# Global sourcing and business & social networks: quality heterogeneity and firms' efficiency *

Giuseppe Vittucci Marzetti † Maria Luigia Segnana ‡
Chiara Tomasi §

December, 2009

**Abstract**

Global sourcing can increase firms' productivity via the quality upgrading of intermediates, but, because of the heterogeneity of suppliers, it also increases screening costs of final firms given the need to search for good suppliers. We build up a simple model to analyze these factors and show that large firms can better exploit the potential gains from quality upgrading. Moreover, we show that business & social networks make both the overall production and firms' profitability increase via the reduction in firms' unit screening costs. There are cumulative beneficial effects of these networks: thicker networks imply higher cost saving and thus further incentives to invest in network linkages. Finally, we sketch a possible extension of the model to analyze the choice of local vs. global sourcing strategies and how their differences, in terms of costs, suppliers' heterogeneity and degree of embeddedness in networks, affect firms' choices and their efficiency.

*Keywords*: Delocalization; Outsourcing; Heterogeneity; Business & social networks; Search costs.

*JEL Classification*: F130; F230; L140; L240; D850.

---

*We would like to thank for their useful suggestions Andrea Fracasso and the participants to the International Conference on "Apparent Antithesis: Globalization and Local Development" (Trento, October 9-11, 2008) organized by the School on Local Development (University of Trento) in collaboration with the OECD LEED Programme and UNDP. Giuseppe Vittucci Marzetti also gratefully acknowledges support for this research from the PAT (Provincia Autonoma di Trento, post-doc scholarship 2006). The usual disclaimers apply.

†Department of Economics, University of Trento, via Inama 5, 38122 Trento, Italy, Phone: +39 0461 882162 Fax: +39 0461 882222, E-mail: giuseppe.vittucci@unitn.it

‡Department of Economics, University of Trento, via Inama 5, 38122 Trento, Italy, Phone: +39 0461 882225, Fax: +39 0461 882222, E-mail: marialuigia.segnana@unitn.it

§Scuola Superiore Sant'Anna and University of Urbino, Email: c.tomasi@sssup.it

## 1 Introduction

A distinct feature of globalization is the pivotal role played by the internationalization of production processes (e.g. Feenstra and Hanson, 1996; Hummels et al., 2001). A growing empirical literature provides evidence on the effects of *global sourcing* on firms' efficiency via *specialization*, *learning*, *variety* and *quality upgrading* mechanisms.

Following this literature, the paper develops a model to analyze the costs and efficiency gains entailed by firms' global sourcing strategies in the case of suppliers' heterogeneity. Indeed, one of the mechanisms through which global sourcing may actually affect firms' productivity is the quality upgrading of intermediate inputs. However, given the quality heterogeneity of suppliers, outsourcing firms incur some *screening costs*, i.e. fixed costs related with the need of acquiring the relevant information on the different suppliers and testing their products, in the search for the best one. The large the quality range of suppliers, the higher these screening costs. By expanding suppliers' heterogeneity, the internationalization of production processes may actually boost firms' screening costs. In this way, the efficiency enhancing effects of global sourcing via quality upgrading can be reduced by the increase of screening efforts.

Within this setting, we show that the increasing size of the market for the outsourcing firms is efficiency-enhancing for two reasons: the economies of scale arising from the fixed costs of searching for a partner and the increasing average quality of the chosen supplier.

Moreover, as recently emphasized by the literature (e.g. Rauch, 2001; Rauch and Casella, 2001), *Business & Social Networks* (BSN) can make it easier to collect information, thus being another source of efficiency gains. We indeed confirm that, assuming quality heterogeneity of suppliers and screening costs, such networks can make firms' production and profitability increase via the reduction in the unit screening cost. In addition, we show that there are cumulative beneficial effects at work in case of BSN. This entails that a well established network is itself an incentive for firms to invest in its further development.

The paper is organized as follows. Section 2 briefly summarizes the main theoretical and empirical background. In Section 3, we set up the theoretical model and discuss the main results. Section 4 sketches a possible extension of the model to deal with the problem of location of external sourcing: *local* vs. *foreign*. Section 5 concludes.

