Offshoring and sequential production chains: A general equilibrium analysis

Philipp Harms
Johannes Gutenberg University Mainz

Jaewon Jung
Dankook University, RWTH Aachen University, THEMA

Oliver Lorz
RWTH Aachen University

Abstract. We present a two-region general equilibrium model in which firms exploit international wage differences by offshoring parts of the production process. Firms have to take into account that production steps follow a strict sequence and that transporting intermediate goods across borders is costly. We analyze how a change in transport costs affects offshoring patterns as well as factor prices, accounting for the general equilibrium effects of firms' decisions. As we demonstrate, a decline in transport costs is likely to have a non-monotonic influence on relative wages and on the volume of offshoring depending on the emergence of different firm types, with domestic wages first decreasing as lower transport costs induce firms to perform large parts of the production chain abroad and then increasing as even lower transport costs provide an incentive to select the lowest-cost location for each production step.

Résumé. Dans cet article, nous présentons un modèle d'équilibre général bi-régional au sein duquel les entreprises profitent des disparités salariales internationales pour délocaliser certaines étapes du processus de production. Les entreprises doivent prendre en considération l'ordre rigoureux des phases de production ainsi que le coût élevé du transport transfrontalier de biens intermédiaires. Nous analysons ici la façon dont la variation des coûts de transport peut affecter les types de délocalisation ainsi que les prix de facteurs, expliquant ainsi les effets sur l'équilibre général liés aux décisions des entreprises. Comme nous le démontrons, une baisse des coûts de transport est susceptible d'avoir une incidence non-monotone sur les salaires relatifs ainsi que sur le volume des délocalisations en fonction de l'émergence de différents types d'entreprises. Conséquemment, les salaires domestiques commencent d'abord à diminuer à mesure que la baisse des coûts de transport incite les entreprises à délocaliser une grande partie

Corresponding author: Jaewon Jung, jung@dankook.ac.kr

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de la chaîne de production à l'étranger, puis finissent par augmenter à mesure qu'une baisse encore plus importante des coûts de transport offre l'opportunité de choisir le lieu de production le moins cher pour chaque étape de production.

JEL classification: D24, F10, F23, L23

1. Introduction

Over the past years, a lot of attention has been devoted to the rapid advance of the "second unbundling" in international trade (Baldwin 2006), i.e., the "offshoring" of production stages, and to its consequences for trade and national labour markets. Workers in industrialized economies in particular are concerned about being exposed to competition from cheaper labour abroad if firms shift an increasing share of their production to other countries. To assess the impact of this development, general equilibrium models have been developed that capture the interdependence between firm decisions, trade flows and labour market outcomes.[1] Many recent analyses of offshoring are based on a specific idea of the production process, according to which production can be interpreted as a set of "tasks" or "production steps." The decision to offshore a certain task depends on relative factor prices and productivity levels as well as on offshoring costs for that particular task (including additional monitoring and communication costs resulting from foreign production). Individual tasks can be ordered with respect to the cost advantage of performing them abroad, and there is a unique "cut-off task" that defines the extent of offshoring. However, this perspective on firms' offshoring decisions ignores the fact that many production processes are *sequential*, i.e., individual steps follow a predetermined sequence that cannot be modified at will.[2] The sequential nature of production would not necessarily change our view on offshoring if the relative costs of performing individual tasks abroad happened to monotonically increase or decrease along the production process. Following the logic sketched above, the first part of the process would be performed domestically and the second one abroad, or vice versa. However, it is

1 Some of the important contributions to this literature include, as an example, Jones and Kierzkowski (1990), Feenstra and Hanson (1996), Kohler (2004) and Grossman and Rossi-Hansberg (2008).

2 See, e.g., Antras and de Gortari (2020), Tyazhelnikov (2019), Antras and Chor (2013), Baldwin and Venables (2013), Costinot et al. (2012, 2013), Harms et al. (2012) or Kim and Shin (2012). Earlier analyses of sequential production processes are provided by Dixit and Grossman (1982), Sanyal (1983), Yi (2003, 2010) and Navaretti and Venables (2004). Fally (2012), Antras et al. (2012) and Antras and Chor (2013) provide empirical measures to characterize sequential production processes. Descriptions of "global value chains" for specific industries (shipbuilding, automotive, electronics, apparel, food) can be found in the publications of the Global Value Chains Center at Duke University (`https://globalvaluechains.org/publications`).

quite unlikely to meet this constellation in practice. More plausibly, potential offshoring destinations have a cost advantage for some particular segments of the production process, whereas preceding and subsequent segments may be performed at lower costs in the domestic economy once the costs of delegation and monitoring are taken into account.

Absent transport costs, this would induce firms to select the lowest-cost location for each production step, implying that unfinished intermediate goods are transported back and forth between countries—possibly several times. Anecdotal evidence for such patterns is provided by, for example, the *Financial Times* (Campbell 2016) and *The Guardian* (Ruddick and Oltermann 2017), which describe how the production sharing for cars and vehicle components between the UK and the European continent involves unfinished goods crossing the Channel several times. Similar constellations are reported for the automotive industry in the USA and Mexico by Pastor (2008) and for the electronics industry in Asia by Haddad (2007), Ando and Kimura (2005) and Athukorala and Yamashita (2006). The latter studies describe the behaviour of Japanese multinationals who ship high-technology core materials to their affiliates in developing East Asia, where they produce basic parts and components; the basic parts and components are then sent back to Japan (or to other high-skill abundant countries) for quality control and/or further processing before they are sent again to developing East Asia, including in particular China, as kits for final assembly.[3]

However, while global value chains that involve multiple border crossings can be observed in reality, they do not necessarily dominate the pattern of international production. This has a straightforward explanation: if sequential production processes with non-monotonic relative costs are combined with substantial costs of shipping intermediate goods across borders, firms may be reluctant to offshore certain steps even if—considered in isolation—these could be performed at much lower costs abroad. The reason is that the domestic country may have a cost advantage with respect to adjacent steps and the costs of shifting back and forth intermediate goods may more than eat up potential cost savings from fragmenting the production process. Such a constellation has important implications for observed offshoring patterns. For example, it may explain why—despite the large international discrepancies in factor prices—certain production processes are less fragmented internationally than one might expect. At the same time, such a setup may generate substantial shifts in the total volume of offshoring as a reaction to rather moderate

3 Note that available data on offshoring derived from, for example, the World Input–Output Database (WIOD), the Global Trade Analysis Project (GTAP) database or the OECD–WTO Trade in Value-Added (TiVA) Database (see Johnson 2014, Koopman et al. 2014, Timmer et al. 2014, Backer and Miroudot 2013) do not differentiate between the use of imported intermediate inputs and the type of offshoring that we have in mind, namely, the delegation of production steps that is associated with unfinished goods crossing a border.

changes of the environment. And finally, it may give rise to a non-monotonic relationship between transport costs and the volume of offshoring.

Baldwin and Venables (2013) and Harms et al. (2012) have shown how such insights regarding the offshoring decision of individual firms can be obtained from partial equilibrium models in which factor prices are exogenous. To arrive at conclusions about the entire economy and to determine the implications of offshoring for labour markets and wages at home and abroad, we need to consider the repercussions of induced factor price changes on firms' optimal behaviour, i.e., we need to model offshoring in a general equilibrium framework. This is what the current paper does. More specifically, we develop a framework that allows determining how changes in transport costs and features of the production process influence both offshoring patterns and factor prices in a world that is characterized by sequential production processes.

We show that the impact of a decrease in transport costs on wages is likely to be non-monotonic, with the ratio of foreign over domestic wages first increasing, then decreasing and finally rebounding as transport costs fall. We derive this result using a two-region framework in which adjustment to exogenous changes takes place both at the extensive and the intensive margins, i.e., as a reaction to decreasing transport costs, both the number of firms that engage in offshoring and the volume of offshoring chosen by individual firms change. Starting from a situation in which all firms decide to perform the entire production process domestically (in the "North"), a decrease in transport costs induces more and more firms to shift their value chain abroad (to the "South") in order to benefit from a lower wage level while avoiding the expenses associated with frequent border crossings. The large expansion in the volume of offshoring associated with "production abroad" raises the relative wage in the South. Once transport costs fall below a critical level, a new firm type emerges that engages in "fragmented production," choosing the lowest-cost location for every production step. This, in turn, reduces offshoring firms' demand for labour and thus the relative wage in the South. Finally, once all firms fragment their production, a further decrease in transport costs is likely to raise the relative wage in the South because the entry of additional firms operating under fragmentation raises the demand for labour more strongly in the South than in the North.

