Agglomeration Economies, Productivity, and Quality Upgrading

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Abstract: Analysis of the urban agglomeration of economic activity has focused on its benefits for firm productivity. But the marginal-cost savings which agglomeration brings about also free up inputs that can be used to produce higher-quality goods, with their own profitability potential. We use plant-product-level data from Japanese manufacturing to examine agglomeration's influences on product quality. Results confirm that quality does grow with region size, suggesting polices aimed at encouraging urban agglomeration improve competitiveness by raising product quality as well as productivity. Total factor productivity alone, therefore, underestimates agglomeration benefits by ignoring the quality incentives that accompany it.

Keywords: Agglomeration, Japanese manufacturing, Product quality, Total factor productivity

JEL classification: D24, L15, R11

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1. Introduction

Agglomeration's influences on regional economies have been extensively examined in the urban economics literature (Ciccone and Hall 1996, Henderson 1986, Henderson 2003). For instance, Rice et al. (2006) demonstrate that most of the urban-rural income gap can be explained by the average productivity difference between city and countryside. Empirical work has identified agglomeration economies – externalities from the spatial concentration of economic activity – as a key determinant of regional productivity gaps (e.g., Combes et al. 2012). In particular, region-level productivity rises 3–8% when region size is doubled (World Bank 2009). Based on such empirical evidence, agglomeration-inducing policies have been implemented in many countries. For example, Japanese government invested 110 billion yen (approximately USD 1.1 billion) in an 'industrial cluster project' from 2001 to 2005 (Nishimura and Okamuro 2011).

Compared with the considerable research attention to regional market size and regional prosperity, the literature has not persuasively explored the role of market structure in an agglomeration context. This does not imply market structure effects are negligible. For example, it is well known that in face of a downward sloping demand curve, namely when market power is present, profit maximizing prices are inversely related to productivity (Foster et al. 2008). The implication is that agglomeration effects on profit will be partially offset because city-level prices are reduced by the agglomeration economy.[1]

Product quality is an important consumer demand factor, boosting consumer willingness-to-pay in vertically differentiated markets. Upgrading quality requires more and better-quality inputs in the production process (Picard and Okubo 2012, Shaked and Sutton 1987). Since agglomeration economies reduce marginal costs and lift marginal products, and since each additional production dollar affords more as well as better inputs, urban firms therefore will market both more and better-quality outputs than rural firms will. A number of articles indeed have addressed the positive effect of region size on product quality. Picard's (2015) theoretical model demonstrates that the larger the region, the better the quality of its goods. This is because a larger region makes better use of the higher fixed costs necessary for quality upgrading. Empirical evidence in Hummels and Klenow (2005) indicate that larger countries tend to export higher-quality goods. Berry and Waldfogel (2010) confirm that product quality in the newspaper and restaurant industries is positively related to the size of the regional market. Yet little attention has been paid to whether agglomeration economies improve product quality, or how quality upgrades alter agglomeration's profit benefits.

Our intention here is to demonstrate, on both theoretical and empirical grounds, the effects of introducing product quality in the context of an agglomeration economy. We find that, modeled as Hicks-neutral technical change, agglomeration economies reduce production

[1] A negative relationship between agglomeration and product prices may also arise because of transport costs. According to much of the New Economic Geography literature (e.g., Krugman 1991), prices of manufacturing goods tend to be low in agglomerated regions on account of the saved transport costs. Empirically, Handbury and Weinstein (2015) conclude that food product prices decline as U.S. market size grows.

marginal costs. That boosts operating profits, which finance the additional inputs necessary for upgrading product quality. This finding motivates us to empirically explore the relationship between region size and quality improvement. In doing so we follow Khandelwal (2010) to estimate product quality at each plant, employing plant-product-level data in Japanese manufacturing. By regressing the estimated product quality on variables reflecting region size, we find statistically significant evidence that agglomeration of economic activity enhances product quality.

This has important implications for firm competitiveness. Product quality is widely regarded to be a precondition for economic development in this globalization era (Amiti and Khandelwal 2013). To gain entry, for example, in any skill-intensive segment of the internationally fragmented production matrix, even developed nations will improve the quality of the intermediate goods they offer (Timmer et al. 2014). Japanese firms are no exception: their share of exports of the intermediate inputs used in global value chains has risen steadily (IMF 2015). To remain competitive they must continue to upgrade product quality, and that is best financed through productivity improvements. We show agglomeration-inducing policies are effective for this purpose: urbanization enables the benefits of agglomeration economies to be distributed between productivity enhancement and quality improvement.

Earlier studies have, as part of efforts to predict the effectiveness of policies that attract agglomeration, often examined their impacts on total factor productivity (TFP). However, if quality upgrading requires increased input use, TFP underestimates agglomeration benefits because it does not count the benefits' contributions to quality enhancement. To say this differently, TFP-based measures of the benefits a firm receives from agglomerating are underestimated if the firm places a high priority on quality enhancement. It therefore will be under-subsidized or neglected in agglomeration-inducing policies, sacrificing employment growth or tax revenue in the host region. Another policy contribution of this paper is therefore to highlight the importance of heretofore ignored agglomeration impacts on product quality.

We next discuss the economic role of product quality and the estimation methods we use to assess it. In section 3 we consider our conceptual and empirical framework, in section 4 our data sources and analytical variables, and in section 5 the empirical results. We conclude with a summary of findings and policy implications.

2. Product Quality and its Estimation

The economic role of product quality at both product and plant-product level has recently attracted attention in the industrial organization and international trade literatures. Quality is considered discretely in these studies, namely as a demand shifter that boosts consumer willingness to pay. If one good is perceived to be of higher quality than another, its demand is greater even if the two have the same price.