## 2 Theoretical and empirical background

The increased resort of firms to global sourcing strategies and the internationalization of production processes in the last two decades has spurred a growing number of studies – empirical (e.g. Feenstra and Hanson, 1996; Hummels et al., 2001) and theoretical (e.g. Grossman and Helpman, 2005; Antràs and Helpman, 2004) – aimed at assessing the actual extent of the phenomenon, together with its main determinants and effects.

Empirical studies have been hampered so far by a lack of systematic statistics, lack partly due to the absence of shared definitions.[1] Economists have adopted different approaches and used several different data: trade statistics in intermediate inputs and in parts and components (Feenstra and Hanson, 1996; Hummels et al., 2001; Yeats, 1998); intra-industry trade measures (Jones and Kierzkowski, 2001); data referring to specific kinds of trade in intermediates, such as the US offshore assembly program (OAP) (Feenstra et al., 1999; Yeats, 1998) or the EU outward processing traffic (Baldone et al., 2001).

These imperfect and different measures nothwithstanding, the studies provide strong evidence of a sustained growth of global sourcing in several industries, such as textiles & footwear, apparel, machinery & electrical equipment, transportation equipment and chemicals.

As for the effects of such practices, economists have analyzed mainly their impact on domestic labour markets and firms' productivity and efficiency.

In particular, the effects of global sourcing on relative wages are determined by the possible downward pressure exerted by foreign sourcing on the wages of unskilled workers in skilled labour-abundant countries, because of the reallocation of the unskilled labour-intensive phases of production processes in unskilled labour-abundant countries (Feenstra and Hanson, 1996; Grossman and Rossi-Hansberg, 2008)

Other studies have instead dealt with the effects of global sourcing on firms' productivity and efficiency. They provide different theoretical arguments for the productivity enhancement effect of global sourcing, namely: increased specialization, learning, innovation, increased variety and quality upgrading.

By relocating outside the inefficient parts of the production process, firms may indeed *specialize* in the phases where they have a comparative advantage. The change in the workforce composition determines an increase in the average productivity of the remaining workers (Amiti and Wei, 2006). Gains may also arise from *learning* effects related with the foreign technology

[1] Despite the diffuse perception of its huge increase, there is no common definition of global sourcing (Feenstra, 1998). Indeed, the term *global* (or *international*) *sourcing* has been used: as a synonym of *delocalization* (or *offshoring*) (e.g. Hummels et al., 1998; Glass, 2004), being it due to external sourcing from abroad – where the production stage crosses both the country's and the firm's boundary – or *vertical FDI* – where instead the phase crosses the national boundary but not the firm's one; to broadly refer to the international trade in intermediate inputs (e.g. Feenstra and Hanson, 1999); for *international partnerships*, thus assuming a minimum level of durability in the supplier-user relation (e.g. Van Long, 2005); or only in case of external service provision (Bhagwati et al., 2004).

In what follows, we use the expression global sourcing in a broad sense, thus including all subcontracting relationships between firms and their suppliers at an international level.

embodied in the imported intermediate inputs (Acharya and Keller, 2007; Eaton and Kortum, 2001). In addition, outsourcing firms might benefit from accelerating the pace of innovative products and services. According to Glass and Saggi (2001), by lowering the marginal cost of production, global sourcing enhances the *incentives for innovation*. Researchers have also considered the possible positive effects due to the *increased variety* of available intermediates, with the related better matching between needed inputs and available ones (Kasahara and Rodrigue, 2005). Finally, imported inputs can increase productivity via *quality upgrading*: global sourcing may in fact allow firms to purchase abroad higher quality inputs (Grossman and Helpman, 1991; Markusen, 1989).[2]

One of the channels through which global sourcing can actually enhance productivity is thus quality upgrading. This argument however entails an assumption of heterogeneity among suppliers, which has been recently introduced in economic modelling in the so-called "new new trade theory" of international trade (e.g. Melitz, 2003; Baldwin and Robert-Nicoud, 2008). The rapid expansion of global sourcing and the enlargement of the market for intermediates has determined a raise in the number of suppliers and a high heterogeneity in the quality of this supply.

Because of such quality heterogeneity, a firm outsourcing a phase of the production process or a service incurs some *screening costs*. Indeed, even if firms can estimate the quality of the supplied inputs, they face some costs related to the needs for: searching for the supplier (Grossman and Helpman, 2002, 2005); collecting all the relevant information on it; testing its products.[3] The larger the quality range of intermediates, the higher these screening costs. By expanding quality heterogeneity, global sourcing may thus boost firms' screening costs.