It is important to note in what respect our approach differs from other contributions that model offshoring under the assumption of a sequential production process. In Antras and Chor (2013), a firm has to decide whether to delegate sequential production steps to independent service suppliers abroad or to integrate these suppliers into its own organization. In a world of incomplete contracts, the firm wants to elicit relationship-specific investments from its suppliers, but is unable to commit to a given payment ex ante. Sequentiality matters in this set-up because investment decisions of upstream producers may influence decisions further downstream. While our approach also considers a sequence of production steps and assumes that the respective tasks are performed on unfinished goods, we abstract from the incentive problems associated with specific organizational arrangements and do not model the potential technological interdependence between subsequent steps. Instead, we assume that it is costly (in terms of labour input) to monitor activities abroad and that these costs vary along with other costs in the production process.

Costinot et al. (2012, 2013) also assume a fixed sequence of production steps, such that there are "upstream" and "downstream" tasks. In their general equilibrium model, tasks can be delegated to other countries at the risk of a mistake that results in a failure of the entire production process. Mistakes made downstream therefore have more severe consequences compared with mistakes further upstream. Our approach differs from Costinot et al. (2012, 2013) as we (implicitly) assume that sufficient monitoring prevents foreign producers from committing mistakes and that the costs of monitoring do not increase systematically as we move from upstream to downstream tasks.[4]

The structure of the production process underlying our model is close to Harms et al. (2012) and Baldwin and Venables (2013), who characterize "snake"-like production as "... processes whose sequencing is dictated by engineering" (Baldwin and Venables 2013, p. 245). Baldwin and Venables (2013) highlight the possibility that the effective costs of performing tasks abroad may vary non-monotonically along the production chain, and they argue that this property, combined with the existence of separation—or transport—costs, may result in a non-monotonic reaction of offshoring to further advances in globalization. While our paper imposes more structure on the functional form that characterizes relative costs, we go beyond Baldwin and Venables (2013) and Harms et al. (2012) by analyzing the "snake" in a general equilibrium setting. We thus combine a plausible description of production processes and their particular implications for the extent and evolution of offshoring with a general-equilibrium perspective that endogenizes factor prices and enables us to assess the consequences of offshoring for countries' industrial structure and labour markets. The specific structure we choose also allows for the coexistence of firms with different production modes in equilibrium.

Finally, our contribution differs from recent general-equilibrium analyses of offshoring with sequential production (Antras and de Gortari 2020, Tyazhelnikov 2019) in two important respects. First, we focus on a two-region setting, juxtaposing the "North" and the "South" instead of allowing for a large number of potential offshoring destinations. Second, we use a specific functional form to characterize the evolution of offshoring costs along the production chain. This structure enables us to highlight the key trade-offs faced by firms with sequential production processes. Moreover, it restricts the set of firms' choices to three potential "production modes" ("domestic production,"

4 As we will show in section 2.2, the difference between "upstream" and "downstream" tasks is much less pronounced in our framework than it is in Antras and Chor (2013) or Costinot et al. (2012, 2013). Nevertheless, firms are limited in their ability to rearrange production steps, and this gives rise to offshoring patterns that would not occur if these constraints did not exist.

"production abroad," "fragmented production") and allows deriving qualitative results on the wage effects of decreasing transport costs.

The rest of the paper is organized as follows. In section 2, we outline the structure of our model. Section 3 discusses the properties of the equilibrium and derives comparative static results. Section 4 provides a summary and some conclusions. Proofs of our analytical findings and the results of numerical simulations are offered in the online appendix.

2. The model

2.1. Preferences

There are two regions, North and South, with an asterisk denoting South-specific variables.[5] Consumers in both regions have Cobb–Douglas preferences over two consumption goods, X and Y. The X sector produces a continuum of differentiated varieties under monopolistic competition. Good Y is homogeneous and is produced in North and South by competitive firms. Good Y can be freely traded and is chosen as numéraire with a price of 1 in both regions. Household preferences are

$$U = X^{\beta} Y^{1-\beta} \text{ and } X = \left[\int_{i \in N} x(i)^{\rho} \, di \right]^{\frac{1}{\rho}}, 0 < \beta, \rho < 1. \tag{1}$$

The index i denotes individual varieties, N is the measure ("number") of these varieties and $\sigma = 1/(1-\rho)$ is the elasticity of substitution between them. Varieties of good X are produced by firms whose headquarters are located in the North. This assumption can be rationalized by arguing that only Northern firms are able to develop and use the blueprints necessary for production. Exporting X-goods to the South is associated with iceberg trade costs $\tau > 1$ per unit. Maximizing utility for given income levels I and I^* yields the following demand system:

$$\begin{aligned} x(i)^d &= \left(\frac{P_X}{p(i)}\right)^{\sigma} X, & x(i)^{d*} &= \tau \left(\frac{P_X^*}{p(i)\tau}\right)^{\sigma} X^*, \\ P_X &= \left[\int_{i \in N} p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}, & P_X^* &= \tau P_X, \\ P_X X &= \beta I, & P_X^* X^* &= \beta I^*, \\ Y &= (1-\beta) I \quad \text{and} & Y^* &= (1-\beta) I^*. \end{aligned} \tag{2}$$

Here, P_X and P_X^* denote the ideal price index for the X-sector in the domestic and the foreign economies, respectively.

2.2. Technologies for production and offshoring

Each region is endowed with given quantities of labour $\bar{L}$ (in efficiency units) and of a fixed composite factor $\bar{R}$. We assume that labour can be employed in

5 Each region should be understood as an aggregate composed of possibly numerous countries.

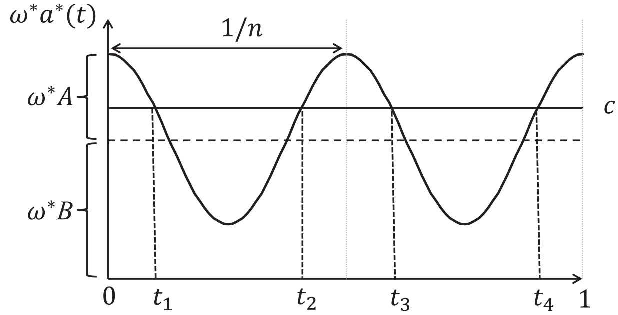

FIGURE 1 Costs along the production chain
NOTES: The horizontal straight line represents (constant) input requirements in domestic labour units c for tasks performed in the domestic economy. The curve $\omega^* a^*(t)$ represents the input requirements (including offshoring costs) in terms of domestic labour units for tasks performed in the foreign economy.

both sectors, whereas the fixed composite factor, which may be land or a natural resource, is specific to industry Y. Production of Y (Q_Y) combines the quantities R_Y and L_Y according to a Cobb–Douglas production function:

$$Q_Y = R_Y^{\alpha} L_Y^{1-\alpha}. \tag{3}$$

We follow Grossman and Rossi-Hansberg (2008) in modelling the production process of any variety $x(i)$ as a continuum of tasks, indexed by t, and ranging from 0 to 1. As in Harms et al. (2012) and Baldwin and Venables (2013), these tasks have to be performed following a strict sequence. To perform an individual task in the North, a certain quantity of efficiency labour is necessary, denoted by the labour coefficient c.[6] For simplicity, we assume that the labour coefficient in the North is the same for all tasks. By contrast, labour coefficients for tasks offshored to the South $a^*(t)$, vary across t in a non-monotonic fashion. For example, offshoring may require additional labour for monitoring or communication with the headquarter in the North, and these monitoring and communication requirements may differ between tasks.[7] In this paper, we restrict our attention to a symmetric cosine specification of the $a^*(t)$ curve:

$$a^*(t) = A\cos(2n\pi t) + B. \tag{4}$$

In what follows, we define the wage in the South relative to the wage in the North as $\omega^* = w^*/w$. Figure 1 compares labour costs to perform individual tasks in the South $\omega^* a^*(t)$ (in domestic labour units) with the costs c of performing these tasks domestically. In figure 1, the South exhibits lower costs

6 Given this linear specification of production in sector X, the existence of sector Y and the specification of its technology add some convexity to the model. See, e.g., Markusen and Venables (1998) as well as Markusen (2002) for a similar approach.