Generally speaking, product quality is varied through a suitable adjustment in the firm's marginal or fixed costs (Shaked and Sutton 1987). Antoniades (2015) argues that R&D

investment – affecting the firm's fixed expenses – is the key ingredient to the kind of innovation that upgrades quality (see also Picard 2015). In contrast, Fan et al. (2015) reason it is an intensive use of inputs, and hence a high marginal-cost, that is responsible for output quality growth. The assumption of a link between product quality and marginal cost can be found in other studies as well, such as in Baldwin and Harrigan (2011), Kugler and Verhoogen (2012), and Hallak and Sivadasan (2013).

Indeed, we can observe trade-offs between marginal cost and quality in a variety of production locales. Crozet et al. (2011) argue that the quality of Champagne depends on the quality of the grapes, which are the primary intermediate good. Grape quality is maintained by avoiding the over-cropping that impairs flavor, and grapes from these vineyards tend to have the better reputation and higher price. Champagne in particular needs time for the lees to acquire an adequate taste complexity. Lexus, the Toyota luxury car brand, is produced in highly sophisticated, computerized manufacturing plants (Kageyama 2007). Because quality requirements in the welding process, body panel fit tolerances, and painting are more stringent in Lexus than in other Toyota vehicles, only veteran technicians are allowed to be involved in it. A third example is the handmade leather bag Birkin, by Hermès, regarded as a symbol of wealth because of its high price and celebrity use. According to the *Calgary Herald* (2010), Birkin bags use leathers from a variety of tanners and are hand-sewn, buffed, painted, and polished by expert artisans. These instances suggest improving product quality requires not only higher fixed costs but higher variable costs.

Because quality upgrading appears to involve additional variable cost, early studies such as Schott (2004) and Hallak (2006) have employed unit value as a quality proxy. Unit values can be easily obtained from trade data but not necessarily in a way consistent with what really constitutes quality. Between two products sold at the same price for example, the one with the more fashionable design or higher functionality tends to have, on account of that quality reputation, the larger market share. Moreover, because unit value reflects cost structure, some high-quality products can be priced lower than their low-quality counterparts. Chinese smartphone company Xiaomi's current share in the Chinese smartphone market exceeds Apple's and Samsung's. This is not only because its products are priced lower – primarily on account of the low wages and mass production in Chinese manufacturing – but because its phones are competitive in design and functionality among Chinese consumers. That competitiveness is not accurately reflected in unit-value-based quality metrics.

An ideal measure of product quality should therefore avoid a unit-price foundation. Berry (1994) develops an alternative approach to product quality measurement, based on logit demand functions. His approach is unique in taking account of products' market-share differences. Among those with identical prices, the highest quality is assigned to the product with the greatest market share. Khandelwal (2010) applies such a method to U.S. trade data on hundreds of manufacturing products to estimate product quality by source country. Using the same quality estimates, Amiti and Khandelwal (2013) examine whether trade liberalization boosts manufacturing quality.[2] In the present study we incorporate agglomeration economies into Khandelwal's (2010) framework to examine how the agglomeration of economic activity influences quality and productivity choices.

3. Conceptual and Empirical Framework

3.1. Agglomeration Effects on Product Quality

Consider a monopolistically competitive market in which product *i*, $i = 1, \ldots, I_j$ in product group *j* is produced in industry *k*. Consumer *n*'s utility for product *i* is structured as

(1) $$V_{ni} = \lambda_i - \alpha p_i + \varepsilon_{ni},$$

where λ_i denotes the i^{th} product's quality, so that the greater the quality the greater is the utility gained from it; and p_i is its price, where parameter $\alpha (> 0)$ represents the utility lost on account of a unit price rise.[3] Random variable ε_{ni} reflects the tastes for the i^{th} good that are idiosyncratic to consumer *n*, allowing each consumer a distinct preference ranking and thus permitting the group *j* products to be horizontally differentiated. Suppose ε_{ni} follows a type I distribution. Then the market share of product *i* in product group *j* is given by

(2) $$s_i = \frac{\exp(\lambda_i - \alpha p_i)}{\sum_{l=1}^{I_j} \exp(\lambda_l - \alpha p_l)}.$$

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[2] Other examples include Smeets et al. (2014) and Bernini et al. (2015). Smeets et al. (2014) investigate the relationship between product quality and foreign outsourcing in the Danish apparel industry. Bernini et al. (2015) explore the effects of firm-level financial structure on the quality of French exports.

[3] Because consumers want the good bringing the higher utility, income is canceled out when they compare utilities of any two goods as long as, in a given product type, income yields the same utility.

Consider now the supply side of the market. Following Fan et al. (2015) we assume that in order to produce any set of differentiated goods, investment must be made in R&D, the quantity of which uniquely determines the good's quality level λ_i. Stated differently, the amount of investment is considered to be a fixed cost of production:

(3) $$FC_i = \lambda_i^{\gamma} f,$$

where f is the R&D investment necessary to develop a product of quality level one ($\lambda_i = 1$) and parameter $\gamma > 0$ indicates that developing a higher-quality product requires a greater investment. For a given λ_i, the production function is defined as (Fan et al. 2015):

(4) $$y_i = A(G_r)\lambda_i^{-\beta} g(\mathbf{x}),$$

where $\mathbf{x}$ is a vector of conventional inputs and $g(.)$ is linearly homogeneous in $\mathbf{x}$. Parameter $\beta > 0$ shows the extent (in percentages) to which output declines when the firm improves product quality by one percent, holding conventional inputs constant. In other words, equation (4) implies producing higher-quality products requires more inputs. Finally, $A_r(.)$ represents the productivity-enhancing externalities in region r that we collectively refer to as agglomeration economies. This productivity is assumed to rise with region size G_r. That is to say, $\partial A/\partial G_r > 0$ (Henderson 2003). Marginal cost of production is then

(5) $$MC_i = \frac{\lambda_i^{\beta} c(\mathbf{w})}{A(G_r)},$$

where $\mathbf{w}$ is the vector of input prices and $c(.)$ is the unit cost of producing a good of quality level one.