But unit screening costs are negatively affected by the density and efficiency of *Business & Social Networks* (BSN) operating across national borders. Such networks have recently come to the forefront of economic analysis as a mean to overcome informal trade barriers (Rauch, 2001; Rauch and Casella, 2001; Rauch and Trindade, 2003). They convey information to discriminate suppliers and thus can reduce unit screening costs.

[2]Not many studies have empirically tested the impact of global sourcing on productivity. Among the few, some employ industry level data to investigate its productivity effects on manufacturing and service sectors (Amiti and Wei, 2006; ten Raa and Wolff, 2001; Fixler and Siegel, 1999). In particular, by using data on all US manufacturing industries over the '90s, Amiti and Wei (2006) find that service and material foreign sourcing is positively correlated with labour productivity; and similar results are reached by Görg et al. (2004) at a micro level.

[3]The perspective here adopted is slightly different with respect to Bartel et al. (2005, 2008), where the fixed costs entailed by outsourcing practices are related with the adjustments to be implemented in the in-house production and the outsourced phase, because of the less than perfect matching between the internal production process and the external inputs produced by misunderstandings, frictions, delivery lags or quality differences.

In what follows, we build up a simple model to analyze the interplay between these three factors: the enhancing of the potential quality; the boost of the screening costs entailed by the increased heterogeneity of the quality of suppliers; and the role of BSN in reducing such costs.

## 3 The model

Let us consider a monopolistic firm $h$ producing a final good and outsourcing the production of the needed intermediate input. For the sake of simplicity, let us assume further that there is no other cost involved in the production of the final good but the cost of the intermediate, and that both the internal cost of its production and the cost of local sourcing for $h$ are always greater than the cost of foreign sourcing.

Assume a unit measure of foreign suppliers $m$ producing the intermediate, uniformly distributed according to the quality of the latter and indexed in descending order according to such quality. Let us suppose that there is a one-to-one relation between this quality and the probability that the intermediate will eventually breakdown when employed in the production of the final good. Let us denote this *breakdown probability* with $\mu$. Apart from this, all the supplied intermediates are homogeneous and their cif cost is the same ($c$).

The quality and the related breakdown probability are not freely observable. In particular, at the beginning of the production period, the firm $h$ bears *screening costs*, $s$. Such costs are related with the need to search for a good partner and testing its supplied intermediate. We assume that these costs are directly proportional to the number of the considered potential partners, $n$ ($n \geq 1$):

$$s = \alpha n \tag{1}$$

where $\alpha$ is the unit cost of screening, which includes the costs entailed in the search for the supplier and the test of its product, encompassing also the costs for collecting all the relevant information on it.

After $n$ screenings, the firm outsources the production of the intermediate to the supplier with the best quality among those actually contacted ($\bar{m}$). Given that the firm cannot freely obtain information on the suppliers and because of the assumption on the distribution of suppliers, each screened supplier can be considered by $h$ a random draw from a uniform distribution of $\mu$ ranging from 0 to 1. Thus, after $n$ screenings, the probability that the intermediate provided by $\bar{m}$ is characterized by breakdown probability $\bar{\mu}$ is equal to:

$$g(\bar{\mu}) = nF'(\bar{\mu})(1 - F(\bar{\mu}))^{n-1} = n(1 - \bar{\mu})^{n-1} \tag{2}$$

where $F(\mu)$ is the cumulative distribution function of $\mu$.

Expected profits of firm $h$ are given by:

$$E(p(q)q - C) = p(q)q - E(C) \tag{3}$$

where $p$ is the price of the final good produced by $h$, $q$ is the quantity sold of the final good and $C$ denotes firm's total costs, whose expected value is:

$$E(C) = s + E(c)q = s + E(E(c|\bar{\mu}))q \tag{4}$$

In Equation (4), $s$ denotes $h$'s screening costs and $c$ its marginal cost. The latter is simply equal to the cost of the intermediate, given the simplifying assumption that $h$ incurs no production cost.[4]