7 In the spirit of Grossman and Rossi-Hansberg (2008), we may envision the input coefficient $a^*(t)$ as being given by $a^*(t) = a_0^* \cdot \delta^*(t)$, where a_0^* is the "pure" input coefficient and $\delta^*(t)$ represents the (non-monontonic) iceberg costs of offshoring.

to perform the tasks $t \in [t_1, t_2]$ and $t \in [t_3, t_4]$ while the North has lower costs for all other tasks. To simplify the analysis, we assume that the first and the last task have to be performed in the North.[8]

The symmetry property of the cosine functional form offers a flexible way to capture the non-monotonic evolution of relative costs along the production process, while it substantially simplifies the analysis in various dimensions. First, instead of determining all separate cut-off values $t_1, t_2, t_3, \ldots$ individually, we can exploit the fact that $t_2 = \frac{1}{n} - t_1, t_3 = \frac{1}{n} + t_1$, etc. That is, the position of the first cut-off determines all other cut-off points. Second, labour costs of performing the segment $t \in [t_3, t_4]$ are identical to those for the segment $t \in [t_1, t_2]$. If a firm finds it profitable to ship the intermediate good abroad and back home to offshore the production tasks between t_1 and t_2, it will do the same for the tasks between t_3 and t_4. In a setting with $n > 2$, the same also holds for all other segments for which the South has a cost advantage. Third, the individual parameters characterizing the cosine function have a straightforward economic interpretation: while the shift parameter B reflects *average* labour requirements in the South, the parameter A captures the *heterogeneity* of the production process. The variable n ($n \in \mathbb{N}^+$) measures the number of "cycles" that $a^*(t)$ completes between $t = 0$ and $t = 1$. We argue that production processes that are characterized by a higher number of cycles. i.e., a larger value of n, are more *sophisticated.* To keep the analysis interesting, we assume that foreign production costs fluctuate around domestic costs more than once (i.e., $n \geq 2$). The first cut-off t_1 is determined by the following condition:

$$c = \omega^* a^*(t_1). \tag{5}$$

While the relative wage $\omega^* \equiv w^*/w$ is exogenous in the partial equilibrium setting of Harms et al. (2012), the current paper determines factor prices endogenously. As can be seen directly from figure 1, an increase in ω^* ceteris paribus raises t_1, i.e., $dt_1/d\omega^* > 0$.[9] The economic intuition behind this result is straightforward: as the foreign wage relative to the domestic wage increases, the cut-off also increases such that firms perform a larger range of tasks at home and offshore a smaller range of tasks to the South.[10]

8 We will later distinguish between various "firm types" who differ in the amount of tasks they offshore. Without the assumption that the first and the last task have to be performed in the North, the number of firm types would proliferate without adding much insight.

9 See online appendix A1 for an analytical derivation.

10 Note that this relationship is not an outcome of our special functional form for the offshoring costs, but would also hold in a more standard model in which offshoring costs are monotonically increasing or decreasing along the production chain. However, as we will show below, non-monotonic offshoring costs imply that offshoring firms may differ in the total volume of tasks they delegate to the South and that adjustment to exogenous parameter changes may take place both at the intensive and at the extensive margin.

Offshoring with positive production volumes in both regions can occur only if each region has a cost advantage for *some* tasks. Technically, this requires that the two curves in figure 1 intersect. Therefore, a necessary condition for offshoring to occur is

$$\frac{c}{B+A} < \omega^* < \frac{c}{B-A}. \tag{6}$$

In the following, we consider only equilibria in which these inequalities are satisfied.

2.3. Costs and prices

As in Yi (2003, 2010), Navaretti and Venables (2004) or Harms et al. (2012), we consider a setting in which performing a task requires the presence of the unfinished intermediate good, and we assume that moving the (intermediate) good between the North and the South is associated with transport costs. For tractability and without loss of generality, we model the costs of shipping intermediate inputs in additive form. More specifically, we assume that any crossing of a border requires additional T units of labour in the sending region. It is for this reason that Northern firms may find it profitable to agglomerate a larger part of the production process at one location rather than paying transport costs each time the unfinished good crosses a border.

In what follows, we will consider three possible firm types that may exist in equilibrium.[11] First, there are *domestic firms* (indexed by d) that do not offshore any task at all. Second, *fragmented firms* (indexed by f) offshore all tasks that can be performed at lower costs in the South, and transport the unfinished good $2n$ times between North and South. Finally, *production-abroad* firms (indexed by a) offshore the entire segment between t_1 and t_{2n} and perform only the first segment between 0 and t_1 and the last segment between t_{2n} and 1 at home.[12] These production-abroad firms agglomerate tasks in the South to save transport costs compared with fragmentation.

Marginal costs of firm type j ($j = d,f,a$) are given by the following expression:

$$C_j = wL_j + w^* L_j^*. \tag{7}$$

11 The notion that different firm types may coexist in equilibrium is reminiscent of the analysis in Markusen (2002). As we will explain below, our framework plus a set of plausible assumptions guarantee that there are no further firm types.

12 This is where our assumption that the first and the last production steps have to be performed domestically becomes relevant. Without this assumption, the set of potential firm types would be larger, possibly including firms that perform *all* production steps abroad, and firms that perform only the first (or the last) part of the production process abroad. Dropping the assumption would reduce tractability without offering much additional insight.

The variables L_j and L_j^* stand for the labour input at home and abroad per unit of output of a representative type-j firm.

After inserting for labour inputs, marginal costs under *fragmented production* can be written as follows:[13]

$$C_f = wc\left[\Omega_f(\omega^*) + \Phi_f(T, \omega^*)\right]. \tag{8}$$

The term $\Omega_f(\omega^*)<1$ in (8) captures the production costs under fragmentation relative to the costs of domestic production, abstracting from transport costs. The striped area in figure 2(a) depicts these costs for the case of $n = 2$. This term strictly increases in the relative wage in the South ω^*. The second term $\Phi_f(T,\omega^*)$ reflects the transport costs T induced by fragmentation, as the good has to cross the border $2n$ times. Consequently, $\Phi_f(T,\omega^*)$ increases in T. As transport costs of shipping the good from the foreign location back home are measured in foreign labour units, $\Phi_f(T,\omega^*)$ also increases in ω^*.

In a similar manner, we can write the marginal costs of a firm that chooses *production abroad* as

$$C_a = wc[\Omega_a(\omega^*) + \Phi_a(T, \omega^*)]. \tag{9}$$

The term $\Omega_a(\omega^*)<1$ measures the relative costs (abstracting from transport costs) of performing almost all tasks abroad compared with the domestic costs of performing these tasks and is represented by the striped area in figure 2(b). As the firm now stays abroad also for segments in which the foreign location has a cost *disadvantage*, $\Omega_a(\omega^*)$ exceeds $\Omega_f(\omega^*)$. Potential cost savings from production abroad are accordingly lower than from fragmentation as long as transport costs are not considered. By contrast, the transport cost term $\Phi_a(T,\omega^*)$ is smaller than under fragmented production because the unfinished good is shipped only twice instead of $2n$ times, i.e., $\Phi_a(T,\omega^*) = \Phi_f(T,\omega^*)/n$. This highlights the key trade-off faced by firms: while fragmentation economizes on the costs for the labour force that is actually involved in the production process, it requires more labour devoted to the transportation of the unfinished good. As with fragmentation, the terms $\Omega_a(\omega^*)$ and $\Phi_a(T,\omega^*)$ are strictly increasing in ω^*.