Given its fixed and marginal cost structure, the firm producing good *i*, and facing demand function (2) for it, maximizes profit with respect to price and quality by solving[4]

$$\max_{p_i,\lambda_i} \Pi_i \equiv s_i M\left(p_i - MC_i\right) - FC_i, \tag{6}$$

in which M denotes total demand in the product group. First-order conditions for profit maximization are

$$p_i - \frac{1}{\alpha} - MC_i = 0, \tag{7}$$

$$s_i M\left(p_i - MC_i - \frac{\partial MC_i}{\partial \lambda_i}\right) - \gamma\lambda_i^{\gamma-1} f = 0. \tag{8}$$

The second-order condition for profit maximization is satisfied as long as the following condition holds:

$$B \equiv A^2\left[(\beta-1)\left(\beta MC_i s_i M\right)^2 + \beta\gamma\left(\beta+\gamma-2\right)s_i MFC_i MC_i + \left(\gamma-\lambda_i-1\right)\left(\gamma FC_i\right)^2\right] > 0. \tag{9}$$

Sufficient conditions for (9) to hold are $\beta > 1$ and $\gamma > \lambda_i + 1$, jointly requiring (from equations 3 and 4) diminishing returns to scale in the production of product quality.

Equation (7) says product price is determined jointly by marginal cost and by the utility loss α suffered on account of a unit price increase. Because marginal costs are a function of product quality, optimal quality is implicitly and jointly determined by equations (7) and (8). Applying the implicit function theorem gives the effects of region size on product quality and price as, respectively,

[4] This firm may be a multi-product firm producing more than one product. However, because we do not consider the economies of scope, we can assume firms maximize their aggregate profits by maximizing profits from individual products.

(10) $$\frac{\partial \ln \lambda_i}{\partial \ln G_r} = \frac{A^2 MC_i s_i M \left[\beta^2 MC_i s_i M + \gamma(\beta+\gamma) FC_i\right]}{B} \frac{\partial \ln A}{\partial \ln G_r},$$

(11) $$\frac{\partial \ln p_i}{\partial \ln G_r} = -\frac{MC_i}{p_i}\left(\frac{\partial \ln A}{\partial \ln G_r} - \beta \frac{\partial \ln \lambda_i}{\partial \ln G_r}\right).$$

From equations (2), (10), and (11) we obtain

(12) $$\frac{\partial \ln s_i}{\partial \ln G_r} = \frac{\lambda_i A^2 MC_i s_i M \left[\beta(\beta-1) MC_i s_i M + \gamma(\beta+\gamma-1) FC_i\right]}{B} \frac{\partial \ln A}{\partial \ln G_r}.$$

Equation (12) is positive as long as sufficient conditions $\beta > 1$ and $\gamma > \lambda_i + 1$ for 2nd-order-condition equation (9) hold.

Because under agglomeration economies $\partial A/\partial G_r > 0$, equation (10) is positive, implying product quality improves with region size. As shown in (5), improved product quality demands an increase in marginal costs ($\partial MC_i/\partial \lambda_i > 0$); but on account of agglomeration economies, the increase is lower in large regions than in small. Hence the third parenthesized term in (8) declines with region size, so that in order for (8) to hold, product quality must improve as region size grows.

Equation (11) shows region size affects product price in two ways. The first term in the parenthesis indicates that, holding product quality constant, region size's productivity improvement effect algebraically reduces size's price effect. For example, if (11) is negative, the productivity effect amplifies region size's downward pressure on prices. In contrast, the second parenthesized term shows region size's quality upgrade effect (as weighted by quality's output elasticity β) algebraically boosts size's price effect. Consequently, region size's net price impact is ambiguous. Finally, equation (12) indicates that a product's market share is larger in large regions than in small ones. These results can be summarized in the following proposition:

Proposition. *Suppose improving product quality requires additional input use. If agglomeration economies are modeled as a Hicks-neutral technical change, then the larger the region size, the greater will be the product quality and the larger the firm's market share in a product-group.*

This proposition will be tested in the following section. However, region size improves product quality by way of more than just agglomeration economy *A*. For example, although we have not explicitly considered region size impacts on material prices **w**, they may indeed be present. Material transport costs and hence prices may, for instance, be cheaper in an urban area if intermediate goods producers tend to agglomerate there (Fujita et al. 1999). As equation (5) shows, reducing **w** has the same qualitative effect on marginal cost as raising *A* does. Thus, urban final-goods producers have in this respect a quality advantage over rural firms. Consequently, because region size's agglomeration economy effects cannot be distinguished from its material-price effects, size's influence on product quality in section 5 below will reflect both agglomeration economies and material prices (Combes et al. 2008).

3.2. Agglomeration Effects on Profit

We next consider how introducing product quality affects our understanding of the impacts of agglomeration on firm profit. Differentiating profit with respect to region size gives:

(13) $$\frac{\partial \ln \Pi_i}{\partial \ln G_r} = \frac{\gamma}{\frac{\gamma - \lambda_i}{\alpha MC_i} + \beta} \frac{\partial \ln A}{\partial \ln G_r}.$$

which is positive whenever $\partial A / \partial G > 0$. Agglomeration economies boost profits, especially when product quality λ_i is high. This finding highlights the effectiveness of agglomeration-inducing policies: firms attracted to agglomerated regions can boost profit directly by improving productivity (represented in $\partial \ln A / \partial \ln G_r$) and indirectly by improving product quality (represented in λ_i and MC_i).

Product quality also has important implications for the measurement of agglomeration economy benefits. TFP is typically obtained in the literature as the difference between revenue – deflated by the k^{th} industry's price index P_k – and the output-elasticity-weighted sum of the input quantities:[5]

(14) $$\ln TFP_i \equiv \ln \frac{R_i}{P_k} - \ln g(\mathbf{x}),$$

where revenue is product price times output:

(15) $$R_i \equiv p_i y_i.$$

Substituting (15) into (14) and using equation (4) allows us to express TFP as:

[5] This applies at least to the Cobb-Douglas production function.

(16) $\ln TFP_i = \ln A - \beta \ln \lambda_i + \ln p_i - \ln P_k$.