Assuming that, in case of breakdown, the firm has to reacquire the input, the expected value of the variable unit costs conditional on $\bar{\mu}$ is:

$$\begin{aligned} E(c|\bar{\mu}) &= (1-\bar{\mu})c + (1-\bar{\mu})\bar{\mu}2c + (1-\bar{\mu})\bar{\mu}^2 3c + \ldots = \\ &= c(1-\bar{\mu})\sum_{i=0}^{\infty}\bar{\mu}^i(1+i) = c(1-\bar{\mu})(\sum_{i=0}^{\infty}\bar{\mu}^i + \sum_{i=0}^{\infty}\bar{\mu}^i i) = \\ &= c(1-\bar{\mu})\left(\frac{1}{1-\bar{\mu}} + \frac{\bar{\mu}}{(1-\bar{\mu})^2}\right) = c + \frac{\bar{\mu}}{1-\bar{\mu}}c = \\ &= \frac{c}{1-\bar{\mu}} \end{aligned} \tag{5}$$

Hence, their unconditional expected value is:

$$\begin{aligned} E(E(c|\bar{\mu})) &= E(\frac{c}{1-\bar{\mu}}) = \int_0^1 \frac{c}{1-\bar{\mu}}\, g(\bar{\mu})d\bar{\mu} = \\ &= cn\int_0^1 (1-\bar{\mu})^{n-2}d\bar{\mu} = \frac{n}{n-1}c \end{aligned} \tag{6}$$

whereas the average quality of the chosen supplier is:

$$E(\bar{\mu}) = \int_0^1 \bar{\mu}\ g(\bar{\mu})d\bar{\mu} = \int_0^1 \bar{\mu}\ n(1-\bar{\mu})^{n-1}d\bar{\mu} = \frac{1}{n+1} \tag{7}$$

Assuming that $h$ maximizes its expected profits by freely setting $q$ and $n$,[5] its profit function is:

$$\pi = \max_{q,n}\ p(q)q - \frac{n}{n-1}cq - \alpha n \tag{8}$$

[4]Removing this assumption does not alter any of the results of the model.

[5]For simplicity, we neglect the integer "problem" and treat the discrete number of screened suppliers ($n$) as a continuous variable.

If we assume further that $h$ faces an isoelastic demand function:[6]

$$q(p) = Ap^{-\epsilon} \tag{9}$$

with $\epsilon > 1$, from the first order conditions of the maximization problem (8) it follows:

$$q = A\left(\frac{\epsilon-1}{\epsilon}\right)^{\epsilon}\left(\frac{n-1}{n}\right)^{\epsilon}\frac{1}{c^{\epsilon}} \tag{10}$$

$$n = 1 + \sqrt{\frac{cq}{\alpha}} \tag{11}$$

and therefore:

$$n^{\epsilon}(n-1)^{2-\epsilon} = \frac{A}{\alpha}\left(\frac{\epsilon-1}{\epsilon}\right)^{\epsilon}\frac{1}{c^{\epsilon-1}} \tag{12}$$

Although the objective function is not concave, it is quasiconcave in the relevant subset and the set of maximizers $(\bar{q}, \bar{n})$ is a singleton (see Appendix).

We can therefore analyze the effects of parameters change on the screening efforts of the firm, its profits and the average quality of the chosen supplier. In particular, we consider two parameters: the market size of $h$ ($A$) and the unit cost of screening ($\alpha$), which is negatively related with the density and efficiency of BSN.

Let us note first that, given the presence of fixed costs directly proportional to the number of screened suppliers and the decreasing effect of an increase in the screening efforts of the firm on the reduction of the expected marginal cost, the supplier actually chosen will produce on average a product whose quality is not maximal. Equation (7) implies this average quality is positively related with the optimal number of screened suppliers ($\bar{n}$), which is in turn related with $A$ and $\alpha$.

As for $A$, from Equation (12) it follows that, the higher the demand faced by $h$, the greater the optimal number of screened suppliers, and hence the

[6] This demand function can be seen as the result of a maximizing rapresentative consumer with a CES utility function as:

$$U = \int_0^I \beta(i)q(i)^{\frac{\epsilon-1}{\epsilon}}di$$

and whose walrasian demand function for good $j$ is therefore:

$$q(j) = \frac{W}{\int_0^I \beta(i)^{\epsilon}p(i)^{1-\epsilon}di}p(j)^{-\epsilon}$$

where $W$ denotes the wealth of such consumer. With $N$ consumers in the market the aggregate demand function faced by $h$ is thus Equation (9), where $A$ is given by:

