shifting parts or components of production abroad, without regard to details such as ownership. As it turns out, firms tend to increase the fraction of intermediates production offshore if ICT
is sufficiently cost effective in managing a fragmented production line. Otherwise, offshoring decreases in response to advances in ICT, thus resulting in a u-shaped pattern of offshoring wrt to advances in ICT.

Though recent years have witnessed a surge in studies on technology and offshoring, they do not distinguish the two aspects and their implications. Rather, many of the studies concentrate on industrial organization aspects along Coasian and Williamsonian lines (such as relationship specificity, hold-up problems, incomplete contracts, search and matching) as determinants of offshoring (see, for instance, the survey by Spencer, 2005, as well as the work by Abramovsky & Griffith, 2006, and Grossman & Rossi-Hansberg, 2008). While per se interesting, they do not explicitly address the question whether advances in ICT indeed promote offshoring in the same manner as, for instance, differences in endowments do.

A second group of studies, such as, for instance, Antrás & Helpman (2004), Yeaple (2005) and Ekholm & Midelfart (2005), to name a few, also relate to trade and technology with a particular focus on ownership structure and organizational form. There, however, the technology-related driving force being firm heterogeneity with respect to productivity rather than ICT (or service links in managing a fragmented production process).

By drawing on the management of fragmented production processes with parts of the production being offshored and ICT affecting the productivity of service links between production blocs, this paper builds on previous work by Jones & Kierzkowski (1990) as well as Francois (1990) and the subsequent literature (e.g. Jones et al., 2005; Francois et al., 2005; Dluhosch, 2006). Yet, while in the same spirit, none of those authors derive the fraction of production that goes offshore endogenously as a function of the cost effectiveness of ICT in managing a fragmented production process.

Unlike Harris (2001) who deals with the network aspects ICT might have and thus the external effects between firms due to ICT (thus featuring also multiple equilibria as do many of the models from this strand), this paper concentrates on the within firm implications of an exogenous increase in the cost effectiveness of ICT. Nevertheless, the paper tracks two engines in the process of offshoring, namely exogenous and endogenous technical change. While the former is obvious and directly related to ICT, the latter emanates from the fact that due to the general equilibrium effects market size changes due to changes in ICT thus affecting in turn the extent to which firms make use of information and communication technologies since they (in the form of IT infrastructure of firms, service personnel etc.) add to the fixed costs of production whereas the pay off of the digital revolution tends to be in the reduction of variable costs of producing another unit of output. Naturally, the extent to which firms can reap economies of scale is prone to changes in market size.

The paper is organized as follows. Section 2 sets out a general equilibrium model with imperfect competition and multistage production. In line with casual observation, the model features trade in intermediates as well as in final goods. Moreover, intermediates (i.e. parts potentially offshorable) are produced with high- and low-skilled labor, with the (relative) skill content endogenously determined. Hence, low- as well as high-skilled labor may be subject to offshoring. Whether or not components are produced offshore inter alia depends on the ICT-related productivity of business services in managing a fragmented production process and their implied effects on local labor demand and on effective labor supplies. Section 3 outlines the equilibria including horizontal trade (i.e. in final goods) and vertical trade (offshoring of production blocs) in the model. Section 4 gives an account of the comparative statics on the fraction of production being produced offshore. For matters of comparison, it proceeds in two steps. First, it explores a benchmark model showing how differences in endowments per se affect the equilibrium fraction of production globally sourced. Second, it examines what happens, if, at the same time, production is rationalized along Adam Smith lines due to advances in information and communication technologies necessary for managing a fragmented production so that the fragmentation of production is facilitated. Though, on face of it, both matters seem to imply that more and more production is being
offshored, they may in fact have very different implications on the fraction of production internationally sourced. Unlike differences in factor proportions, the effect of a productivity increase in business services for handling and managing a fragmented production process is ambiguous. The section also identifies crucial parameters in determining the sign of the net effect, provided that factor price equalization and incomplete specialization is sustained by trade balance equilibrium. Section 5 concludes.

2. The Model

Consider two countries, Home and Foreign, each being populated by a given number of low- and high-skilled individuals, $L, L^*$ and $H, H^*$ respectively. Variables and parameters denoted by an asterisk refer to Foreign, those without to Home. If each individual inelastically supplies one unit of labor to the market factor proportions are $\kappa = L/H$ and $\kappa^* = L^*/H^*$ respectively. In principle, there is no restriction on $\kappa$. However, in line with recent concerns in many industrialized countries, we will assume that Home is relatively high-skill abundant as compared to Foreign, i.e. $\kappa < \kappa^*$. Moreover, we will assume without loss of generality that $H = H^*$, thus saving on notation as well as dimensionality.

2.1 Demand for Final Goods

Focusing first on final goods, we suppose that there are two types of goods. Both of them are nested into individual utility according to a Cobb-Douglas function with expenditure shares $\mu$ and $(1 - \mu)$, namely

1. a set of differentiated manufactured goods, with a subset of those goods of domestic and another subset of foreign origin. The former are supplied in quantity $x_i$ (with $i = 1, ..., n$), the latter in quantity $x_j$ (with $j = 1, ..., n^*$); i.e. goods indexed $i$ are produced in Home while those indexed $j$ are Foreign made, with each of the varieties $i = 1, ..., n$ and $j = 1, ..., n^*$ supplied by a single firm

2. homogenous consumer services which are supplied in quantities $x_0$ and $x_0^*$ and which will also serve as numéraire.

As in the standard love-of-variety case, utility of a representative individual of type $\kappa \in \{L,H\}$ shall be described by the following function:

$$U_\kappa = \left( \sum_{i=1}^{n} e_{i,\kappa}^\eta + \sum_{j=1}^{n^*} e_{j,\kappa}^\eta \right)^\frac{\eta \mu}{\eta - 1} c_{0,\kappa}^{1 - \mu}$$

with $c_{0,\kappa}$ the consumption of consumer services, $e_{i,\kappa}, e_{j,\kappa}$ the consumption of differentiated goods and $\eta$ the (constant) elasticity of substitution between varieties $i = 1, ..., n, j = 1, ..., n^*$ for $n, n^*$ large.

Now, if each individual in Home is either low or high skilled and supplies one unit of labor, it receives wage $w_\kappa$, which can be spend on the two types of goods. Maximizing eq. (1) subject to individual budget constraints, $w_\kappa = c_{0,\kappa} + \sum_{i=1}^{n} p_i c_{i,\kappa} + \sum_{j=1}^{n^*} p^*_j c_{j,\kappa}$, thus yields each individual's demand as a function of his income and (relative) prices of the differentiated goods. To keep the analysis as simple as possible we will suppose that the differentiated goods are completely symmetrical so that relative prices within each subset of goods are the same, i.e. $p_i = p$ and $p_j = p^*$. 