Equation (16) expresses TFP as a sum of agglomeration economies, product quality, individual product price, and the industry's aggregate price index. In the conventional approach to quantifying region size's effect on agglomeration economies ($\partial \ln A / \partial \ln G_r$), TFP is regressed on region size *G* without controlling for product quality *λ* or for individual product price *p*. But because quality and price are also influenced by region size (equations 10 and 11), differentiating (16) with respect to region size gives[6]

$$\frac{\partial \ln TFP_i}{\partial \ln G_r} = \left(1 - \frac{MC_i}{p_i}\right)\left(\frac{\partial \ln A}{\partial \ln G_r} - \beta \frac{\partial \ln \lambda_i}{\partial \ln G_r}\right). \quad (17)$$

The first parenthesis in (17) represents the Lerner index: the greater the firm's market power in product *i*, the greater the TFP improvement that can be accounted for by region size. The second parenthesized term is the one we saw in equation (11), namely the difference between region size's agglomeration economy effect and its output-elasticity-weighted quality effect.

It follows from equations (16) and (17) that regressing TFP on region size *G* in the absence of any control over product quality and price will yield biased estimates of region size's impact on agglomeration economies. In particular, the effect is biased downward on account of the increased use of inputs to upgrade quality.[7] In other words, solving equation (17) for

[6] The derivative of the industry price index with respect to region size is assumed to be zero. As the industry price index is aggregated at the national level, it is not likely that an infinitesimal change in size of a single region will significantly affect the industry price index.
[7] We cannot directly examine the impacts of quality upgrading on TFP as suggested in equations (16) and (17) because estimation of plant-product level TFP is not possible. Most of our sample plants produce multiple products but we do not know how much factor inputs are used to produce individual products.

$\partial \ln A / \partial \ln G_r$ shows the firm allocates the benefits of region-size-induced agglomeration economies between improved productivity ($\partial \ln TFP_i / \partial \ln G_r$) and improved quality ($\partial \ln \lambda_i / \partial \ln G_r$).

We have shown in equation (13) that estimates of region size's agglomeration economy effects can be used to determine its profit effects as well. Although TFP has conventionally been used for this purpose instead, we have shown that it underestimates agglomeration benefits by ignoring the quality upgrading factor, especially in industries where upgrading involves substantial use of more – as opposed to better – inputs.

3.3. Product Quality Estimation

Following Khandelwal (2010) and Amiti and Khandelwal (2013), we base our empirical analysis on indirect utility function (1), whose determinants are the product's quality and price and consumer *n*'s specific preference for it following a type I distribution. When each buyer selects a unit of the utility-maximizing good from the j^{th} product group, the i^{th} product's market share demanded is given by (2). For tractability, consumers are allowed to reject every product in the j^{th} group in favor of an external one, the utility of which is normalized at zero ($\lambda_{ot} - \alpha p_{ot} = 0$). In that case, Berry (1994) shows the log difference between the i^{th} and the external product's demanded market share can be expressed as:

(18) $$\ln s_{it} - \ln s_{ot} = \lambda_{it} - \alpha p_{it},$$

where *t* denotes year and s_{ot} is the external product's market share in year *t*.

Product characteristics such as an automobile's fuel efficiency or a cereal's sugar content can be used as quality proxies (e.g., Berry et al. 1995, Nevo 2001). Data of that sort, however, are unavailable. Rather than use proxies, and following Khandelwal (2010), we assume product quality λ_{it} can be represented by three factors: year fixed effects (δ_t), plant-product fixed effects (δ_i), and product-year fixed effects (δ_{it}).[8] Year fixed effects capture product qualities subject to time-specific macroeconomic shocks, while plant-product fixed effects capture the quality elements which are time-invariant – namely that reflect plant-specific capacities to produce high-quality goods. Product-year fixed effects – deviations from average quality – are treated as the residual. Equation (18) then can be rewritten as

(19) $$\ln s_{it} - \ln s_{ot} = -\alpha p_{it} + \varphi \ln size_{it-1} + \delta_t + \delta_i + \delta_{it} .$$

where $size_{it-1}$ is plant size reflected in the number of individuals employed.

We estimate (19) individually for each product group. Three econometric issues need to be addressed in doing so. First, as will be discussed in section 4, product classifications here are taken to be at the 6-digit-level. Increasingly finer classes would allow market shares to reflect increasingly "hidden" varieties in the product group (Khandelwal 2010).[9] The more hidden the varieties in a group, that is, the larger will be its market share. We use lagged plant size ($size_{it-1}$) in (19) to control for possibly hidden product varieties, the underlying assumption being that large plants would offer greater product diversity than their small counterparts do.

[8] As plant is a unit of analysis in our empirical studies, *i* refers to a plant-product rather than firm-product combination.

[9] For example, apparel producers in a product group can offer varying colors or sizes for an identical price.

Second, our data offer no possibility of representing the consumption of an external product.[10] Nevertheless because its market share would by definition take the same value for every product in a group, it would clearly be a component of our year fixed effects. Accordingly, (19) can be estimated in the rearranged form

$$(19') \qquad \ln s_{it} = -\alpha p_{it} + \varphi \ln size_{it-1} + \xi_t + \delta_i + \delta_{it},$$

where $\xi_t \equiv \ln s_{ot} + \delta_t$.

Finally, as market prices are determined simultaneously with product shares, appropriate instruments are needed for consistent estimates of equation (19′)'s price parameter. Two instruments are used here for doing so: prices of the non-*i* plant-products in the j^{th} group, and annual fuel prices by prefecture. Prices at other plants, representing their own marginal costs of production, can to some extent explain plant *i*'s price p_{it} if production technologies do not vary much within a group. Price changes at these other plants also should on average be unrelated to plant *i*'s quality deviations δ_{it} from its own average quality. Contemporaneous shocks on marginal production costs should affect product quality at every plant – including the i^{th} – but are captured by the year fixed effects on quality (Nevo 2001, Khandelwal 2010). As components of marginal costs, fuel prices similarly can influence product prices but are unrelated to δ_{it} if improving product quality requires no additional energy use. Rather, as we have discussed in section 2, quality is more often upgraded by an intensification of worker skill and fixed capital.