$$A = \frac{WN}{\int_0^I \beta(i)^{\epsilon}p(i)^{1-\epsilon}di}$$

quality of the intermediate. Moreover, the marginal effect of an increase of the market size on firm's profits by the envelope theorem is:

$$\frac{\partial \pi}{\partial A} = \frac{1}{\epsilon}\left(\frac{\bar{q}}{A}\right)^{\frac{\epsilon-1}{\epsilon}} = \frac{1}{\epsilon}\left(\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}\left(\frac{\bar{n}-1}{\bar{n}}\right)^{\epsilon-1}\frac{1}{c^{\epsilon-1}} \tag{13}$$

which turns out to be positively related with $\bar{n}$. Therefore, given that a bigger $A$ entails a greater $\bar{n}$, the positive effect of marginal increases of $A$ on firm's profits becomes larger the larger the initial level of $A$.

Hence, in presence of quality heterogeneity of suppliers and screening costs, the differential efficiency gains from market expansions tend to increase with the initial level. This leads to our first result:[7]

**Proposition 1** *Big firms can better exploit the potential gains from quality upgrading and have got an advantage in the international arena.*

Let us consider now the effects of changes in the unit cost of screening ($\alpha$). From Equation (12) it follows that a decrease of $\alpha$ makes $\bar{n}$, $\bar{q}$ and the quality of the chosen suppliers all increase. Thus, our model predicts that "thicker" transnational networks, via the increase in the effectiveness of the screening efforts, can entail an increase of firm's efficiency, which comes from the increase in the average quality of the intermediate, and an expansion of production.

**Proposition 2** *Denser and more efficient transnational BSN improve firms' efficiency and make production increase.*

Moreover, given that the effect of a marginal increase of $\alpha$ on firm's profits is simply equal to:

$$\frac{\partial \pi}{\partial \alpha} = -\bar{n} \tag{14}$$

this effect interacts with the previous one creating cumulative incentives for firms to invest in the development of transnational BSN. In particular, given that, the more the initial thickness of the network, the greater the optimal number of screened suppliers, then the higher the cost saving the firm would obtain by reducing further $\alpha$ and thus its incentive to invest in the network.

[7] It is instructive to consider what happens instead in the more standard case of a monopolistic firm incurring costant marginal costs ($c$) and facing an isoelastic demand curve like (9). In this case, although the effect of a marginal increase of the market size on firm's profits is clearly still positive:

$$\frac{\partial \pi}{\partial A} = \frac{1}{\epsilon}\left(\frac{\bar{q}}{A}\right)^{\frac{\epsilon-1}{\epsilon}} = \frac{1}{\epsilon}\bar{p}^{1-\epsilon} > 0$$

it remains costant across different initial market sizes:

$$\frac{\partial \pi}{\partial A} = \frac{1}{\epsilon}\left(\frac{\epsilon}{\epsilon-1}c\right)^{1-\epsilon} = \frac{1}{\epsilon}\left(\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}\frac{1}{c^{\epsilon-1}}$$

**Proposition 3** *Developed transnational BSN are themselves incentive for firms to invest in their further development.*

Hence, our model predicts that transnational BSN increase the overall production and firms' profitability. Moreover, it shows that a developed transnational network constitutes in itself an incentive for firms to invest in its further development.[8]

## 4 A possible extension: foreign vs. local sourcing

The benchmark model can be easily modified to analyze the mutual exclusive strategies of external sourcing: *local* vs. *foreign*, by considering the differences between local and foreign suppliers and investigating how these differences, in terms of costs, heterogeneity and degree of embeddedness in networks, can affect final firms' strategies and their efficiency.

Such extension allows to focus upon the linkages between the characteristics of local systems and firms' sourcing strategies. In particular, by assuming that local business networks are more developed than transnational ones and that the heterogeneity of local suppliers is less pronounced, we can investigate firms' choice between local and global sourcing and how they interact with the previous factors determining firms' overall efficiency.

In so doing, let us suppose that, along with the foreign providers ($m^*$), there is a supply of local providers ($m$) that firm $h$ can alternatively resort to for the provision of the intermediate.