Aggregation over all individuals in Home then implies the left hand set of aggregate demand functions (2). The right hand set of (2) lists the corresponding demand functions in Foreign.

\[ c_0 = (1 - \mu)Y \]
\[ c_i = \frac{\mu Y}{p \left( n + n^* \left( \frac{p}{p^*} \right)^{\eta-1} \right)} \]
\[ c_j = \frac{\mu Y}{p \left( n^* + n \left( \frac{p^*}{p} \right)^{\eta-1} \right)} \]

with aggregate consumption \( c_0 = c_{0,L} + c_{0,H} \), \( c_i = c_{i,L} + c_{i,H} \), \( c_j = c_{j,L} + c_{j,H} \) and aggregate income \( Y = w_L L + w_H H \), or, invoking the NIPA, \( Y = c_0 + \sum_{i=1}^n p c_i + \sum_{j=1}^n p^* c_j \). By analogy, we obtain aggregate consumption in Foreign \( c_0^*, c_i^*, c_j^* \). Supposing that factor price equalization holds, aggregate income in Foreign is \( Y^* = w_L L^* + w_H H^* \), or \( Y^* = c_0^* + \sum_{i=1}^n p c_i^* + \sum_{j=1}^n p^* c_j^* \) for that matter.

### 2.2 Adding Complexity to the Model: Supply and Multistage Production

First, the easy part: the consumer services sector of both countries is assumed to be a constant-returns perfect-competition industry which employs low-skilled labor according to the linear production function \( x_0 = L_0 \) and \( x_0^* = L_0^* \) respectively. If factor price equalization is sustained in trading equilibrium prices of consumer services are the same across countries, as are wages for the low skilled at \( w_L = 1 \).

Second, the complex part: recall that, in the differentiated sector, production consists of \( n \) (Home) and \( n^* \) (Foreign) firms, each supplying one line of goods in monopolistic competition à la Chamberlin. Suppose furthermore that firms make zero profits due to free entry into the business. Here, we need to accommodate the options of

i) fragmenting production into different production blocs so that producers can reap economies of scale along Smithian lines, no matter whether the production of the resulting components is eventually located at Home or abroad

ii) offshoring some of those production blocs.

Let therefore

i) index \( z_i \) denote the extent of fragmentation (or number of intermediates aka production blocs) and

ii) fraction \( \tau \) be the share of the total value of all intermediates which is produced offshore.

Both, i) and ii), will be determined endogenously. However, \( z_i \) will be determined on the micro- or firm-level and \( \tau \) on the macro-level (via trading equilibrium). The eventual offshoring of some of the components and their import, assembly and re-export (after having been incorporated into the differentiated goods) thus reflects the sort of vertical specialization often alluded to in the recent literature on trade.

Consider next the implications of production fragmentation: as in any standard monopolistic competition trade model, production of each variety involves fixed \( F \) and variable costs \( v x_i \). However, in contrast to
those models, variable costs depend on the extent of fragmentation \( z_i \) chosen, with the Smithian cost savings abiding by the following iso-elastic function \( \bar{v}z_i^{\gamma}x_i \), and with parameter \( \gamma \) the effectiveness of fragmentation in cost reduction. Think of \( \gamma \) as a measure of the productivity of ICT: the larger \( \gamma \), the lower the variable costs of producing another unit of output. Yet, cost savings are restricted by two aspects. First of all, the coordination of intermediates production entails some extra costs for business services for planning, steering and supervising a fragmented production process, with the additional costs incurred depending on the extent of fragmentation \( z_i \) but not on output \( x_i \). So, let \( p_z \) denote the price of those business services per fragment, so that \( p_zz_i \) is the total additional cost per product line for managing a production process fragmented at scale \( z_i \). However, \( p_z \) is also endogenous to the model: if each additional intermediate requires exactly one unit of business services and if each of those units is produced by just one unit of high-skilled labor with price \( w_H \), additional costs in fact amount to \( w_Hz_i \), with \( w_H = p_z \). Producers thus face a trade off: on the one hand, more production blocs mean that variable costs are lower; on the other hand, additional business services add to the fixed costs of each variety. The optimal extent of fragmentation \( z_i^{*\text{opt}} \) depends on the net effect. The second restriction emanates from the fact that in order to ensure economically meaningful results in general equilibrium we will consider cost effectiveness generally to be bounded by \( \gamma < 1/(\eta - 1) \). Hence, with \( (x_i, p_i) \) the revenues of each of the \( n \) producers, costs \( (x_i, p_i, - w_Hz_i) \) or \( \left( F + \bar{v}z_i^{\gamma}x_i \right) \) for that matter, are due to intermediates which may be either produced at Home or abroad (recall that revenues equal costs due to the assumption of free entry).

While the fixed- vs. variable-cost perspective says something about the behavior of costs as output is varied, it does not tell us anything about the factors of production, which are required in order to produce the output. Here, unlike in the most basic monopolistic competition cum love-of-variety models in which all varieties are produced with a single factor of production, we will assume that the production of intermediates themselves is a Cobb-Douglas composite with factor income shares \( \theta \) (high skilled) and \( (1-\theta) \) (low skilled) and thus \( \left( (1-\theta)/\theta \right)H_m/L_m \) the marginal rate of substitution between skill levels and \( H_m \in \overline{H} \) and \( L_m \in \overline{L} \) labor units allocated to intermediates production. Note though that, ceteris paribus, fewer labor units are required the larger the fragmentation index \( z_i \). This set up reflects the fact that parts of the tasks offshored may contain high- as well as low-skilled elements with the mixture determined endogenously. As with the NIPA, if aggregated, both perspectives (fixed plus flexible or high plus low skilled) must yield the same costs though.

Yet, switching back to the fixed- vs. variable-cost perspective, we now know that profits of firm \( i \) in the differentiated goods sector are \( \pi_i = x_{i}p_{i} - \bar{v}z_i^{\gamma}x_i - F - w_Hz_i \) with optimal behavior with respect to \( x_i \) and \( z_i \) as shown in Appendix 1. Since all firms share the same cost structure and demand, optimal behavior in symmetric product market equilibrium yields the scale (3), the price (4), and the extent of fragmentation (5)

\[
x_{i} = \left( \frac{(\eta - 1)F}{1 - \gamma(\eta - 1)} \right)^{\frac{1}{\gamma}} \left( \frac{\gamma}{w_H} \right)^{\frac{\gamma}{1 - \gamma(\eta - 1)}}^{\frac{1}{\gamma}} / \bar{v} \quad (3)
\]

\[
p_{i} = \left( \frac{\eta}{\theta} \right)^{\gamma} \left( \frac{(1 - \gamma(\eta - 1))w_H}{\gamma\overline{F}} \right)^{\frac{1}{\gamma}} \quad (4)
\]

\[
z_{i} = \frac{\gamma(\eta - 1)F}{(1 - \gamma(\eta - 1))w_H} \quad (5)
\]

Recall that the differentiated goods are considered as completely symmetrical. With technology parameters \( \gamma \) the same across countries, and factor prices equalized in trading equilibrium, we thus obtain \( x_i = x_j = x^* = x, \) \( z_i = z_j = z^* = z \) (and, for sake of completeness, \( p_i = p_j = p^* = p \) \( \forall i = 1, ..., n \) and \( \forall j = 1, ..., n^* \).
Hence, given parameter values $\gamma$, $\eta$, $\bar{\nu}$, $\bar{F}$, firm behavior crucially depends on the relative price of business services $p_Z$ or, due to the 1:1 input-output ratio in the production of business services, wages per unit of high-skilled labor $w_H$. However, with trade, relative wages of high-skilled labor are determined by world supply and demand.