Firms in sector X set their profit-maximizing prices at a constant markup over their marginal costs:

$$p_j = \frac{\sigma}{\sigma - 1} C_j, \tag{10}$$

13 Equations (A8) and (A9) in online appendix A1 demonstrate how to derive the closed-form expressions for $\Omega_f(\omega^*)$ and $\Phi_f(T,\omega^*)$ in equation (8). Equation (A11) in online appendix A1 does the same for $\Omega_a(\omega^*)$ and $\Phi_a(T,\omega^*)$ in equation (9).

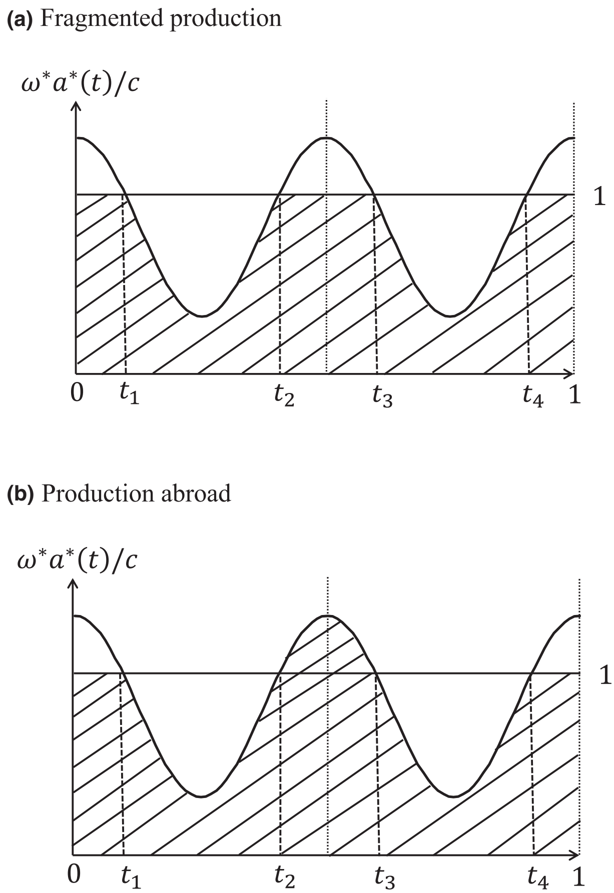

FIGURE 2 Relative production costs with offshoring ($n = 2$)
NOTES: The curve $\omega^* a^*/c$ reflects the relative costs of performing an individual task in the foreign economy. The striped area in panel (a) reflects relative costs for all tasks (net of transport costs) under *fragmented production*, i.e., for a firm that chooses the lowest-cost location for each task. The striped area in panel (b) reflects relative costs (net of transport costs) for a *production-abroad* firm that offshores all tasks between t_1 and $1 - t_1$.

with $j \in \{d,f,a\}$. All active firms in the X-sector have to incur fixed costs, which reflect the necessity to use F_j units of their own output to support production.[14] In units of the numéraire good, the fixed costs amount to a multiple of marginal costs $F_j C_j$, with $F_j > 0$. For the fixed costs of different

14 One interpretation of this specification is that, regardless of the eventual output, firms require a certain number of test models before they can start producing for the market. On top of this, offshoring firms have to maintain a monitoring and communication infrastructure in order to sustain operations abroad.

firm types, we assume $F_d < F_f < F_a$.[15] For simplicity, we assume that the fixed costs of a certain firm type (d, f, a) do not depend on the number of "cycles" actually offshored, i.e., once a firm has chosen a certain production mode, there is no "discount" in terms of lower fixed costs for reducing the range of tasks offshored to the South.[16]

Free entry ensures zero profits of all active firms in the market. With price setting according to (10), the zero profit condition can be written as

$$p_j x_j = \sigma C_j F_j. \tag{11}$$

We can combine (10) with (11) to derive production of a firm of type j in equilibrium, which is proportional to the fixed costs F_j:

$$x_j = (\sigma - 1) F_j. \tag{12}$$

It follows from (12) and our assumption on the ordering of fixed costs ($F_a > F_f > F_d$) that $x_a > x_f > x_d$. Combining these different levels of output in equilibrium with downward-sloping demand curves, as characterized by (2), requires that $p_a < p_f < p_d$. This, in turn, implies—via the markup-pricing equation (10)—that (endogenous) marginal costs are ordered as follows: $C_a < C_f < C_d$.

That is, if domestic and offshoring firms are both active in the market, offshoring firms have lower marginal costs than domestic firms. The reason is that the higher fixed costs as a result of offshoring necessitate higher sales, which materialize only at lower prices and thereby at lower marginal costs. As we show in online appendix A2, the differences in marginal costs C_j across firm types, combined with our assumptions on fixed costs, guarantee that no other production modes than the three discussed above exist in equilibrium.[17]

3. Equilibrium

3.1. Equilibrium definition and labour market clearing

An equilibrium is defined by an optimal cut-off value t_1, a vector of wages as well as prices and quantities in the X and Y sectors, and an industrial structure as represented by the number of firms of type j (N_j), with $j \in \{d,f,a\}$, such that

15 We choose this particular ordering of fixed costs based on the notion that the costs of maintaining a monitoring and communication infrastructure is higher for production-abroad firms than for fragmenting firms.

16 As we show in online appendix A2, this assumption is sufficient—though not necessary—for narrowing down firms' decision to a choice between three production modes.

17 In online appendix A2, we also analyze a more general specification of fixed costs in which F_j depends on the number of offshored production cycles—with similar results.

(a) firms of a given type in the X-sector set profit-maximizing prices,
(b) offshoring firms choose the optimal cut-off value t_1,
(c) free entry results in zero profits of all active firms in equilibrium,
(d) factor prices in the Y-sector reflect marginal products and
(e) goods and factor markets clear.

Labour market equilibrium in the North and the South requires $L_X + L_Y = \bar{L}$ and $L_X^* + L_Y^* = \bar{L}^*$, where L_X and L_X^* denote total employment in the X-sector in the North and the South, respectively. For the Cobb–Douglas technology (3), we can derive labour demand in sector Y as a function of the relative wage ω^*:

$$L_Y = L_Y(\omega^*) \,\text{and}\, L_Y^* = L_Y^*(\omega^*), \tag{13}$$

with $dL_Y/d\omega^* > 0$ and $dL_Y^*/d\omega^* < 0$.[18] With (13), we can express the labour supply available to firms in the X-sector (at home and abroad) as a function of ω^*:

$$L_X(\omega^*) = \bar{L} - L_Y(\omega^*) \,\text{and}\, L_X^*(\omega^*) = \bar{L}^* - L_Y^*(\omega^*). \tag{14}$$

The total (domestic and foreign) labour demand of firms in the X-sector is given by

$$\sum_j \sigma N_j L_j(\omega^*) F_j = L_X(\omega^*) \,\text{and} \sum_j \sigma N_j L_j^*(\omega^*) F_j = L_X^*(\omega^*), \tag{15}$$

where the domestic and foreign labour demands of firms of type j—$L_j(\omega^*)$ and $L_j^*(\omega^*)$—are determined by the cut-off condition (5).

3.2. Production regimes

In what follows, we distinguish between equilibria in which all X-sector firms choose the same production mode and equilibria in which firms with different production modes coexist. We will refer to these constellations as *pure* and *mixed production regimes*: for example, a *pure domestic* production regime is characterized by $N_d > 0$ and $N_a = N_f = 0$, a *mixed domestic/fragmented* regime is characterized by $N_d > 0, N_f > 0$ and $N_a = 0$, etc. In what follows, we will label production regimes by lowercase letters, with $\{d\}$ referring to a pure domestic regime, $\{d, f\}$ to a mixed domestic/fragmentation regime, $\{a, f\}$ to a mixed production-abroad/fragmentation regime etc.