The unit cost of screening of local suppliers for firm $h$ ($\alpha$) are smaller than the correspondent costs in case of foreign suppliers ($\alpha < \alpha^*$). This is the result of, on the one hand, the geographical and cultural proximity between $h$ and its local suppliers; on the other, the existence of local BSN usually more developed than transnational ones.[9]

Moreover, because local providers are more spatially and technologically concentrated, we assume that they are less heterogeneous in terms of quality than the suppliers on international markets. In particular, we suppose that, like foreign suppliers, there is continuum of local suppliers producing the intermediate suitable for $h$, which are uniformly distributed according to its breakdown probability $\mu$, but, unlike foreign suppliers, in case of local providers the latter ranges from $t_m$ to $t_M$, where $0 \leq t_m \leq t_M \leq 1$.

[8] The previous effects could be dimmed by pronounced decreasing returns to scale in the investments made for network developments. They are instead emphasized assuming seemingly increasing returns of such investments.

[9] This greater development of local networks compared to transnational ones can be itself the result of the above proximity. Notwithstanding, it should be properly retained as an independent factor that contributes towards reducing the unit costs of screening in case of local suppliers.

Finally, we assume that local providers sell the intermediate at a price ($c$), not smaller than the cif cost of acquiring the intermediate on international markets: $c \geq c^*$.

Firm $h$ can make either local or foreign sourcing. In particular, $h$ will decide to make foreign sourcing if and only if:

$$\pi^*(A, \alpha^*, c^*) > \pi(A, \alpha, c, t_m, t_M) \tag{15}$$

where $\pi^*$ and $\pi$ are the expected profits in case of, respectively, foreign and local sourcing.

The interplay between the differences in the previous features of local and foreign providers, also in terms of the different BSN they are embedded in, determines the location of the supplier chosen by firm $h$.

Such differences can impact in opposite directions on the relative profitability of local vs foreign sourcing strategies. For istance, the higher unit costs for screening foreign suppliers rather than local ones makes *ceteris paribus* local sourcing more profitable. And the same happens because of the ceiling threshold in the distribution of local suppliers in terms of breakdown probability of the intermediate ($t_M$). On the contrary, the higher cost of the intermediate supplied locally ($c$) and the floor threshold ($t_m$) both make foreign sourcing a more efficient strategy. Thus, we can assume that there exists a firm $h$ to which the two strategies give on average the same profit and we can thus analyze the impact of changes in the parameters on these expected profits.

# 5 Conclusions

The paper analyzes the effects of global sourcing on the efficiency of final firms via quality upgrading of intermediates, entailed by the increased availability of suppliers, taking also into account the role of Business & Social Networks (BSN) in facilitating supplier-user relations and improving information diffusion.

Indeed, when new sourcing opportunities arise, the increased quality range of suppliers may allow firms to acquire higher quality inputs, but it also increases the extent of screening efforts. Global sourcing is thus a potential efficiency enhancing strategy for firms, but the potential gains may be partly offset by the boost of screening costs produced by the increased heterogeneity of suppliers.

Within this setting, we show that big firms have got an advantage in international arena since they can better exploit the potential gains of the increased availability of suppliers. Moreover, BSN have cumulative beneficial effects in reducing these costs: thicker networks imply higher cost saving and thus further incentives to invest in network linkages, making them thicker and thicker.

In a sketched extension of the model, we frame the problem of external sourcing at a local vs foreign level for final firms as a problem of supplier-user matching, by considering the differences between local and foreign suppliers in terms of costs, heterogeneity and degree of embeddedness in networks.

Because of the potential greater heterogeneity of foreign suppliers, transnational BSN are usually more effective in enhancing firms' efficiency than local BSN, but thicker local BSN can help reducing the probability of firms to globally source and therefore reduce the "negative" impact of globalization on local production systems.

# A Appendix

The Hessian of the objective function of (8) is:

$$\mathbf{H} = \begin{pmatrix} 2p'(q) + p''(q)q & \frac{c}{(n-1)^2} \\ \frac{c}{(n-1)^2} & -\frac{2cq}{(n-1)^3} \end{pmatrix} = \begin{pmatrix} -\frac{\epsilon-1}{\epsilon^2} A^{1/\epsilon} q^{-(\epsilon+1)/\epsilon} & \frac{c}{(n-1)^2} \\ \frac{c}{(n-1)^2} & -\frac{2cq}{(n-1)^3} \end{pmatrix} \quad (16)$$