Moreover, as alluded to previously under ii), the (optimal) number of intermediates $z$ according to eq.(5) may be partly produced locally or partly produced abroad, with the fraction $\tau$ of imports (“extent of offshoring”) determined endogenously. Hence, costs $\tau(xp - w_H z)$ (or $\tau(F + \bar{\nu} \gamma x)$ for that matter) are due to imported intermediates while $(1 - \tau)(xp - w_H z)$ (or $(1 - \tau)(F + \bar{\nu} \gamma x)$ for that matter) stem from intermediates produced in Home.

3. Equilibrium with Offshoring

3.1 Market Clearing: Preliminaries

Collecting the information thus far, we have

- two types of final goods, a set of differentiated goods and consumer services and
- two types of inputs for differentiated goods, namely intermediates (i.e. components of domestic and foreign origin) and business services for managing a fragmented production process.

In order to be able to determine the trade pattern, two of them are considered tradable while the other two are non-tradables. In particular services, i.e. consumer services and business (or headquarter) services, will be considered as not (directly) tradable.

As to services, local supply of consumer services thus equals local demand in equilibrium, i.e. $x_0 = c_0$ and $x_0^* = c_0^*$ in Home and in Foreign respectively. Note that with factor price equalization and the underlying simple linear production function, consumer services will nevertheless cost the same at Home and abroad, so that we can invoke the integrated economy approach and therefore consumer services can also be used as numéraire.

Likewise, business services (“head-quarter services”) are supplied locally in perfect competition.

However, in contrast to consumer services, business services are produced by high-skilled labor only with employment $H_S$ and with production of output $Z$ subject to a simple linear production function $Z = H_S$. Price $p_Z$ then equilibrates supply $Z$ and demand $\sum_{i=1}^{n} z_i$ in business services. However, though themselves considered as non-tradable, business services are indirectly tradable once they are incorporated in differentiated goods. If countries are linked via trade and if factor price equalization obtains via horizontal and vertical trade, the relative price of business services is thus driven by demand and supply for high-skilled labor in the world economy, so that firms producing differentiated goods actually face the same relative price $p_Z = w_H$ for those services, independent of location.

Next, consider trade. Here, we have to distinguish between two sorts of trade flows. Due to the love of variety, each country is both an exporter and an importer of differentiated final goods. This gives rise to horizontal, intra-industry trade. However, since production of these goods may be partly (internationally) fragmented into several production blocs, some of the production blocs in direct production may be produced locally, others globally sourced. This gives rise to vertical trade. The specialization pattern can thus be described by two variables, namely $n$ as compared to $n^*$ (the number of differentiated goods in horizontal trade) and $\tau$ (the fraction of intermediates giving rise to vertical trade).
Figure 1 provides a graphical account of the nexus between production fragmentation, offshoring and trade flows with Home (Foreign) either specializing in differentiated goods or in intermediates production. In the example of Fig.1, Home is an exporter in differentiated goods while importing other varieties and intermediates. Correspondingly, Foreign is a net importer of differentiated goods, and exports intermediates.

Due to the properties of the utility and thus demand functions, exports and imports in differentiated goods and thus the intra-industry parts of trade are straightforward. If \( n^* \) differentiated goods are produced in Foreign and if \( Y^w = Y + Y' \), a fraction \( Y'/Y'^w \) of the output \( x \) of each industry is marketed locally (with total value \( (Y'/Y'^w)x^np \)) while the rest of the output, that is \( (Y/Y'^w)x^*p \), is exported at price \( p \) in exchange for varieties supplied by Home. The same applies to Home, with the image reversed: due to the demand by Foreigners for Home’s varieties, Home obtains export revenues of \( (Y'/Y'^w)x^np \) while the rest (that is \( Y/Y'^w \) times the total value \( x^np \) of production in manufacturing) is consumed domestically.

However, if production of differentiated goods is – for example – divided into \( z_{opt} = 3 \) production blocs and if one of the three intermediates is produced abroad, Home imports \( n \) intermediates besides its imports in final goods \( (Y'/Y'^w)x^np \). Hence, the total value of imported intermediates is \( (1/3)n(xp - pZ) \) (i.e. a third of all final sales minus value added in terms of business services), and \( (2/3)n(xp - pZ) \) is domestically sourced. Generally speaking, a fraction \( \tau \) of direct production is globally sourced in each production line, with \( \tau \) determined by relative factor prices. With production fragmentation in Home requiring a total of \( n_{new} \) in terms of extra expenditures on business services, value added in direct production is \( n(xp - wHz) \) of which \( \tau(xp - wHz) \) of each manufacture is thus imported and \( (1 - \tau)(xp - wHz) \) domestically sourced.

Hence, while consumer as well as business services are non-tradable, differentiated goods and intermediates are internationally tradable. The fraction of intermediates that goes offshore is thus driven by two equilibrium conditions, namely (i) the trade balance equilibrium (Section 3.2) and (ii) the requirement that all markets for non-tradables, that is consumer and business services, are cleared locally which is a stronger assumption than world market clearing and thus must be considered separately (Section 3.3).

### 3.2 Trade Balance and Replication of the Integrated Economy

A first restriction on offshoring is that it must be compatible with trade balance equilibrium. As illustrated in Fig.1, Home exports a fraction of its locally produced value of manufactured goods \( x^np \) according to Foreign’s share in world income \( (Y'/Y'^w) \) while importing a fraction according to its own share in world income (that is \( Y/Y'^w \)) of the value of those supplied by Foreign – if individual demand covers all of the differentiated goods on offer, as is assumed with love of variety, and if – due to the symmetry of the set up – firms charge the same price \( p \). If each of the \( n \) firms in Home offshores a part \( \tau \) of its direct production (that is the value of gross output \( xp \) minus that of locally tied management services \( wHz \)), expenditures on foreign build intermediates are \( \tau(n(xp - wHz)) \). Trade balance thus requires that the value of exports (LHS) equals the value of import (RHS)

\[
\left(1 - \frac{Y}{Y'^w}\right)x^np = \tau(n(xp - wHz)) + \frac{Y}{Y'^w}x^*p
\]  

(6)

Restricting our analysis to specialization patterns for which factor price equalization obtains allows substituting some of the variables in eq. (6) by their equilibrium values, which obtain when both countries
are completely integrated. In particular, we know that with prices of consumer services normalized to unity and production functions \( x_0 = L_0, x^*_0 = L^*_0 \) wages for the low skilled are \( w_L = w^*_L = 1 \).