In a *pure domestic regime* ($\{d\}$), we have $L_X^* = 0$ and equation (14) pins down the relative wage (ω^*) in equilibrium as well as total domestic employment in the X-sector (L_X). Combining this result with the first equation in (15) allows determining the equilibrium number of firms N_d. Conversely, if all firms engage in the same type of offshoring—either in a pure production-abroad ($\{a\}$) or a pure fragmentation regime ($\{f\}$)—we have $L_X^* > 0$, and equations (14) and (15) can be combined to yield

18 A formal derivation of this and subsequent results is provided in online appendix A1.

$$\frac{L_j(\omega^*)}{L_j^*(\omega^*)} = \frac{\bar{L} - L_Y(\omega^*)}{\bar{L}^* - L_Y^*(\omega^*)}. \tag{16}$$

The left-hand side of (16) is increasing in ω^* for $j = a,f$, while the right-hand side is decreasing. Equation (16) thus determines a unique relative wage ω^*. The equilibrium number of firms N_j with $j = a$ or $j = f$ can then be determined from (15) after inserting ω^* into (14) to obtain L_X.

Because of our assumption of imperfect competition and production mode–specific fixed costs F_j, our model also allows for equilibria in which different firm types coexist. In this case, equations (14) and (15) are not sufficient to determine all endogenous variables. Instead, we need to invoke an additional equation that makes sure that the zero-profit condition (11) is simultaneously satisfied for different production modes.

In a *mixed production regime* in which firms with different production modes j and k coexist, equation (12) implies $x_j/x_k = F_j/F_k$. Because it follows from (2) and (10) that $x_j/x_k = (p_j/p_k)^{-\sigma}$ and $p_j/p_k = C_j/C_k$, we obtain the condition

$$C_j F_j^{1/\sigma} = C_k F_k^{1/\sigma}, \tag{17}$$

which has to be satisfied for two different production modes j and k to coexist in equilibrium. If this condition is violated, the production mode with the lower marginal cost/fixed cost-combination is chosen by all firms. For a mixed regime in which offshoring firms—choosing *fragmentation* (f) or *production abroad* (a)—coexist with *domestic firms*, condition (17) together with equations (8) or (9) requires

$$\left[\Omega_j(\omega^*) + \Phi_j(T,\omega^*)\right] F_j^{1/\sigma} = F_d^{1/\sigma}, j = f, a. \tag{18}$$

Hence, the marginal cost advantage of offshoring firms has to be offset by their higher fixed costs, such that both offshoring and domestic firms make zero profits in equilibrium.

Equation (18) determines the equilibrium relative wage ω^* in a mixed regime with domestic and offshoring firms. The corresponding cut-off value t_1 follows from condition (5). The cut-off, in turn, determines employment of offshoring firms, and we can combine the equilibrium relative wage ω^* with (14) and (15) to determine the number of firms N_d and N_j, with $j = a$ or f. For $j = a$, a *mixed domestic/production-abroad regime* ($\{d,a\}$) exists for given values of the exogenous parameters if both N_d and N_a exceed zero, while $N_f = 0$. For $j = f$, a *mixed domestic/fragmentation regime* ($\{d, f\}$) exists if N_d and N_f exceed zero, while $N_a = 0$.

Similar relationships hold in an equilibrium in which fragmented and production-abroad firms coexist ($\{a, f\}$), i.e., $N_f, N_a > 0$, while $N_d = 0$. In this case, the relative wage is determined by

$$\left[\Omega_f(\omega^*) + \Phi_f(T,\omega^*)\right] F_f^{1/\sigma} = \left[\Omega_a(\omega^*) + \Phi_a(T,\omega^*)\right] F_a^{1/\sigma}. \tag{19}$$

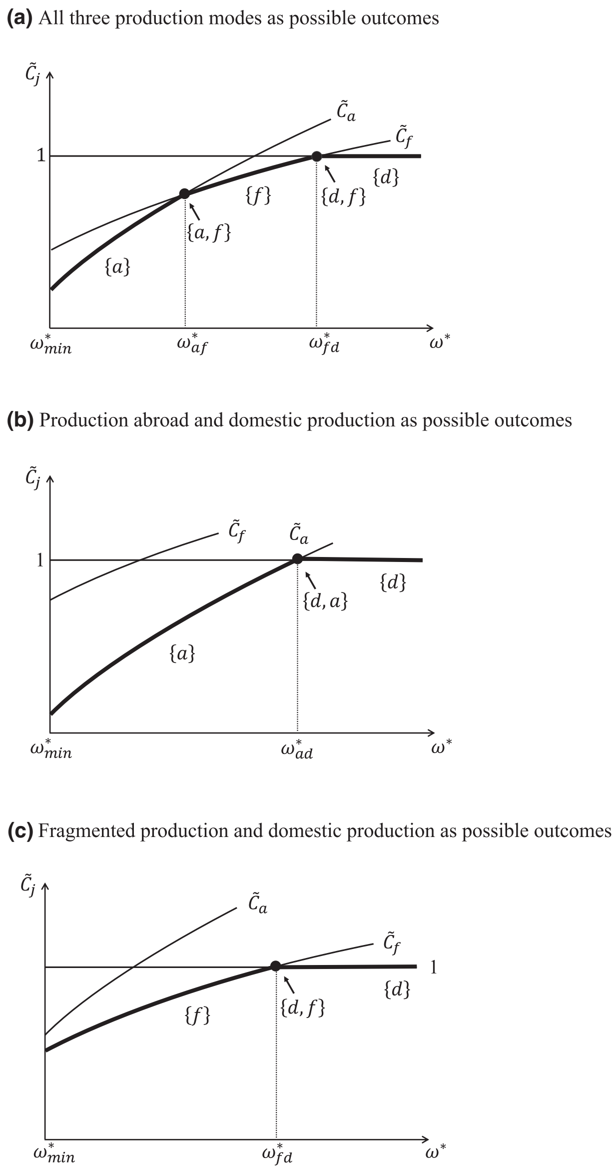

FIGURE 3 Relative wages and relative marginal/fixed costs
NOTES: The curves depict marginal/fixed cost combinations (relative to the costs associated with domestic production) for different production modes. The bold segments indicate the lowest-cost production mode. Relative wages defined by the intersection of curves support mixed production regimes.

In figure 3, the curves $\tilde{C}_j$ depict marginal costs for the two different types of offshoring firms (already incorporating their respective fixed costs), relative to marginal costs incurred by a domestic firm. Both curves are strictly increasing in ω^*. The lower bound for the relative wage ω^*_{min} is determined by (6). In online appendix A1, we demonstrate that the curve $\tilde{C}_a = C_a F_a^{1/\sigma}/(C_d F_d^{1/\sigma})$ is steeper than $\tilde{C}_f = C_f F_f^{1/\sigma}/(C_d F_d^{1/\sigma})$—at least at the intersection of the two lines. However, we are still left with different possibilities of whether and where the "relative marginal cost lines" intersect. This is reflected by the constellations (a) to (c) described by figure 3.

A mixed regime is located at $\tilde{C}_a = 1$ (regime $\{d,a\}$), at $\tilde{C}_f = 1$ (regime $\{d,f\}$) or at $\tilde{C}_f = \tilde{C}_a < 1$ (regime $\{a,f\}$). As described above, these points of intersection determine the respective equilibrium relative wage ω^*, which can then be fed into (14) and (15) to derive the equilibrium number of firms. For example, if the values of N_d and N_f are strictly positive for $\omega^* = \omega^*_{fd}$, a *mixed domestic/fragmented* production regime ($\{d,f\}$) exists. By contrast, *pure* regimes with only one firm type emerge if the equilibrium relative wage falls into the interval between two points of intersection: there is, for example, a *pure fragmented* equilibrium ($\{f\}$) if the value of ω^* determined by (16) falls into the open interval $(\omega^*_{af}, \omega^*_{fd})$ and if ω^*, combined with (15), implies a strictly positive number of fragmenting firms, i.e., $N_f > 0$.

The bold lines in figure 3 thus show the firm types prevailing in equilibrium, depending on the relative wage ω^*. In figure 3(a), a pure regime with only production-abroad firms ($\{a\}$) exists if the relative wage in the South is very low, i.e., $\omega^* < \omega^*_{af}$.[19] In this region, fragmented firms or domestic firms would make negative profits if the zero profit condition for production-abroad firms were satisfied. At the intersection point ω^*_{af}, a *mixed fragmented/production-abroad* regime ($\{a,f\}$) exists, i.e., $N_a, N_f > 0$ and $N_d = 0$. For a higher value of ω^*, only fragmented firms exist ($\{f\}$), up to the next intersection point ω^*_{fd} in which fragmented and domestic firms coexist ($\{d,f\}$). For even higher relative wages, only domestic firms exist in equilibrium ($\{d\}$).