[10] Imported products are often used as the outside product in previous studies. However, we cannot obtain the value of imports for each product because the concordance table between the product classification in the Census of Manufactures and that in trade statistics is not available.

3.4. Identifying Agglomeration Economies

After obtaining the equation (19′) parameter estimates, we can estimate product quality in each plant-product and year as

(20) $$\hat{\lambda}_{it} = \hat{\delta}_i + \hat{\delta}_{it} = \ln s_{it} + \hat{\alpha} p_{it} - \hat{\varphi} \ln size_{it-1} - \hat{\xi}_t ,$$

where year fixed effects estimates ξ_t are deducted from $\hat{\lambda}_{it}$ to eliminate factors unattributable to quality itself.[11] Given these product quality estimates, we evaluate the agglomeration effects on product quality by way of

(21) $$\hat{\lambda}_{it} = \kappa_0 + \kappa_1 \ln G_{rt} + \theta_i + \mu_{it} .$$

A statistically significant positive sign on region size G_{rt} indicates agglomeration economies enhance product quality.

Plant-product fixed effects (θ_i) are included in (21) to control for unobserved plant heterogeneity (Henderson 2003, Martin et al. 2011). In particular, high urban product quality may partly be due to the decisions of firms already producing a high-quality good to relocate into a city rather than by agglomeration economies (Picard and Okubo 2012). Region size parameter κ_1 therefore might suffer from the simultaneity bias induced by any correlations between region size and unobserved economic shocks on plant-product quality μ_{it} (Combes and Gobillon 2015, Martin et al. 2011). To correct for such bias, we apply GMM estimation to equation (21)'s first difference, namely

[11] Note that year fixed effects reflect not only time-specific shocks on product quality but the market share of the external product.

(22) $$\Delta\hat{\lambda}_{it} = \kappa_1 \Delta \ln G_{rt} + \Delta\mu_{it} ,$$

A first-difference specification of this sort provides the natural candidates for instruments. After an economic shock, region size would presumably converge over time to a certain level. The first difference of the log of region size should then be negatively correlated with the year $t-2$ region size. We consequently instrument the first-differenced explanatory variables in (22) by their level in year $t-2$. The exclusion restriction remains valid as long as region size in year $t-2$ does not affect the change in the unobserved shock between $t-1$ and t (Martin et al. 2011).

4. Data and Variables

The *Census of Manufactures*, published by Japan's Ministry of Economy, Trade and Industry (METI), is the primary data source in this study. Its microdata are available only for plants with four or more employees.[12] A unique identification number is assigned to each plant and product, facilitating construction of a panel of individual plant-products from 1994 through 2007.[13] Product classifications are frequently revised, although revisions in the 1994 – 2007 period were relatively minor. A given product can therefore be easily matched across years by way of the concordance table. Our key variables – shipment value and quantity – are available at the

[12] All establishments in the manufacturing sector are covered in a census in calendar years ending in 0, 3, 5, and 8. By contrast, only establishments with four or more employees are covered in other years.

[13] The plant identification number is revised every five years. Thus, we use the concordance table provided by the RIETI to construct a panel of plant-product-level data.

6-digit product classification level.[14] We exclude poorly defined categories such as "miscellaneous telecommunication equipment," in which products are so heterogeneous that quantity measures have little meaning.[15] Following Khandelwal (2010), we also restrict our sample to differentiated goods – grouped on the basis of Rauch's (1999) conservative product classifications – in order to be consistent with the model assumptions laid out in the previous section. After eliminating product groups with few observations, 380 product groups remained in the sample.

The *Census of Manufactures* provides information about plant location at two administrative levels: prefecture and municipality. We use the 47 prefectures as our geographical regions because municipalities are too small to capture much agglomeration. Workers commute across, and firms transact with suppliers and customers beyond, municipality borders. On the other hand, a prefecture is also an administrative unit, and administrative boundaries do not necessarily coincide with a natural economic zone. Geographical units similar to U.S. metropolitan statistical areas (MSA) do not exist in Japan. The newspaper firm Asahi-Shimbun (2007) has however identified 110 Japanese metropolitan regions on the basis of commuting patterns. For robustness, we compare the results obtained from using their regional designations with those from using the official prefectures. Annual prefecture fuel prices and populations, and annual municipal populations, are obtained respectively from *Retail Price*

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[14] The first four digits of the product codes mostly correspond to the 4-digit International Standard Industrial Classification.
[15] For example, among 1,842 product groups, quantity shipped is reported for 765 groups in 2007.

Survey, *Population Estimates*, and *Basic Resident Registration,* published by the Ministry of Internal Affairs and Communications (MIC).

Market share s_{it} of plant-product *i* is constructed as the ratio of the shipped quantity of product *i* to the total quantity shipped in its 6-digit product group. Product price p_{it} is the value of shipment divided by quantity shipped. Observations in the top and bottom 1% of each product group's price distribution are dropped to exclude outliers. Plant employee numbers in year $t-1$ are used as proxies for lagged plant size ($size_{it-1}$).

Earlier studies of agglomeration have considered two types of externalities: localization economies and urbanization ones (e.g., Combes et al. 2008, Martin et al. 2011). A firm's localization economies are the productivity-enhancing externalities it enjoys arising from the spatial concentration of firms in its own industry, and its urbanization economies are the economies it enjoys arising from the concentration of all firms in the region. Following Martin et al. (2011), a localization economy (LOC_{it}) is a spatial concentration measured as one plus the number of employees in plant *i*'s industry and region minus the number in plant *i* itself.[16] An urbanization economy (MP_{rt}) is instead proxied by regional population (Henderson 1986).