Given that the upper left element of $\mathbf{H}$ is negative, if its determinant is positive the matrix is negative definite. The condition is therefore:

$$|\mathbf{H}(q,n)| = \frac{2c(\epsilon-1)}{\epsilon^2(n-1)^3}\left(\frac{A}{q}\right)^{\frac{1}{\epsilon}} - \frac{c^2}{(n-1)^4} > 0$$

This condition valued at $(\bar{q}, \bar{n})$ becomes:

$$\frac{\epsilon-1}{\epsilon}\frac{\bar{n}-1}{c}\left(\frac{A}{\bar{q}}\right)^{\frac{1}{\epsilon}} > \frac{\epsilon}{2}$$

$$\frac{\epsilon-1}{\epsilon}\frac{\bar{n}-1}{c}\bar{p} > \frac{\epsilon}{2}$$

Given that:

$$\bar{p} = \frac{\epsilon}{\epsilon-1}\frac{\bar{n}}{\bar{n}-1}c$$

it follows that the condition for a critical point $(\bar{q}, \bar{n})$ to be a local maximum is:

$$2\bar{n} > \epsilon \quad (17)$$

Let us denote the left hand side of Equation (12) with $r(n)$. Taking the logarithm of this function and differentiating it with respect to $n$ we obtain:

$$\frac{d\log r(n)}{dn} = \frac{d}{dn}\left(\epsilon\log n + (2-\epsilon)\log(n-1)\right) = \frac{2n-\epsilon}{n(n-1)} \quad (18)$$

which is stricly positive provided that condition (17) is satisfied. The limits of $r(n)$ are:

$$\lim_{n\to+\infty} r(n) = \left(\lim_{n\to+\infty}\frac{n}{n-1}\right)^{\epsilon}\lim_{n\to+\infty}(n-1)^2 = \lim_{n\to+\infty}(n-1)^2 = +\infty$$

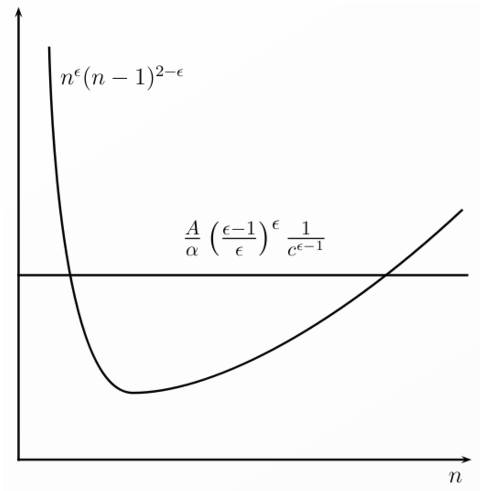


Figure 1: Critical points of $n$ when $\epsilon > 2$

$$\lim_{n\to 1^+} r(n) = \begin{cases} 0 & \text{if } \epsilon \leq 2 \\ +\infty & \text{if } \epsilon > 2 \end{cases}$$

Hence, we can have two cases. If $1 < \epsilon \leq 2$, then $r(n)$ is a strictly increasing monotonic function approaching to 0 when n tends to its inferior limit. Thus, there is one and only one possible value of $n$ (with the associated value of $q$) for which Equation (12) is satisfied and such value satisfies also condition (17). On the contrary, if $\epsilon > 2$, then $r(n)$ is a convex function reaching its minimum at $n = \epsilon/2$. Within reasonable values of the parameters, the situation will be the one depicted in Figure 1. Hence, in this case there are two critical points, but the only one that satisfies condition (17) is the largest one.[10]

## References

Acharya, R. and W. Keller (2007). Technology transfer through imports. Working Paper 13086, NBER.

Amiti, M. and S. J. Wei (2006). Service offshoring and productivity: Evidence from the United States. Working Paper 11926, International Monetary Fund.

Antràs, P. and E. Helpman (2004). Global sourcing. *Journal of Political Economy 112*(3), 552–580.

Baldone, S., F. Sdogati, and L. Tajoli (2001). Patterns and determinants of international fragmentation of production. evidence from outward process-

[10]Quasiconcavity in the relevant subset can be proved by looking at the bordered Hessian.

ing trade between the EU and the countries of Central-Eastern Europe. *Weltwirtshaftliches Archiv*, 80–104.

Baldwin, R. E. and F. Robert-Nicoud (2008, January). Trade and growth with heterogeneous firms. *Journal of International Economics 74*(1), 21–34.