The exposition in figure 3 suggests a "knife-edge" property of mixed production regimes, which seems to require a very specific combination of parameter values in order to exist. Note, however, that the model is characterized by various margins of adjustment, including the number of firms of different types (N_j). It is for this reason that mixed regimes are compatible with a broad set of parameter values.[20]

While figure 3(a) is based on parameter constellations that potentially allow for all three production modes to occur in equilibrium, figure 3(b)

19 More specifically, such an equilibrium exists if the wage implied by (16) falls into that interval and if the value of N_a implied by that wage and (15) is strictly greater than zero.

20 Online appendix A5 contains numerical simulations that illustrate this property. An analogy in trade theory is factor price equalization, which may emerge for various parameter constellations as long as countries' factor endowments are located inside the diversification cone.

depicts a situation where marginal costs of fragmented production are relatively high—due, for example, to high transport costs T. In this case, no regime involving fragmented production exists. Depending on the relative wage, there can be only a pure domestic regime ($\{d\}$), a mixed domestic/production-abroad regime ($\{d,a\}$) or a pure production-abroad regime ($\{a\}$).[21] Conversely, no production-abroad firms exist in a constellation as depicted by figure 3(c).[22] For *three* production modes to coexist, the three curves in figure 3 would have to intersect in one point. We consider this to be an extremely unlikely outcome, and in what follows we do not analyze such an equilibrium.

3.3. Comparative static analysis: The effects of lower transport costs

Apparently, the production regime that emerges in equilibrium depends on a whole range of parameters—in particular the two economies' factor endowments, the properties of the a^*-function, as defined by (4), the fixed costs F_j, etc. In what follows, we focus on the role of transport costs (T) for the relative wage and the intensive/extensive margin of offshoring.

Of course, if transport costs T are infinite, offshoring is too costly to be an attractive option, and only domestic production emerges in equilibrium. Conversely, if $T = 0$, if the fixed costs of fragmentation (F_f) are not too high and if the equilibrium relative wage for the pure fragmented regime satisfies (6), all firms exploit international cost differences by choosing fragmentation. However, if we depart from these extreme cases, the effect of varying T on firms' production mode and their chosen volume of offshoring is less obvious. To analyze the effect of declining border-crossing costs with endogenous wages, we can use the graphical framework introduced in figure 3. When doing so, we assume that the underlying parameters allow for the full set of production regimes, i.e., a situation as depicted by figure 3(a). In figure 4, lowering T shifts the curves $\tilde{C}_f$ and $\tilde{C}_a$ downward, reflecting the fact that a decline in transport costs makes both types of offshoring less costly relative to domestic production. This effect is stronger for fragmented production, as the good is transported forth and back $2n$ times compared with only two times with production abroad. As figure 4 shows, the relative wage ω^* *increases* if the economy starts off and remains in a production regime in which offshoring firms coexist with domestic firms. In this case, the decline in production costs induces the entry of additional offshoring firms, which raises labour demand in the South relative to the North and eventually increases the relative wage. The higher relative wage ω^*, in turn, induces offshoring firms to reduce the range of tasks delegated to the South, i.e., to increase the cut-off value t_1. Hence, offshoring increases at the *extensive margin*, i.e., the number of firms

21 The condition for such a situation to emerge is that the point of intersection of the $\tilde{C}_f$ and $\tilde{C}_a$ curves is to the right of ω^*_{ad}.

22 For such a situation to emerge, we need $\tilde{C}_a > \tilde{C}_f$ for $\omega^* = \omega^*_{min}$.

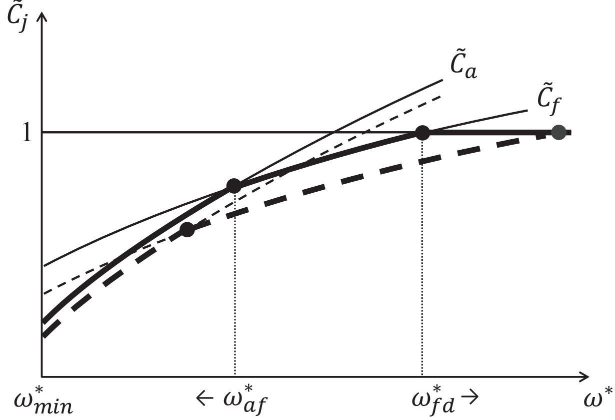

FIGURE 4 The effect of decreasing transport costs on threshold wages and production regimes

NOTES: The solid (dotted) curves depict marginal/fixed cost combinations (relative to the costs associated with domestic production) for different production modes before (after) a decline in transport costs. The bold segments indicate the lowest-cost production mode. Relative wages defined by the intersection of curves support mixed production regimes.

engaged in offshoring, but decreases at the *intensive margin*. As we will show below, the first effect dominates, i.e., if the economy remains in a mixed regime with domestic production and offshoring, decreasing transport costs raise the total volume of offshoring, which we define as offshoring firms' demand for foreign labour (L^*_X).[23]

It may seem puzzling that, starting in a mixed regime, falling transport costs do not immediately throw the economy into another production regime, i.e., that one of the firm types does not vanish completely as T decreases. Instead, the economy moves to a new point of intersection of the two "relative marginal cost curves," staying in the mixed production regime. This can be explained as follows: suppose that we start out with a mixed domestic/fragmented regime ($\{d,f\}$), which is characterized by an equilibrium relative wage ω^*_{fd} and by strictly positive values N_d and N_f. Now let the transport cost T decline marginally. If the economy immediately moved to a pure equilibrium with all firms choosing fragmentation ($\{f\}$), the relative wage ω^* would increase substantially. This, in turn, would raise the marginal/fixed-cost combination for fragmenting firms above the marginal/fixed-cost combination of domestic firms, contradicting the notion that fragmentation is the lowest-cost

23 As we demonstrate in online appendix A3, the discrepancy between the adjustment at the intensive and the extensive margin could also emerge in a setting in which foreign input coefficients (including costs of offshoring) are monotonically decreasing or increasing. However, in such a setup firms would never choose production abroad.

production mode. Hence, instead of inducing an immediate move from a mixed to a pure production regime, declining transport costs result in a smooth increase of the relative wage and a gradual decline of the number of firms who choose domestic production (N_d).[24]

Figure 4 also demonstrates that, if the economy starts off and remains in a regime in which *fragmented production* and *production abroad* coexist ($\{a,f\}$), the downward shift of the $\tilde{C}_f$ and $\tilde{C}_a$ curves results in a *lower* value of ω^*. Here, fragmented production becomes more attractive relative to production abroad, such that the number of fragmented firms compared with production-abroad firms increases. Because fragmentation implies a lower volume of tasks being delegated to foreign countries, this results in a decline in labour demand in the South relative to the North, a decline in ω^* and eventually a larger range of offshored tasks at the firm level, i.e., a lower value of t_1. This result stands in sharp contrast to the previous cases in which domestic firms coexisted with offshoring firms.

Finally, if the economy starts off and remains in a pure production regime, the effect of falling border-crossing costs on relative wages and offshoring at the extensive and intensive margins depends on how lowering T affects labour demand at home and abroad and how this influences the labour market equilibrium as defined by (14) to (16).

Lemmas 1 and 2 summarize the results illustrated by figure 4, and describe the effect of a decline in T on relative wages and on offshoring at the intensive and extensive margin. Moreover, they show how the *total volume of offshoring* (L_X^*) reacts to a reduction of transport costs.[25]

LEMMA 1. *In a mixed production regime in which domestic* (d) *and offshoring firms* (*fragmented or production abroad,* $j = f,a$) *coexist* ($N_d > 0$ *and* $N_a > 0$ *or* $N_d > 0$ *and* $N_f > 0$), *a decline in transport costs* T*:* (*i*) *raises the number of offshoring firms* N_j*, increasing offshoring at the extensive margin,* (*ii*) *raises the wage in the South relative to the wage in the North,* ω^**,* (*iii*) *raises the optimal cut-off* t_1*, reducing offshoring at the intensive margin and* (*iv*) *raises the total volume of offshoring* L_X^*.