To construct the factor accounting for urbanization economies, we take advantage of the notion of market potential, adjusting it to account for the divergences between Japan's administrative regions and its natural economic boundaries. Market potential in the specialized

[16] Industries are delimited on the basis of the 3-digit industrial classifications. As data on the number of workers used to produce an individual product is unavailable in a multi-product plant, a plant's industrial classification is assigned on the basis of the principal good it produces, as measured in value of shipments in the year concerned.

sense we use here, and originally introduced in Harris (1954) and extensively discussed in the New Economic Geography literature (Fujita et al. 1999), refers to the mean firm's proximity to intermediate and final goods markets and producers. In most empirical work (e.g., da Mata 2007), it is taken to be the sum of the populations in the r^{th} and all other regions, each weighted by the inverse of the total transportation cost from the r^{th} to the region of interest. That is, our market-potential measure is

$$MP_{rt} = \sum_{c} \frac{Pop_{ct}}{\tau_{rct}}, \tag{23}$$

where Pop_{ct} denotes population in region c in year t. τ_{rct} in equation (23) represents transport cost from region r to c in year t and is defined as

$$\tau_{rct} = p_{rt}^{f} d_{rc}, \tag{24}$$

where p_{rt}^{f} is fuel price in region r and year t, and d_{rc} is the inter-regional (great-circle) distance between regions r and c.[17] Intra-regional distance is given by $2/3\sqrt{Area_r/\pi}$, where $Area_r$ denotes the area of region r. Summary statistics are reported in Table 1.

5. Estimation Results

Equation (19′) is individually estimated for each of the 380 product groups. Space limitations prevent reporting each estimation result. Estimate summaries – including mean, median, and 10th and 90th percentile values – are therefore given instead in Table 2. A price elasticity is

[17] Fuel prices exhibited large fluctuations (from 87 to 146 yen per liter) during the sample period. If average fuel mileage does not vary much across years, equation (24) measures the average cost of fuel consumption to transport goods between the two regions.

obtained for each of the 380 estimates by multiplying its price coefficient by the corresponding product price. Overall, our data fit well with the postulated logit demand model. Price coefficients are negative and significant in 335 of the 380 groups. The regression model satisfies the over-identification test, a significantly low first-stage F-statistic p-value found in 289 groups. The third row of Table 2 shows the average and median coefficients of plant size are positive, suggesting that the market share rises with plant size. The larger the plant size, that is, the more varieties that will be unidentified at the 6-digit product classification level. Finally, the median price elasticity here, -0.596, is very close to the -0.58 in Khandelwal (2010).[18]

Given the Table 2 parameter estimates, product quality in each of approximately 700,000 plant-product combinations is obtained from equation (20) and employed in the estimation of equation (22).[19] Note that plant-product fixed effects in equation (21) disappear when the product-quality first differences are computed in (22), and only residuals, namely the short-run product quality variations, remain for estimation. Thus, (22) explains agglomeration's quality upgrade effects in only the short run. To observe the contributions of such short-run variations to overall product quality variation, we carry out the variance decomposition shown in Table 3.[20] Most product quality variation is explained by the plant-product fixed effects,

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[18] These elasticities are rather low because the temporal price variation in plant-product-level observations is low also (Khandelwal 2010).

[19] Product groups with positive price coefficients are excluded in the following analysis.

[20] Since average product quality cannot be compared directly across product groups, the table presents the average standard deviation across groups.

although the contributions of the residuals are non-negligible.

Estimates of equation (22)'s product-quality determinants are presented in Table 4.[21] Market potential (urbanization economy) parameters are significantly positive in all four specifications, implying strongly that proximity to intermediate and final-good markets and producers is key to improving product quality. In both prefectures and metropolitan areas, GMM estimates of the market-potential coefficients are greater than in the OLS estimates. Plants undergoing shocks that would weaken product quality must apply additional inputs to resist them, demanding therefore additional production factors, including additional workers. Differences between the OLS and GMM estimates may reflect this negative correlation between population and product quality shocks.

Before we consider agglomeration's quality effects quantitatively, a comment is in order on the interpretation of our parameter estimates. Although not explicitly raised in section 2.1, a case may be made that agglomeration economies reduce the fixed costs (FC_i) involved in a quality upgrade (equation 3). For example, because at least part of the knowledge spillovers facilitated by an urban environment – and which can benefit R&D performance – are invariant to product volume, they will be fixed rather than variable benefits to the plant, so that the positive relationship between product quality and region size in Table 4 can be interpreted as a consequence of reduced fixed cost. On the other hand, considering the lag between R&D

[21] Instruments are LOC_{rt-2}, MP_{rt-2}, and population in region r in year $t-2$.

investment and upgraded-product output, quality upgrades from R&D investments are unlikely to be contemporaneously correlated with market-potential shocks. And if the fixed costs of quality upgrading do not vary significantly in the short run, they will be captured by plant-product fixed effects θ_i in (21). Market potential's positive sign in equation (22) therefore suggests that quality upgrades come by way of reduced marginal rather than fixed cost.

The literature normally has expressed an agglomeration effect in terms of the productivity impact of doubling a city size (e.g. Rosenthal and Strange 2004). In specification (2) for example – estimated with the prefecture-level data by GMM – we find that doubling market potential lifts product quality by 0.241 unit.[22] The lift is 0.178 unit if metropolitan-level data are used. Either way, agglomeration's quality impacts are quite large: 47.7% (= 0.241 / 0.505) or 35.2% (= 0.178 / 0.505) of short-run quality variation is explained by agglomeration economies.

Next we estimate product-quality equation (22) separately for small and large plants (Table 5).[23] Since small plants are more dependent on local economic conditions than their larger counterparts are, they are more likely to benefit from agglomeration economies (Acs et al. 1994, Martin et al. 2011). The same argument likely holds when it is product quality that is being explained. Indeed, market-potential effects are positive and significant in Table 5 only in equation (22)'s small-plant models. Furthermore, these effects are about double those in Table

[22] Product quality bears no specific unit (see equation 1).
[23] A plant is considered large if average plant employment during the estimation period exceeded its median.