Factor price equalization at \( w_L = w^*_L = 1 \) also fixes the value marginal product of low-skilled labor in the direct production of differentiated goods as otherwise labor would move between sectors until wages in both of the industries are equalized. Similarly, supposing that the integrated economy is replicated by trade, wages for the high skilled \( w_H \) in both of the economies are determined by the equality of the value marginal product in business services and in direct production of differentiated goods, i.e. the sectors which employ high-skilled labor, and with the same wage earned in both of the countries, \( w_H = w^*_H \) (see Appendix 2 for the derivation of \( w_H \) in trading equilibrium). Provided that the integrated economy is replicated via international specialization in final goods production and intermediates so that factor price equalization obtains, wages of the high skilled are a function of parameters \( \mu \) (the share of income spent on differentiated goods), \( \eta \) (the elasticity of substitution between differentiated manufactures), \( \theta \) (which relates to the marginal rate of substitution between skill levels), \( \gamma \) (how fragmentation affects variable costs) and \( \kappa, \kappa^* \) (factor proportions in Home and in Foreign).

\[
\frac{w_H}{H} = \frac{\theta \eta + (1 - \theta) \gamma (\eta - 1)}{\eta - \mu \eta (\eta + (1 - \theta) \gamma (\eta - 1))} \left( \frac{\kappa + \kappa^*}{2} \right) \quad (7)
\]

With markets of differentiated goods and intermediates in Home and Foreign fully integrated, and high-skilled endowment the same, i.e. \( H = H^* \), world income is thus \( Y^W = (\kappa + \kappa^* + 2w_H) \bar{\Pi} \), national income in Home \( Y = (\kappa + w_H) \bar{\Pi} \). Using eqs (3)-(5) and recalling that \( Y^* = Y^W - Y \) and \( n^* = n^W - n \), eq. (6) can thus be rewritten in the form of eq. (8), as demonstrated in Appendix 3.

\[
\tau_{TB} = \frac{\eta \bar{F} - \mu (1 - \gamma (\eta - 1)) (\kappa + w_H) \bar{\Pi}}{n (\eta - \gamma (\eta - 1)) \bar{F}} \quad (8)
\]

\( \tau_{TB} \) thus denotes the restriction on the extent of offshoring implied by the trade balance. With wages given by eq. (7), and parameters \( \eta, \mu, \gamma, \kappa, \bar{F}, \bar{H} \), cross-country sourcing is thus a function of the (still to be determined) number \( n \) of firms in Home. Figure 2 displays the loci \( (\tau, n) \) which, according to eq.(8), are compatible with balanced trade.\( ^{\text{viii}} \) The potential equilibria constitute an upward sloping curve in \( \tau, n \)–space (see the Appendix 5 for a detailed examination): the more Home is specialized in differentiated goods (that is the larger the net exports in final goods), the larger may be the fraction of direct production offshored (that is imports of intermediates).\( ^{\text{ix}} \)

However, markets of non-tradables must be cleared locally rather than internationally. This applies to (i) consumer services, (ii) the labor composite needed for the production of intermediates, which remains located at Home and (iii) the business services for managing production. Implicit in the fiction of an integrated world economy was the assumption that world supply equals world demand in services which however is now to be specified more precisely with these markets being cleared at the national level. By drawing on the national income and production accounts, this nexus yields a second equation in \( \tau \) and \( n \).

### 3.3 Non-tradables Equilibrium

With respect to non-tradables, it suffices to focus on (ii), that is the local labor composite needed for the part of components production that remains located at Home. This is because the latter also entails the equilibrium employment and thus supply in both, the consumer and the business services industry.
According to the national income and production accounts, costs of producing \((ii)\) at Home must equal the cost for the labor composite at the (local) equilibrium price \(p_C\) of a unit of the labor bundle.

\[
(1-\tau)n(F + v\gamma x) = p_C \left(H_m\right)\left(L_m\right)^{\theta}\theta
\]

with \(L_m\) and \(H_m\) the equilibrium employment in the production of intermediates. At \(L_m > 0\) and \(H_m > 0\) Home is thus incompletely specialized.

After a number of transformations (see Appendix 4 for details), eq. (9) yields

\[
\tau_{NTB} = 1 - \frac{(\mu \kappa - (1-\mu)w_H)F(1-\gamma(\eta-1))}{(1-\theta)(\eta-\gamma(\eta-1))nF}
\]

as a second restriction on the fraction \(\tau\) of production offshored, namely the one implied by local market clearing in (labor) services. Recall that national income is \(Y = (\kappa + w_H)F\) and thus determined by eq. (7), so that the condition for the markets in non-traded goods being cleared locally provides a second equation in the number of firms \(n\) in Home and the fraction of production \(\tau\) globally sourced.

While providing a restriction on \(\tau\), eq. (10) also shows that the range of economically feasible ratios of factor proportions in order for specialization to be incomplete is limited by an upper bound on low skilled labor abundance in Foreign (given factor proportions in Home): an interior solution requires the first term in brackets in the numerator to be positive (i.e. \(\mu \kappa > (1-\mu)w_H\)), or equiv., \(\kappa^*/\kappa < 2(1-\theta)(\eta-\gamma(\eta-1))(1-\mu)(\theta \eta + (1-\theta)(\eta-1)\gamma)\). This means that for any given factor endowment in Home there is an upper bound on low-skilled labor abundance in Foreign with the exact threshold a function of parameter values relating to the elasticity of substitution in demand between the various differentiated goods \(\eta\), the fraction \(\mu\) of income spent on those goods and the parameter \(\theta\) relating to the elasticity of substitution between skill levels in intermediates production for that matter, and the technology parameter \(\gamma\).

Figure 2 depicts the combinations \(\tau, n\) resulting from eq. (10) for \(\kappa^*\) within the admissible range (given \(\kappa = 1\)). As with the trade balance restriction, the resulting “non-tradables restriction” \(\tau_{NTB}\) slopes monotonically upwards in \(\tau, n\)–space (see Appendix 5): the larger the number of differentiated goods \(n\) produced at Home, the larger must be \(\tau\) in order to free resources for the local labor composite needed in the production of differentiated goods.