LEMMA 2. *In a mixed production regime in which the two types of offshoring firms coexist* ($N_a > 0$ *and* $N_f > 0$*, but* $N_d = 0$), *a decline in transport costs* T*:* (*i*) *lowers the wage in the South relative to the wage in the North* ω^**,* (*ii*) *reduces the optimal cut-off* t_1*, i.e., raises offshoring at the intensive margin and* (*iii*) *lowers the total volume of offshoring* L_X^*.

Lemmas 3 and 4 consider the effect of reducing transport costs in a *pure production regime* in which all firms choose either production abroad or fragmentation.

24 A formal exposition of this argument is provided in online appendix A4.

25 For proofs, see online appendix A1.

Lemma 3. *In a pure production regime in which all firms choose production abroad* ($N_a > 0$, *but* $N_d = N_f = 0$), *a decline in transport costs T:* (*i*) *raises the number of offshoring firms* N_a, *increasing offshoring at the extensive margin,* (*ii*) *raises the wage in the South relative to the wage in the North* ω^*, (*iii*) *raises the optimal cut-off* t_1, *reducing offshoring at the intensive margin, and* (*iv*) *raises the total volume of offshoring* L_X^*.

Lemma 4. *In a pure production regime in which all firms choose fragmentation* ($N_f > 0$, *but* $N_d = N_a = 0$), *a decline in transport costs T:* (*i*) *raises the number of offshoring firms* N_f, (*ii*) *raises the relative wage* ω^*, *raises the cut-off* t_1 *and raises the total volume of offshoring* L_X^* *if* $L_f < L_f^*$ *and* (*iii*) *lowers the relative wage* ω^*, *lowers the cut-off* t_1 *and lowers the total volume of offshoring* L_X^* *if* $L_f > L_f^*$.

In a pure production regime with offshoring, the influence of varying transport costs on the relative wage depends on the relationship between L_j^* and L_j. This is because T appears in both the numerator and the denominator of the left-hand side of (16). As the decline in T lowers the labour demands L_j and L_j^* by the same absolute amount, the effect on the relative labour demand L_j/L_j^* depends on initial employment at home and abroad. In a pure production-abroad regime, we have $L_a^* > L_a$, and the relative wage ω^* *increases* as a result of lower transport costs (lemma 3). For a pure regime with fragmented production, the relationship between L_f^* and L_f is less clear-cut, depending on the parameters that determine the initial equilibrium.[26]

The above results suggest a pattern as depicted in figure 5:[27] for very high levels of T, all firms choose domestic production ($\{d\}$) and border-crossing costs do not affect firm choices or the relative wage. Once T crosses a critical threshold, the economy moves into the mixed domestic/production-abroad regime ($\{d,a\}$), and a further decline of T raises the relative wage ω^* and the total volume of offshoring (lemma 1). However, while the number of firms who delegate some tasks to other countries increases, the range of tasks actually delegated by individual firms decreases (i.e., the cut-off value t_1 increases). Further drops in T move the economy into a pure production-abroad regime ($\{a\}$), and the relative foreign wage (ω^*) continues to grow (lemma 3). Next, the economy moves into a mixed fragmented/production-abroad regime ($\{a,f\}$), and the relative wage, the cut-off value t_1, as well as the total volume of offshoring, decrease (lemma 2). Eventually, for very low levels of T, all firms choose fragmented

26 Using (A4) and (A5) as well as the specification of a^* in (7), it can be shown that $L_f < L_f^*$ if $\frac{A}{2n\pi} sin(2n\pi t_1) + (c+B)t_1 < \frac{B}{2n}$.

27 In figure 3, the constellation depicted in figure 5 is based on the assumption that underlying parameters guarantee that $\tilde{C}_a$ is smaller than both 1 and $\tilde{C}_f$ for some values of T, i.e., that a pure production-abroad regime exists. Moreover, we assume that $L_f < L_f^*$ in the pure fragmented-production regime.

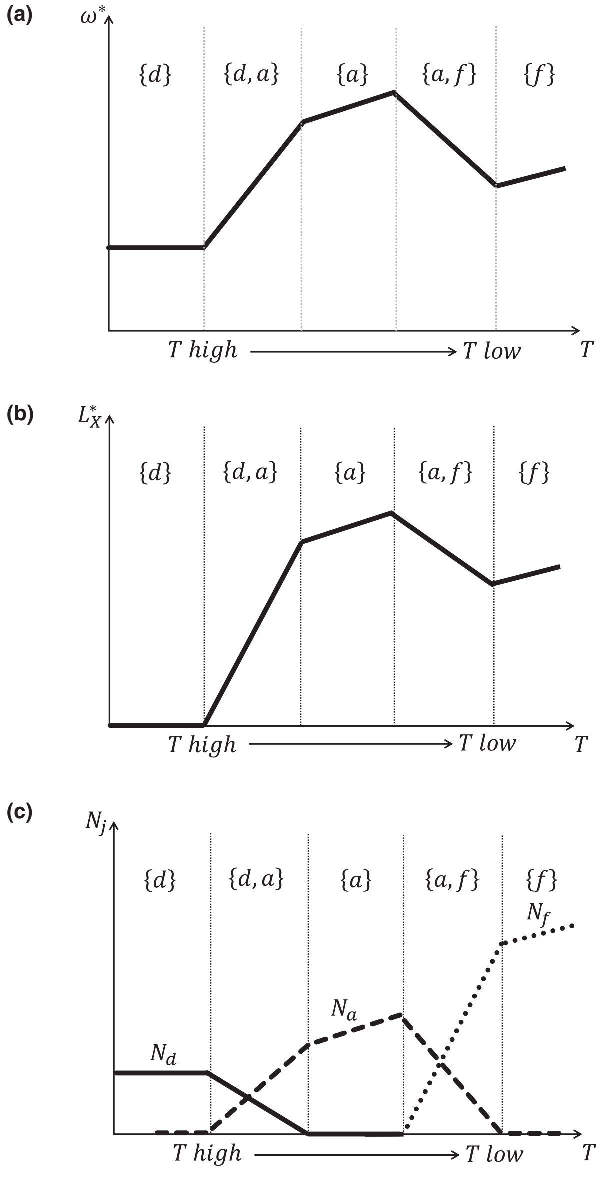

FIGURE 5 Decreasing transport costs, relative wages, the total volume of offshoring and the number of different firm types

NOTES: Panel (a) describes the evolution of the foreign relative wage ω^* as a function of (declining) transport costs T. The letters in curled brackets indicate the production regimes prevailing at given levels of T. Panel (b) describes the evolution of the total volume of offshoring L_X^*. Panel (c) describes the evolution of the number of firms N_j. Note that the figure refers to a specific parameter constellation that allows for all three production modes, as depicted by figure 3(a).

production ($\{f\}$), and both the relative foreign wage and the total volume of offshoring increase as T further declines (lemma 4(ii)).

There are some important qualitative findings to take away from this analysis. First, the reaction of relative wages to declining transport costs is possibly nonmonotonic. In fact, ω^* first increases, then decreases (and eventually increases again) as globalization—reflected by falling transport costs—intensifies. Second, decreasing transport costs do not necessarily raise the total volume of offshoring. They do so at high levels of T, i.e., if offshoring firms coexist with domestic firms (see lemma 1), but they don't once some firms choose fragmented production and others choose production abroad (lemma 2). Finally, there is a potential discrepancy between the adjustment at the extensive and the intensive margins, i.e., the share of tasks shifted abroad by individual firms may actually decrease while the total volume of offshoring increases.