4. Localization economy (LOC_{rt}) effects are unexpectedly negative and significant in the large-plant models, implying that, among large plants, an industry's spatial concentration worsens product quality. This may be because congestion costs experienced by large plants operating in large regions are high enough to outweigh the agglomeration benefits.

Table 6 shows the corresponding determinants of a product group's plant market share. Market-potential's impact on market share is positive and statistically significant in both geographical-unit specifications: the greater the market potential, the greater the plant market share. In short, supporting the proposition in section 3.1, results suggest that both product quality and market share rise with region size.

Because sales destination is unavailable in our data at plant-product level, demand equations (19′) have been estimated with the product's national rather than regional market shares. The national market share of a product traded mainly in the region it is produced could conceivably bias localization and urbanization's effects on both quality and market share. For example, a positive demand shock in a region may boost its firms' national but not local product market shares. This bias however is unlikely to be serious in the present case. Locally traded goods are mainly homogeneous ones like ready-mixed concrete, subject to substantial transport cost (Syverson 2004). According to Rauch's (1999) classifications, these homogeneous products are already excluded from our estimates.

To check for the bias anyway, we further excluded from our data differentiated product groups traded primarily within a given region and re-estimated the Tables 4-6 regressions at the prefecture level. In particular, prefecture-level input-output tables were used to compute intra-regional trade volumes for each prefecture and four digit-level industry.[24] The ratio of intra-regional trade to total production were then averaged across prefectures in each industry, and product groups belonging to any industry whose average ratio exceeds 50% were excluded from the sample. With this, determinants of product quality (pooled and by plant size group) and plant-product market shares were re-examined. Table 7 confirms that our results are robust to the exclusion of differentiated product groups traded mainly locally.

We have so far regarded agglomeration effects in the short run, namely on annual changes in product quality. Yet Table 3 shows quality variations to be strongly determined by plant-product fixed effects, namely plant-specific capacities to produce high-quality goods in the long run, and it is also important to identify the regional factors affecting these long-run capacities. Following Martin et al. (2011), plant-product fixed effects are regressed in Table 8 against the average determinant levels (in our case $\ln LOC_{it}$ and $\ln MP_{rt}$) over the period in which observations exist for the specific plant-product group. Contrary to the short-run case in Table 4, localization economies significantly improve product quality in both of the two geographical unit specifications. Short- and long-run differences among localization and urbanization impacts can be explained by the following three factors. First and as discussed

[24] Prefecture-level input and output (I-O) tables are compiled by 47 prefectural governments but only 18 prefectures provide I-O tables at 4-digit industry-level.

above, if plant-product fixed effects reflect the fixed costs of quality upgrading, Table 8's long-run results imply that plant spatial concentration improves R&D efficiency while reducing the cost of quality improvement. Second, when product consumption is mainly local, the region size reflected in $\ln LOC_{it}$ and $\ln MP_{rt}$ determines the highest fixed cost a plant can pay (Picard 2015). Consequently, our long-run results suggest that urban plants producing locally consumed products are able to bear greater fixed costs than rural plants are. Third, because our long-run estimation model does not identify any causality between plant-product fixed effects and region size, it may be reflecting the reverse causality that plants producing high-quality products prefer to locate in large regions (Picard and Okubo 2012).

6. Summary and Conclusions

Agglomeration economy is a key to the understanding of regional economic performance and has attracted great attention in academic and policy circles. The body of empirical evidence appears to suggest that, all else constant, doubling region size lifts firm productivity by 3–8%. But agglomeration's influences on product quality have not been adequately attended to. Given that quality is one of the most important factors in consumer demand, it is imperative that we focus on the kinds of agglomeration policies that will facilitate quality improvements essential to firm competitiveness.

The present study has been an effort in that direction. Partly for consistency with earlier product-quality representations, we extend Berry (1994) and Khandelwal's (2010) logit demand framework by introducing a product quality dimension to the firm's strategic decision-making. Our theoretical discussion indicates that the productivity improvement due to agglomeration economy frees the inputs necessary for quality enhancement. The empirical analysis confirms this quality-enhancing effect in Japanese manufacturing.

We find that policies to attract new firms to a market area can have very strong product-quality implications. New arrivals to an urban area have an incentive to allocate their received agglomeration benefits to quality as well as productivity. This extra benefit can provide an extra incentive to agglomerate, intensifying the benefits enjoyed by the market incumbents and reinforcing the positive externality feedback.

Two comments are in order. First, not every agglomeration subsidy is successful in inducing a positive dynamic impact. We have found evidence here of quality upgrades in the agglomeration record that is available to us. It remains for future research to identify the policy combinations best suited to the positive feedbacks that would enhance quality in a more general setting. Second, policy makers need to pay greater attention to the kind of industries they wish to attract. In those in which quality improvement requires increased input use, total factor productivity underestimates agglomeration benefits by ignoring the incentives it provides to improve quality. As long as based solely on entrants' likely TFP gains, agglomeration subsidies therefore will be biased toward industries in which quality is not a principal concern. Geographic market policies will under-perform until cognizant of agglomeration's quality dimension, allowing a proper balance between the quality and productivity factors that maximize overall competitiveness.