As proven in Appendix 6, the trade-balance restriction \(\tau_{TB}\) is steeper than the non-tradables restriction \(\tau_{NTB}\). Moreover, the number of firms sustained by trade balance restriction is larger as \(\tau\) goes to zero than those sustained by \(\tau_{NTB}\), provided that \(\kappa^* \geq \kappa\), as is assumed. The economic rationale is that more differentiated goods can be produced if Home can specialize on those parts of production which are comparatively high-skill intensive. If, by contrast, endowments were the same in both of the economies, both of the curves shared the same intercept with the \(x\)-axis, which means that there was no offshoring. The properties of these two restrictions on the equilibrium extent of outsourcing ensure that there is a unique solution \(\tau, n\) in trading equilibrium.

The two conditions, i.e. eqs (8) and (10), jointly determine the equilibrium fraction of direct production in Home which is globally sourced as
\[ \tau_{\text{equil.}} = \frac{(\eta(1 - \mu\theta) - \gamma(\eta - 1)\mu(1 - \theta))w_H - (\theta\eta + \gamma(\eta - 1)(1 - \theta))\mu\kappa}{(1 - \mu\theta)w_H - \theta\mu\kappa(\eta - \gamma(\eta - 1))} \]  

(11)

with \( w_H \) according to eq.(7). Note that the numerator and the denominator are both positive for \( \kappa < \kappa^* \). However, in order to get a better grasp of the driving forces of offshoring, the impact of trade and technology will be analyzed in disaggregate perspective, with the effects on both of the restrictions considered separately.


First, we will consider the benchmark-case of variations in factor proportions on the equilibrium extent \( \tau \) of offshoring. Suppose that the trading area expands, with the new competitors being more low-skill abundant. How does this affect the trade balance and the markets for non-tradables?

Take the trade balance restriction. Suppose that previously, that is before the enlargement, the rest of the trading area was slightly low-skill abundant with a fraction \( \tau_1 \) of intermediates sourced from abroad. Figure 3 then shows the impact of an increase in the ratio of low- to high-skilled labor in Foreign (that is Foreign becoming in effect more low-skill abundant). As a result, the trade-balance restriction shifts downwards in \( \tau, n \)-space (or towards the south-east): holding \( n \) for the moment constant, Foreign offers a greater variety of goods \( n^* \) than previously was the case since low-skilled labor is not conducive to exploiting economies of scale. Hence, the scale of production in each differentiated industry is lower while the number of varieties is larger. Due to the love of variety, Home’s imports of differentiated goods increase which c.p. results in a trade balance deficit. In order for trade to be balanced again, Home’s imports of intermediates (and therefore \( \tau \)) decline. Hence, on face of it, the trade effect seems to curb rather than boost offshoring. However, since the effect is derived without consideration of the markets for non-traded goods, it is only half the story.

At the same time, the curve of combinations \( \tau, n \) for which markets in non-traded goods are cleared, shifts upwards which means that the number of firms \( n \) producing differentiated goods decreases in Home as \( \kappa^* \) increases. The decrease is due to the fact that the production and thus supply of non-tradables must equal demand. With a (constant) fraction of income spent on both groups of goods, differentiated goods and consumer services, markets of non-tradables are affected by an increase in \( \kappa^* \): as income in terms of consumer services increases in Home, so do expenditures on consumer services. Hence, low-skilled employment in consumer services is larger than otherwise while low-skilled employment and the value of the labor composite in the local intermediates sector shrinks (RHS of eq. (9)). The production of differentiated goods thus becomes more skill-intensive, and firms increase the fraction of intermediates production offshore.

Appendix 7 provides proofs as regards the direction of shifts. Since the trade-balance curve shifts downwards and the non-tradables curve upwards in \( \tau, n \)-space, offshoring increases. Equation (11) confirms the economic intuition since the first derivative of the equilibrium fraction of production globally sourced with respect to labor abundance \( \kappa^* \) in Foreign is positive:

\[ \frac{d\tau_{\text{equil.}}}{d\kappa^*} = \frac{\gamma(\eta - 1)\mu(1 - \theta)\kappa}{\theta\mu\kappa(1 - \mu\theta)w_H(\eta - \gamma(\eta - 1))} > 0 \]  

(12)
Hence, in this case offshoring unambiguously increases, though at a decreasing rate (i.e. 
\[ d^2 \tau_{equil.}/d\kappa^2 < 0 \] since \( \theta\mu\kappa < (1 - \mu\theta)w_H \) for \( \kappa < \kappa^* \)).

In the calibration exercise of endnote 8, which is displayed in Fig.3, outsourcing increases from \( \tau_1 \) to \( \tau_2 \) as Foreign becomes more low-skill abundant. Hence, specialization effects outweigh any (induced) technology effect on multistage production. Notably, since the fraction \( \tau \) of direct production being offshored increases in \( \kappa^* \), so does the share of imports in exports (i.e. “vertical specialization”): if Foreign accounts for a fraction \( \tilde{Y}/Y_w \) of world income, it also consumes a fraction \( \tilde{Y}/Y_w \) of world output (with homothetic preferences), so that of the total value of production which has been offshored (that is \( \tau n(xp - w_Hz) \)), a fraction \( \tilde{Y}/Y_w \) is being re-exported again. The share of imports in exports is thus \( \tau(xp - w_Hz)/xp \). Since the ratio of direct production \( (xp - w_Hz) \) to output \( xp \) does not depend on labor abundance in Foreign, it follows directly that the share of imports in exports depends on how \( \tau \) is affected by low-skilled labor abundance in Foreign.

However, if, due to ICT-related advances in managing a fragmented production process, fragmentation along Smithian lines becomes more effective in cost reduction, cross-border sourcing may either increase or decrease. Consider first the impact of technology on the trade balance in Fig.4. As in Figs 2 and 3, the box represents all combinations of \( \tau \) and \( n \) for which factor price equalization obtains, with the range of \( \tau \) increasing in \( \gamma \). The thin curves in both of the panels refer to the trade balance equilibrium, the thick curves to market clearance in non-tradables. If \( \gamma \) increases, the trade-balance restriction unambiguously shifts upwards in \( \tau, n \)-space (i.e. in north-western direction): with the number of goods produced in Home held constant, the number of Foreign-made goods \( n^* \) is lower the larger \( \gamma \) while economies of scale are exploited more extensively. Hence, given \( n \), Home’s net exports in final goods, \( (n - n^*) \) increase. Since the value of intermediates production increases by less, offshoring (and thus imports of intermediates) must be larger for trade to be balanced.

Yet, at the same time, the non-tradables curve is also being pushed upwards. As income is larger in Home (due to \( \gamma \) and thus productivity being larger), so are expenditures for locally produced consumer services. More low-skilled labor is thus employed in consumer services – at the expense of low-skilled employment in the local production of intermediates. With consumer services and headquarter (i.e. business) services expanding, the value of labor bundles employed in the local intermediates production decreases (RHS of eq. (9)). On the other side (that is the LHS of eq. (9)), though, scale increases (again, due to \( \gamma \) increasing), as do therefore costs in intermediates production for a given number \( n \) of goods. Hence, the fraction \( \tau \) of production offshored must ceteris paribus (that is when focusing exclusively on the impact of \( \gamma \) on non-tradables) be larger in order to over-compensate the increase in scale.