The comparative static analysis described in this section focused on the effects of lowering transport costs T. While we think that this change is of particular interest, it is of course desirable to also explore the effects of varying the other parameters that characterize firms' technologies. Unfortunately, it is hardly possible to derive unambiguous comparative static results for these parameters. However, a numerical analysis presented in online appendix A5 offers some important insights on how changes in these parameters affect relative wages as well as offshoring at the extensive and the intensive margin.

4. Summary and conclusions

In this paper, we have analyzed the extent of offshoring in a two-region (North/South) general equilibrium model that is based on three crucial assumptions. First, a firm's production process follows a rigid structure that defines the sequence of production steps. Second, the costs of offshoring vary in a nonmonotonic fashion along the production chain. Third, each task requires the presence of an unfinished intermediate good whose transportation across borders is costly. We believe that these assumptions are quite plausible for a wide range of industries. As a consequence, some firms may completely refrain from offshoring, or agglomerate production steps in one region, even if performing individual tasks in the other region would be associated with lower costs: the reason is that transport costs do not justify shifting the unfinished good across borders several times. This simple trade-off may result in firms preferring "domestic production" or "production abroad" over "fragmentation."

Using this basic structure and setting up a general equilibrium model along these lines, we have analyzed the influence of a decrease in transport costs—interpreted as a symptom of intensifying globalization—on the volume of offshoring and relative wages. Most importantly, we have shown that, as transport costs move from very high to very low levels, the relative wage in the South may fluctuate depending on the competing firm types in the market. Our assumption on the sequential nature of the production process combined with a nonmonotonic evolution of offshoring costs and the existence of transport costs is crucial in generating this result: starting from a situation in which all production steps are performed domestically, a decrease in transport costs first induces firms to relocate almost the entire production process abroad, and the increasing demand for foreign labour raises the relative wage in the South. As transport costs decline further, firms increasingly “re-shore” those production steps that are cheaper to perform domestically, thus reducing labour demand and the wage abroad. Finally, once only fragmented production firms prevail in the market, further decreases in transport costs raise again labour demand and the wage abroad.

We believe that the simplicity of our model—in particular, the symmetry of the $a^*(t)$ function—has allowed us to derive some novel results, which are likely to carry over into a more general environment. The challenge ahead is to expand the framework to accommodate additional features of reality, for example, by introducing a non-symmetric shape of the $a^*(t)$ function or by allowing for transport costs (T) that vary along the production chain. In fact, dropping the symmetry property and letting costs vary systematically between earlier and later production segments may create a richer picture of possible offshoring patterns. For example, transport costs could be higher for later tasks, as the intermediate product becomes more valuable along the production process. In this case, additional firm types may emerge that offshore only the initial parts of the production chain, performing the later tasks at home.

The second challenge is to assess the welfare effects of globalization: while reducing T lowers the resources that are not used productively ceteris paribus, this induces an increase of offshoring at the *extensive margin* and may therefore raise total transport costs. At the same time, the number of firms rises, which raises utility because of the “love of variety” built into the model. Combining these insights with the results concerning the evolution of factor prices and incomes and evaluating the resulting net effects on agents’ welfare in North and South is an interesting challenge ahead.

Finally, it is important to gauge the empirical relevance of sequential production processes for the economy as a whole. Our contribution rested on the assumption that *all* firms have to cope with a rigid sequence of production steps. This may be as unrealistic as the notion that production processes can be rearranged freely by every firm.[28] We believe that identifying the extent of “sequentiality” characterizing real-world production processes holds ample promise for future research.

Supporting information

Supplementary material accompanies the online version of this article.

28 The framework developed by Tyazhelnikov (2019) allows for production “trees”—i.e., processes that combine “spider”-like and “snake”-like components.

References

Ando, M., and F. Kimura (2005) "The formation of international production and distribution networks in East Asia." In *NBER-East Asia Seminar on Economics*, vol. 14, pp. 177–216. Chicago: University of Chicago Press

Antras, P., and D. Chor (2013) "Organizing the global value chain," *Econometrica* 81, 2127–204

Antras, P., D. Chor, T. Fally, and R. Hillberry (2012) "Measuring the upstreamness of production and trade flows," *American Economic Review* 102, 412–41

Antras, P., and A. de Gortari (2020) "On the geography of global value chains," *Econometrica* 88, 1553–98

Athukorala, P., and N. Yamashita (2006) "Production fragmentation and trade integration: East Asia in a global context," *North American Journal of Economics and Finance* 17, 233–56

Backer, K.D., and S. Miroudot (2013) "Mapping global value chains," OECD Trade Policy Papers, no. 159

Baldwin, R. (2006) "Globalisation: The great unbundling(s)," paper for the Finnish Prime Minister's Office

Baldwin, R., and A. Venables (2013) "Spiders and snakes: Offshoring and agglomeration in the global economy," *Journal of International Economics* 90, 245–54

Campbell, P. (2016, October 16) "UK car industry fears effects of Brexit tariffs on supply chain," *Financial Times*. Retrieved from `http://www.ft.com/content/c397f174-9205-11e6-a72e-b428cb934b78`

Costinot, A., J. Vogel, and S. Wang (2012) "Global supply chains and wage inequality," *American Economic Review* 102, 396–401

—— (2013) "An elementary theory of global supply chains," *Review of Economic Studies* 80, 109–44

Dixit, A.K., and G. M. Grossman (1982) "Trade and protection with multistage production," *Review of Economic Studies* 49, 583–94

Fally, T. (2012) "Production staging: Measurement and facts," mimeo

Feenstra, R.C., and G. H. Hanson (1996) "Globalization, outsourcing, and wage inequality," *American Economic Review* 82, 240–45

Grossman, G.M., and E. Rossi-Hansberg (2008) "Trading tasks: A simple theory of offshoring," *American Economic Review* 98, 1987–97

Haddad, M. (2007) "Trade integration in East Asia: The role of China and production networks," World Bank Policy Research Working Papers, no. 4160

Harms, P., O. Lorz, and D. Urban (2012) "Offshoring along the production chain," *Canadian Journal of Economics* 45, 93–106

Johnson, R. (2014) "Five facts about value-added exports and implications for macroeconomics and trade research," *Journal of Economic Perspectives* 28, 119–42

Jones, R.W., and H. Kierzkowski (1990) "The role of services in production and international trade: A theoretical framework." In R. Jones and A. Krueger, eds., *The Political Economy of International Trade*. Oxford: Blackwell Publishers

Kim, S-J., and H. S. Shin (2012) "Sustaining production chains through financial linkages," *American Economic Review* 102, 402–406

Kohler, W. (2004) “International outsourcing and factor prices with multistage production,” *Economic Journal* 114, C166–C185

Koopman, R., Z. Wang, and S-J. Wei (2014) “Tracing value-added and double counting in gross exports,” *American Economic Review* 104, 459–94

Markusen, J.R. (2002) *Multinational Firms and the Theory of International Trade*. Cambridge, MA: The MIT Press

Markusen, J.R., and A. J. Venables (1998) “Multinational firms and the new trade theory,” *Journal of International Economics* 46, 183–203

Navaretti, G.B., and A. J. Venables (2004) *Multinational Firms in the World Economy*. Princeton, NJ: Princeton University Press

Pastor, R.A. (2008) “The future of North America: Replacing a bad neighbor policy,” *Foreign Affairs* 87, 84–98

Ruddick, G., and P. Oltermann (2017, March 3) “A Mini part’s incredible journey shows how Brexit will hit the UK car industry,” *The Guardian*. Retrieved from www.theguardian.com/business/2017/mar/03/brexit-uk-car-industry-mini-britain-eu

Sanyal, K.K. (1983) “Vertical specialization in a Ricardian model with a continuum of stages of production,” *Economica* 50, 71–78

Timmer, M.P., A. Erumban, B. Los, R. Stehrer, and G. J. de Vries (2014) “Slicing up global value chains,” *Journal of Economic Perspectives* 28, 99–118

Tyazhelnikov, V. (2019) “Production clustering and offshoring,” mimeo, University of Sydney

Yi, K-M. (2003) “Can vertical specialization explain the growth of world trade?,” *Journal of Political Economy* 111, 52–102

—— (2010) “Can multistage production explain the home bias in trade?,” *American Economic Review* 100, 364–93