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Table 1: Summary Statistics of Pooled Data

Variable	Unit	Obs.	Mean	Std. dev.
Price	Yen	712,265	217.26	8,795.66
Market share	Index, 0-1	712,265	0.01	0.03
Plant size	Person	712,265	63.88	372.78
# Employees in same industry and prefecture	Person	32,494	2,772.03	8,924.63
Market potential (prefecture)	Number	658	5,557.14	3,328.48
# Employees in same industry and metropolitan area	Person	47,403	1,828.23	8,113.67
Market potential (metropolitan area)	Number	1,540	4,531.53	2,275.64

Source: METI, Census of Manufactures, various years
MIC, Retail Price Survey, various years
MIC, Population Estimates, various years
MIC, Basic Resident Registration, various years

Table 2: Distribution Statistics of Plant-Product Demand Function Estimates

Statistic	Mean	Median	10th percentile	90 percentile
Price coefficient	-0.426	-0.018	-1.001	-0.000
Price coefficient, *p*-value	0.049	0.000	0.000	0.146
Coefficient on plant size	0.403	0.439	-0.015	0.779
Price elasticity	-0.567	-0.596	-0.944	-0.187
Over-identification restrictions, *p*-value	0.456	0.437	0.055	0.874
First stage *F*-stat, *p*-value	0.001	0.000	0.000	0.000
Observations per estimation	1874	499	164	3080
Total estimations		380		
Total observations		712,265		

Note: To construct this table, equation (19′) is individually estimated for each of the 380 product groups, that is in which the dependent variable is plant market share in a product group. *p*-values are obtained from the standard errors adjusted for within-plant correlation. Of the 380 groups, price coefficients are negative and significant in 335. The regression model satisfies the over-identification test and has significantly low first-stage *F*-statistic *p*-values in 289 groups. In each product group, price elasticity is computed by multiplying the price coefficient by the group's average product price. Sample size is 380.

Table 3: Product Quality Variance Decomposition

	Std. dev.	Correlation with product quality
Product quality	1.662	1.000
Plant-product fixed effects	1.575	0.994
Residuals	0.505	0.430

Note: Table gives the average standard deviations and correlations across product groups. Sample size is 369.

Table 4: Determinants of Plant-Product Quality, Pooled Data

	(1)	(2)	(3)	(4)
	Prefecture		Metropolitan area	
Variable	OLS	GMM	OLS	GMM
$\Delta\ln LOC$	0.010***	-0.011	0.001	-0.093*
	(0.003)	(0.064)	(0.003)	(0.053)
$\Delta\ln MP$	0.035***	0.241***	0.034***	0.178***
	(0.009)	(0.071)	(0.009)	(0.055)
F-stat, p-value	0.00		0.00	
R-squared	0.00		0.00	
Hansen's J statistic, p-value		0.63		0.55
First-stage F-stat, p-value, LOC		0.00		0.00
First-stage F-stat, p-value, MP		0.00		0.00
Observations	593,027	489,758	593,027	489,758

Notes: * and *** indicate statistical significance at 10 percent and 1 percent level, respectively. Dependent variable is the first difference of product quality. Values in parentheses are standard errors adjusted for within-plant-product correlation.

Table 5: Determinants of Plant-Product Quality, by Plant Size Group

	(1)	(2)	(3)	(4)
	Prefecture		Metropolitan area	
Variable	Small plants	Large plants	Small plants	Large plants
$\Delta\ln LOC$	0.175*	-0.139*	0.055	-0.189***
	(0.101)	(0.084)	(0.086)	(0.069)
$\Delta\ln MP$	0.430***	0.029	0.389***	-0.060
	(0.085)	(0.109)	(0.066)	(0.083)
Hansen's J statistic, p-value	0.84	0.05	0.58	0.26
First-stage F-stat, p-value, LOC	0.00	0.00	0.00	0.00
First-stage F-stat, p-value, MP	0.00	0.00	0.00	0.00
Observations	211,127	278,631	211,127	278,631

Notes: * and *** indicate statistical significance at 10 percent and 1 percent level, respectively. Dependent variable is the first difference of product quality. Values in parentheses are standard errors adjusted for within-plant-product correlation.

Table 6: Determinants of Plant-Product Market Share, Pooled Data

Variable	(1) Prefecture	(2) Metropolitan area
Δln*LOC*	-0.057	-0.141**
	(0.074)	(0.061)
Δln*MP*	0.223***	0.148**
	(0.080)	(0.062)
Hansen's J statistic, *p*-value	0.10	0.15
First-stage *F*-stat, *p*-value, *LOC*	0.00	0.00
First-stage *F*-stat, *p*-value, *MP*	0.00	0.00
Observations	489,758	489,758

Notes: ** and *** indicate statistical significance at 5 percent and 1 percent level, respectively. Dependent variable is the first difference of plant market share in a product group. Values in parentheses are standard errors adjusted for within-plant-product correlation.

Table 7: Determinants of Plant-Product Quality (Pooled and by Plant Size Group) and of Plant-Product Market Share, Excluding Products Traded Mainly Locally

	(1)	(2)	(3)	(4)
	Product quality			Market share
Variable	All plants	Small plants	Large plants	All plants
Δln*LOC*	0.038	0.192*	-0.083	0.020
	(0.063)	(0.100)	(0.083)	(0.073)
Δln*MP*	0.340***	0.463***	0.206*	0.389***
	(0.070)	(0.086)	(0.108)	(0.080)
Hansen's J statistic, *p*-value	0.98	0.86	0.13	0.42
First-stage *F*-stat, *p*-value, *LOC*	0.00	0.00	0.00	0.00
First-stage *F*-stat, *p*-value, *MP*	0.00	0.00	0.00	0.00
Observations	452,222	202,984	249,238	452,222

Notes: * and *** indicate statistical significance at 10 percent and 1 percent level, respectively. Dependent variable is indicated in the header of the respective column. Values in parentheses are standard errors adjusted for within-plant-product correlation. Prefecture-level data are used in the estimation. Product groups that are mainly traded within a prefecture are excluded from the sample.

Table 8: Long-Run Determinants: Plant-Product Fixed Effects

	(1)	(2)
Variable	Prefecture	Metropolitan area
Average ln*LOC*	0.078***	0.062***
	(0.016)	(0.013)
Average ln*MP*	-0.004	-0.050
	(0.035)	(0.062)
F-stat, *p*-value	0.00	0.00
R-squared	0.60	0.60
Observations	94,431	94,431

Note: *** indicates statistical significance at 1 percent level. Dependent variable is plant-product fixed effect on product quality. Product fixed effects are included in both estimations. Values in parentheses are standard errors adjusted for within-product correlation.