Other than in the previous case, in which one curve shifted upwards and the other downwards in \( \tau, n \)-space, both curves thus shift upwards (see Appendix 8 for a mathematical treatment). Holding \( n \) constant, the trade balance and the markets for non-tradables thus seem to require an increase in offshoring for equilibrium to obtain. However, the number of firms in Home does not remain constant. Depending on the slopes of the curves and the relative impact of technology on the trade balance and on non-tradable markets, offshoring either increases or decreases. Hence, the net effect may be positive or negative. Moreover, the sign of the net effect may also change as fragmentation continues to become more cost effective with other parameter values unchanged.

Figure 5 gives a graphical account of the parameter values crucial in determining the sign of the net effect: the u-shaped curves in the left hand panel display the equilibrium extent of offshoring according to eq. (11) as a function of \( \gamma \). The top-most curve shows the equilibrium fraction that goes offshore, \( \tau_{equil.} \).
given that $\kappa^*/\kappa = 2$, with the two curves below showing the situation for the example of $\kappa^*/\kappa = 1.7$ and $\kappa^*/\kappa = 1.5$ respectively. With Foreign more low-skill abundant, offshoring is thus larger for any given cost effectiveness of fragmentation. This result is robust throughout the range of economically relevant parameter values $\gamma$.

All of the curves have a minimum within the economically relevant range of $\gamma$. As displayed, offshoring decreases for $\gamma$ small and increases otherwise, however, with the $\gamma$ for which $\tau_{\text{equil}}$ reaches a minimum decreasing in $\kappa^*/\kappa$. The center panel of Fig.5 pools all combinations of $\kappa^*/\kappa, \gamma$ for which $\tau_{\text{equil}}$ reaches a minimum within the economically relevant parameter range. Notably, the first derivative of eq. (11) wrt $\gamma, \partial \tau_{\text{equil}}/\partial \gamma$, changes sign, with $\partial \tau_{\text{equil}}/\partial \gamma < 0$ for $\gamma$ small and $\partial \tau_{\text{equil}}/\partial \gamma > 0$ for $\gamma$ large. Appendix 9 provides a detailed discussion. As shown, the more low-skill abundant Foreign is compared to Home, the lower the cost effectiveness parameter $\gamma$ tends to be at which offshoring rebounds (after initially decreasing). The right hand panel of Fig.5 displays combinations of parameter values $\mu, \theta$ for which the minima of $\tau_{\text{equil}}$ with respect to $\gamma$ decrease in $\kappa^*/\kappa$ (grey shaded area).

Figure 6 displays the impact of an increase in cost effectiveness on fragmented production and offshoring (with the same parameter values as in the left hand panel of Fig.5 and the parameter range confined to cases which are compatible with factor price equalization) and the implied effect on the share of imports in exports. At low values of $\gamma$, the share in exports decreases while at high values of $\gamma$ it increases, as is the case with the fraction of direct production outsourced. However, the share in exports attains a minimum at higher values of $\gamma$ than the share in direct production offshored, or of imported intermediates for that matter. The reason is that the share of indirect production (or business services for that matter) in gross production is larger the more effective fragmentation is in reducing costs. Consequently, the impact of an increase in $\tau$ on the share of imports in exports is being softened.

Though on face of it advances in managing a fragmented production process via improvements in ICT seem to promote offshoring with Home specializing in high-skill intensive end-production, cross-national sourcing and the share of imports in exports may actually decline. Another implication of the relative factor price and the income-effects on non-tradables outweighing the specialization effect is that integration with low-skill abundant countries need not be accompanied by an increase in offshoring, if, at the same time, fragmentation becomes more effective in reducing costs of production but cost effectiveness of ICT is still small.

5. Conclusions

Integration with low-skill abundant countries is generally thought to promote outsourcing of low-skill intensive parts of production. However, in principle, there are two reasons as to why cross-border sourcing can save on costs: (i) differences in endowments across countries allow at least one component to be produced more cheaply than if locally produced; (ii) unit costs of production are lower with production fragmented than if integrated – at given factor proportions.

In fact, both of the mechanisms are somehow linked, so that it is impossible to completely disentangle the effects of international trade and ICT-related technical change. This is because production fragmentation entails both, a change in technology and in trade flows, as do endowments (via induced technical change as transmitted by changes in relative factor prices). Nevertheless, some interesting differences emerge in trying to dissect the various engines relevant to the process of global sourcing.

On face of it, the two reasons have similar effects on offshoring in the sense that both seem to work towards a specialization of the skill-abundant country on skill-intensive parts of production, with the low-
skill intensive parts being internationally sourced. In case of factor-proportions driven specialization this result is probably more straightforward than in case of ICT-driven production fragmentation. In case of production fragmentation this effect is mediated through an increase in the demand for management skills which are necessary for supervising a fragmented production process: advances in communication and information technologies suggest that the effectiveness of fragmentation in terms of cost reduction increases (business services become more productive by using more advanced information and communication technologies), thus increasing ceteris paribus also the demand for ICT-related skills.

Yet, as shown in the paper, advances in coordinating a fragmented production process need not entail an increase of imports in exports (or global sourcing for that matter). Depending on parameter values quite the opposite may be the case – despite the fact that the skill-abundant country enjoys a comparative advantage in managing a fragmented production process, and despite the fact that those advances should make it easier to relocate parts of production abroad. As a corollary, integration with low-skill abundant countries need not inflate offshoring but may well deflate offshoring – if at the same time fragmentation becomes more effective in cutting costs but parameters related to cost effectiveness have not yet surpassed a critical level.

Appendix 1

From the first order conditions \( \frac{\partial \pi_i}{\partial x_i} = 0 \) and \( \frac{\partial \pi_i}{\partial z_i} = 0 \), we obtain

\[
\begin{align*}
\pi_i &= \left( \frac{\eta}{\eta - 1} \right) \bar{v} z_i^{-\gamma} \\
\gamma_i &= \left( \frac{w_H}{\eta v} \right)^{1+\gamma} z_i \tag{1a}
\end{align*}
\]

The zero-profit condition implies

\[
\gamma_i = \left( F + w_H z_i \right) \left( p_i - \bar{v} z_i^{-\gamma} \right) \\
\gamma_i = \left( \eta - 1 \right) F + w_H z_i \bar{v} z_i^{-\gamma} \\
\gamma_i = \frac{(\eta - 1) F + w_H z_i}{\bar{v} z_i^{-\gamma}} \\
\gamma_i = \frac{(\eta - 1) F + w_H z_i}{\bar{v} z_i^{-\gamma}} \tag{3a}
\]

Inserting eq. (1a) into the RHS of eq. (3a) yields

\[
\gamma_i = \frac{(\eta - 1) F + w_H z_i}{\bar{v} z_i^{-\gamma}} \tag{4a}
\]

Equating eq. (2a), together with eq. (4a), yields eq. (5), and, by inserting eq. (5) into eqs (1a) and (2a), we obtain eqs (3) and (4).