Bartel, A., S. Lach, and N. Sicherman (2005, February). Outsourcing and technological change. Working Paper 11158, National Bureau of Economic Research.

Bartel, A., S. Lach, and N. Sicherman (2008, February). Outsourcing and technological innovations: A firm-level analysis. Discussion Paper 3334, IZA.

Bhagwati, J., A. Panagariya, and T. N. Srinivasan (2004). The muddles over outsourcing. *Journal of Economic Perspectives 18*(4), 93–114.

Eaton, J. and S. Kortum (2001). Trade in capital goods. *European Economic Review 45*, 1195–1235.

Feenstra, R. C. (1998). Integration of trade and disintegration of production in the global economy. *Journal of Economic Perspective 12*(4), 31–50.

Feenstra, R. C., G. Hanson, and D. L. Swenson (1999). Offshore assembly from the united states: Production characteristics of the 9802 program. Working Paper 98-10, UC Davis.

Feenstra, R. C. and G. H. Hanson (1996). Foreign investment, outsourcing and relative wages. In R. C. Feenstra, G. M. Grossman, and D. Irwin (Eds.), *The Political Economy of Trade Policy: Papers in Honor of Jagdish Bhagwati*, pp. 89–127. MIT Press.

Feenstra, R. C. and G. H. Hanson (1999). The impact of outsourcing and high-technology capital on wages: Estimates for the United States, 1979-1990. *Quarterly Journal of Economics August*, 907–940.

Fixler, D. J. and D. Siegel (1999). Outsourcing and productivity growth in services. *Structural Change and Economic Dynamics 10*, 177–194.

Glass, A. J. (2004). Outsourcing under imperfect protection of intellectual property. *Review of International Economics 12*(5), 867–884.

Glass, A. J. and K. Saggi (2001). Innovation and wage effects of international outsourcing. *European Economic Review 45*, 67–86.

Görg, H., A. Hanley, and E. Strobl (2004). Outsourcing, foreign ownership, exporting and productivity: An empirical investigation with plant level data. Research Paper 2004/08, Globalisation, Productivity and Technology.

Grossman, G. and E. Helpman (2005). Outsourcing in a global economy. *Review of Economic Studies 72*, 135–159.

Grossman, G. and E. Rossi-Hansberg (2008). Trading tasks: a simple theory of offshoring. *American Economic Review 98*(5), 1978–1997.

Grossman, G. M. and E. Helpman (1991). *Innovation and Growth in the Global Economy.* Cambridge, MA: MIT Press.

Grossman, G. M. and E. Helpman (2002). Integration versus outsourcing in industry equilibrium. *The Quarterly Journal of Economics 117*(1), 85–120.

Hummels, D., J. Ishii, and K. Yi (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics 54*(1), 75–96.

Hummels, D., D. Rapoport, and K.-M. Yi (1998). Vertical specialization and the changing nature of world trade. *Federal Reserve Bank of New York Economic Policy Review 4*, 79–99.

Jones, R. W. and H. Kierzkowski (2001). A framework for fragmentation. In S. W. Arndt and H. Kierzkowski (Eds.), *Fragmentation: New production patterns in the world economy*, pp. 17–34. Oxford and New York: Oxford University Press.

Kasahara, H. and J. Rodrigue (2005). Does the use of imported intermediates increase productivity? Technical Report Working Paper 20057, RBC Financial Group Economic Policy Research Institute.

Markusen, J. (1989). Trade in producer services and in other specialized intermediate inputs. *American Economic Review 79*(1), 85–95.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica 71*(6), 1695–1725.

Rauch, J. E. (2001). Business and social networks in international trade. *Journal of Economic Literature 39*(4), 1177–1203.

Rauch, J. E. and A. Casella (Eds.) (2001). *Networks and Markets.* New York: Russell Sage Foundation.

Rauch, J. E. and V. Trindade (2003). Information, international substitutability, and globalization. *The American Economic Review 93*(3), 775–791.

ten Raa, T. and E. N. Wolff (2001). Outsourcing of services and the productivity recovery in U.S. manufacturing in the 1980s and 1990s. *Journal of Productivity Analysis 16*, 149–165.

Van Long, N. (2005). Outsourcing and technology spillovers. *International Review of Economics & Finance 14*(3), 297–304.

Yeats, A. J. (1998). *Just How Big is Global Production Sharing?* Washington: World Bank.