Appendix 2

Note that due to the crts properties of the labor composite industry we can exploit Samuelson’s (1949) integrated-economy approach with respect to the production of intermediates. Hence, the value of world output of the labor composite industry must equal the costs for intermediates in the world economy. Denoting the price of a labor composite bundle by \( p_c^w \) we thus obtain

\[
p_c^w \left( L_n \right)^{1-\theta} \left( H_n \right)^{\theta} = \left( n + n^* \right) \left( F + \bar{v} z^{-\gamma} x \right)
\]
as equilibrium condition. Recalling that $c_i + c^*_i = x_i$ with $x_i = x$ for $\forall i = 1, \ldots, n$, eq. (2) implies $\left(n + n^*\right) = \mu Y^n / (xp)$. Substitution of $xp$ by use of eqs (3) and (4) yields $\left(n + n^*\right) = \mu Y^n (1 - \gamma (\eta - 1)) (\eta F)$. And, since $Y^n = (\kappa + \kappa^* + 2w_H)/\eta F$, and, moreover, since, drawing on eqs (3) and (5), $\bar{v}z^{-\gamma}x = (\eta - 1)F / (1 - \gamma (\eta - 1))$, the previous equilibrium condition can be rewritten as

$$p_C^n \left( L_m^w \right)^{\gamma - \theta} \left( H_m^w \right)^{\theta} = \frac{\mu (\kappa + \kappa^* + 2w_H) F (\eta - \gamma (\eta - 1))}{\eta}$$

Since labor market equilibrium requires that the value marginal product in terms of consumer services is the same for any given skill level, i.e. for the low skilled in consumer services and in the labor composite industry, or $(1 - \theta) p_C^w \left( L_m^w \right)^{\gamma - \theta} \left( H_m^w \right)^{\theta} = 1$ for that matter, the LHS can be rewritten

$$\frac{\left( L_m^w \right)}{(1 - \theta)} = \frac{\mu (\kappa + \kappa^* + 2w_H) F (\eta - \gamma (\eta - 1))}{\eta}$$

with $L_m = \bar{L} + \bar{T} - (L_0 + L_0^*)$ according to the full employment condition. Market clearing for consumer services implies $L_0 = (1 - \mu)Y$ and $L_0^* = (1 - \mu)Y^*$, so that labor market clearing requires $L_m = (\kappa + \kappa^*) F - (1 - \mu) (\kappa + \kappa^* + 2w_H) F$. Substitution of $L_m^w$ in the previous equation by use of this expression and solving for $w_H$ thus yields eq. (7).

Appendix 3

Recall that $n^* = (n^w - n)$ with $n^w = \mu Y^n / (xp)$ (see Appendix 2). Substitution of $n^*$ in eq. (6) thus yields $n xp = m (xp - w_H z) + \mu Y$; substitution of $w_H z$ and $xp$ by use of eqs (3), (4), and (5) gives $n \eta F = m F (\eta - \gamma (\eta - 1)) + \mu (1 - \gamma (\eta - 1)) Y$. $Y$ and $w_H$ can be eliminated by $Y = (\kappa + w_H) H$ and eq. (7). Solving for $\tau$ then yields eq. (8).

Appendix 4

Remember that the value marginal product for low skilled labor must be the same in consumer services and in the production of intermediates for differentiated goods, i.e. $1 = p_C (1 - \theta) L_m^w H_m^w$. Solving for $p_C$ and inserting the result into eq. (9), yields $(1 - \tau) n (F + \bar{v}z^{-\gamma}x) = L_m / (1 - \theta)$ with $L_m = \bar{L} - L_0$ (full employment condition), and, via (local) market clearing in consumer services, $L_m = \bar{L} - (1 - \mu)Y$ and thus $L_m = \bar{L} - (1 - \mu) (\kappa + w_H) F$. Substituting $L_m$ and $\bar{v}z^{-\gamma}x$ according to Appendix 2), and solving for $\tau$ yields eq. (10).

Appendix 5

The first derivative of the trade balance condition (8) is unambiguously positive:
\[ \frac{\partial \tau_{TB}}{\partial n} = \frac{\mu(1 - \gamma(\eta - 1))}{n^2(\eta - \gamma(\eta - 1))^E} > 0 \]

as is the first derivative of the non-tradables restriction (10)

\[ \frac{\partial \tau_{NTB}}{\partial n} = \frac{(\mu \kappa - (1 - \mu)w_H)(1 - \gamma(\eta - 1))^H}{(1 - \theta)n^2(\eta - \gamma(\eta - 1))^E} > 0 \]

Recall from eq. (10) that \( \mu \kappa > (1 - \mu)w_H \) for interior solutions, i.e. \( 0 < \tau < 1 \).

**Appendix 6**

Since \( (1 - \mu \theta)w_H > \mu \theta \kappa \) (which results from the condition of \( n > 0 \) in equilibrium), we obtain \( \frac{\partial \tau_{TB}}{\partial n} > \frac{\partial \tau_{NTB}}{\partial n} \) when comparing both slopes.

Notably, \( n_{TB} \bigg|_{\tau \to 0} = \frac{\mu(1 - \gamma(\eta - 1))(\kappa + w_H)^H}{\eta^F} \)

and \( n_{NTB} \bigg|_{\tau \to 0} = \frac{(\mu(\kappa + w_H) - w_H)(1 - \gamma(\eta - 1))^H}{(1 - \theta)(\eta - \gamma(\eta - 1))^E}. \)

So that \( n_{TB} \bigg|_{\tau \to 0} > n_{NTB} \bigg|_{\tau \to 0} \) if \( \eta w_H > \mu(\theta \eta + (1 - \theta)\gamma(\eta - 1))((\kappa + w_H). \)

Note that eq. (7) implies \( \eta w_H = \mu(\theta \eta + (1 - \theta)\gamma(\eta - 1))\left(\frac{\kappa + \kappa^*}{2} + w_H\right). \)

Therefore, \( n_{TB} \bigg|_{\tau \to 0} > n_{NTB} \bigg|_{\tau \to 0} \) holds true for all \( \kappa^* > \kappa. \)

**Appendix 7**

The first derivative of the trade balance condition (8) with respect to \( \kappa^* \) is negative:

\[ \frac{\partial \tau_{TB}}{\partial \kappa^*} = -\frac{\mu(1 - \gamma(\eta - 1))}{n(\eta - \gamma(\eta - 1))^E} \left(\frac{\partial w_H}{\partial \kappa^*}\right) < 0 \]

with \( \frac{\partial w_H}{\partial \kappa^*} > 0 \) qua inspection of eq. (7). Hence, the tradables curve shifts downwards in \( \tau, n \)–space. By contrast, the first derivative of the non-tradables curve eq. (10) with respect to \( \kappa^* \) is positive

\[ \frac{\partial \tau_{NTB}}{\partial \kappa^*} = \frac{(1 - \mu)(1 - \gamma(\eta - 1))^H}{(1 - \theta)n(\eta - \gamma(\eta - 1))^E} \left(\frac{\partial w_H}{\partial \kappa^*}\right) > 0 \]

so that the latter curve shifts upwards.

**Appendix 8**
The tradables curve eq. (8) shifts upwards as $\gamma$ increases:

$$\frac{\partial \tau_{TB}}{\partial \gamma} = \left( (\eta - 1)(\kappa + w_H) + (1 - \gamma(\eta - 1)) \frac{\partial w_H}{\partial \gamma} \right) \left( \mu T \right) (\eta - \gamma(\eta - 1)) > 0$$

Notably,

$$\frac{\partial w_H}{\partial \gamma} = \eta \frac{(1 - \mu)(\eta - 1)}{(\eta - \mu (\eta + (1 - \mu) \gamma(\eta - 1)))} \left( \frac{\kappa^*}{2} + \frac{\kappa}{2} \right) > 0$$

The same applies to the non-tradables curve eq. (10)

$$\frac{\partial \tau_{NTB}}{\partial \gamma} = \left( (1 - \mu)(1 - \gamma(\eta - 1)) \frac{\partial w_H}{\partial \gamma} \right) (\eta - \gamma(\eta - 1))$$

$$\frac{\partial \tau_{NTB}}{\partial \gamma} = \left( (1 - \mu)(1 - \gamma(\eta - 1)) \frac{\partial w_H}{\partial \gamma} \right) (\eta - \gamma(\eta - 1)) > 0$$

Appendix 9

Setting the first derivative of eq. (10) wrt $\gamma$ equal to zero, i.e. $\frac{\partial \tau_{equil.}}{\partial \gamma} = 0$, and solving for $\gamma$ yields

$$\gamma = \left( \frac{1}{(1 - \mu)^2} \left( \frac{1 + \frac{\kappa^*}{\kappa}}{2} - \theta \left( \frac{1 + \frac{\kappa^*}{\kappa}}{2} + \mu \right) \right) \left( 1 - \frac{1}{(1 - \mu)(1 - \mu)} \left( \frac{1 + \frac{\kappa^*}{\kappa}}{2} - \mu^2 \theta \right) \right) \right)$$

which decreases in $\left( \frac{\kappa^*}{\kappa} \right)$ for all $\mu < 1/(1 + \theta)$ since $\frac{\partial \gamma}{\partial \tau_{equil.}} \Big|_{\gamma=0} / \partial \left( \frac{\kappa^*}{\kappa} \right) < 0$ for all $\frac{\mu^2 \theta + \mu \theta + \mu - 1}{(1 - \mu)(1 - \mu)} \leq 1$.

Endnotes

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i. The classic reference here is, of course, the costs of a 3-minute transatlantic telephone call which plummeted from 60.42 US-$ in 1960 to 0.40 US-$ in 2000 (at constant 2000 US-$, IMF, 2002); on the rapid decline of information and communication costs related to computers in particular see, for instance,
Mann & Funk Kirkegaard (2006), Ch.3 (on PPIs for PCs and DRAMs); on the impact of IP telephony on international calling rates see OECD (2003, p.29-38). Ordinary transportation costs, by contrast, declined by much less: in ocean shipping (i.e. the bulk of transportation in terms of weight as well as value) containerization led to a fall by 3-13% of shipping costs since the mid 1980s; air shipping costs per ton-kilometer though dropped by some 92% between 1955 and 2004. See Hummels (2007) for a detailed account.

ii. Surely, new cleavages might emerge in this process. Consequently, it may well be debatable whether Friedman’s metaphor is appropriate.

iii. See, for instance, Brainard & Collins (2006).

iv. Blinder’s numbers are not undisputed though, as is shown by the critical assessment by Baldwin (2009).

v. Quantitative studies trying to explicitly estimate the impact of information and communication costs on trade and offshoring are still few in numbers though. For an exception see, for instance, Freund & Weinhold (2004); Fink, Mattoo & Neagu (2005) focus mostly on trade in general and on the sectoral composition of trade rather than on offshoring in particular.

vi. This assumption reflects the empirical fact that while skill intensity increased in manufacturing, a considerable amount of low skilled labor found employment, for instance, in the retail sector.

vii. Notably, this assumption does not neglect that, in reality, business services themselves may also be tradable, but is owed to the fact that we want to determine the trade pattern wrt the trade in parts and components.

viii. The following parameters were used in the calibration exercise of Figs 2 and 3:

<table>
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<th>Parameter</th>
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<tr>
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ix. With parameter values according to the previous table, incomplete specialization requires $\tau < 0.86$ for $\kappa^* = 1.1$ and $\tau < 0.96$ for $\kappa^* = 1.6$.

x. Recall that $\eta > 1$, $\theta < 1$, and $\eta > \gamma(\eta - 1)$.

xi. Inserting parameter values as given in endnote 8 yields iso-offshoring curves $\left(\kappa^*/\kappa\right) = 0.3333\left(60 - 36\gamma - \gamma^2\right)(2 + \gamma)^2$. Notably, the numerator is larger than zero within the admissible range of $1 > \gamma$. Moreover, the curve has a negative slope of $-10.67(6-\gamma)/(2+\gamma)^3$ (as is shown in the center panel of Fig.5 with the axes reversed).

References


Figure 1. Trade in Components and in Final Goods

Figure 2. Equilibrium Conditions on Offshoring
Figure 3. Impact of Low-Skill Abundance on Offshoring

\[ \tau = 0.96 \]
\[ \tau = 0.86 \]

Equilibrium fraction offshored for ratio of low to high skilled labor in Home 1.0, in Foreign 1.6

Equilibrium fraction offshored for ratio of low to high skilled labor in Home 1.0, in Foreign 1.1

Thin curves: trade balance restriction; thick curves: non-tradables restriction

Arrows indicate shift in response to changes in the factor proportions differential

Figure 4. Impact of Technology on Offshoring

Equilibrium fraction offshored for ratio of low to high skilled labor in Home 1.0, in Foreign 1.7, \( \gamma = 0.4 \)

Equilibrium fraction offshored for ratio of low to high skilled labor in Home 1.0, in Foreign 1.7, \( \gamma = 0.6 \)

Thin curves: trade balance restriction; thick curves: non-tradables restriction

Arrows indicate direction of shift in response to changes in ICT-related productivity parameters
Figure 5. Impact of Technology and Low-skill Abundance on Offshoring
Figure 6. Impact of Technology on Imports in Exports