Product Quality and Innovation
Hungarian Firm Level Data

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ABSTRACT

Innovation enhances other performance indicators of a firm beside productivity. Buyers are ready to pay higher price for higher quality or more suitable products due to innovation. Product prices, however, reflect the market position of the firm, too. Demand functions estimated using transaction level trade and domestic sales data yield firm level measure for quality. Productivity, size and foreign ownership increase, while the effect of innovation depends on the price elasticity used for estimating firm level quality; innovation decreases quality when elasticities are low, and increases when elasticities are high.

JEL codes: F14, L15, L25

Keywords: trade, quality, scope, innovation

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Termékminőség és innováció
Magyar vállalati adatok alapján

Halpern László

ÖSSZEFOGLALÓ

Az innováció a termelékenységen kívül a vállalat egyéb teljesítmény-mutatóira is jótékonyan hat. Az innováció következtében jobb minőségű vagy az igényeihez közelebbi termékekért magasabb árat hajlandó fizetni a vásárló. A termékárat azonban a vállalat piaci helyzete is befolyásolja. Tranzakció szintű adatok alapján keresleti függvény segítségével a vállalati szintre aggregált minőséget meg lehet becsülni. Az így becsült minőséget növeli a termelékenység, a méret és a külföldi tulajdon aránya. Az innováció hatása az árrugalmasságtól függ; kisebb rugalmasság esetén csökkenti, nagyobb rugalmasság esetén növeli a minőséget.

JEL: F14, L15, L25
Tárgyszavak: külkereskedelem, minőség, választék, innováció

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Introduction

The positive association between firm level productivity and innovation is confirmed by many authors.[1] It is also widely known that innovation might have impact on other indicators of firm performance. Quality upgrade of existing products or new products meeting the demand better can be the outcome of a successful innovation. Higher quality products are sold for higher prices; the production of differentiated products is costlier. Prices are often used as a proxy for quality. However, it is known that firms may charge higher prices in a monopolistic market, prices do reflect the market power of firms, too.

This paper first defines different indicators of performance beside productivity. They cover mostly prices aggregated to the firm level. The share of differentiated product reflects the ability of a firm to produce sophisticated tailored to the customer's need. The concentration of the product portfolio of the firm may assess the ability of the firm to specialize to a small number of products which then allows to concentrate resources to further develop these products.

An empirical framework is applied to assess the effect of innovation on the above performance indicator. Relevant firm characteristics are used as controls: productivity, size, foreign ownership, and imports.

The next step is to address product quality. There is an ongoing discussion about the pros and cons of different approaches. The main challenge is how to specify the demand which is able to fight the inherent endogeneity between quantities and prices. The suggested methods seem to work properly on aggregate or industry level, but rather few tools are available for data at firm level. Even the ability of these tools is rather limited as small countries may only trade with countries of the same currency like the Eurozone. The alternative to use the elasticity estimates made for other countries is a source of bias.

Partner and product level transaction data was used to estimate the demand function for exports and imports. The available data made possible to estimate the demand for domestic sales, too. Different specifications were used to test the variability of the price elasticity. The time varying firm fixed effect is interpreted as a quality indicator. These quality estimates highly correlate with each other, and autocorrelated, though the correlation coefficient was rather low for estimates from exports and imports.

In the final step these quality estimates were the dependent variables and the same controls were applied as for the price indicators of firm performance, imports excepted. Most control variables have significant and positive effect on quality with the exception of innovation. According to these estimation results the innovation has a negative effect on quality.

Finally, the potential explanation for the seemingly contradicting results are discussed and the possible future directions are outlined.

Data

Two product level data sets are matched with detailed firm income and balance sheet data between 2000 and 2016. The first data set contains product and partner level data of foreign trade at HS8 level of manufacturing firms. The second one is from the Industrial production and sales survey called Prodcom survey. Product category changes and the difference between the foreign trade and Prodcom categories made necessary to create a time invariant product

[1] See Dai and Cheng (2018), Dai, Sun and Liu (2019), Lööf, Larijani, Cook and Johansson (2015) Shu and Steinwender (2018), Siedschlag and Zhang (2014).

category separately for Manufacturing and Prodcom data.[2] Both samples contain product level export data, what makes possible to analyze the difference on the investigated relationships.

There are close to 3000 firms in the Prodcom sample in the early years, what went below 2000 by the end of the observation period. The number of products also declined from between 1200 and 1300 below 1100 in the Prodcom sample. The tendency was just the opposite for the foreign trade sample; the product number increased from 1300 to 1500 for the exports and from 1500 to 1550-70 for the imports.[3]

Prodcom firms employ one third of the industrial labor between 2001 and 2004, their share declines to one fourth. Manufacturing sample firms employed two thirds of Manufacturing labor in the early period what then declined to 55 percent. The average firm size in the Manufacturing sample grew from around 80 to above 110. Firms in the Prodcom sample are bigger, the average size was higher by around 50 percent.

Innovation data was taken from the Community Innovation Surveys (CIS). There are seven waves of biannual surveys between 2004 and 2016. The number of manufacturing firms increased from 2200 to above 3800 within this period. Their average size was similar to that of Prodcom firms, however, there is a strong downward trend. As in this paper the main focus is the interaction between innovation and performance, the availability of the data is defined by the shorter period of CIS survey and by the intersection of CIS and either of Prodcom or of Manufacturing firms in our foreign trade data.

Innovation and performance

Empirical firm level papers dealing with the effect of innovation on performance are mostly limited to the productivity. This paper widens the list of firm level performance characteristics by analyzing the effect on different export price and on other indicators of exports and imports as well. Eight different indicators were defined; they are mostly related to price. The list is the following:

1) weighted average of new export products relative price, where the new export product price is divided by the average price of the same new export product of other firms;
2) same as 1) confined to the continuing partners only;
3) weighted relative price of export products which are above the median quantity growth rate;
4) weighted relative price of export products which are below the median quantity growth rate;
5) weighted normalized price (ratio of the difference between the price and the minimum price to the difference between the maximum and the minimum prices);
6) the share of export products in the highest price quantile;
7) share of differentiated export products;
8) product concentration of exports.

Indicators 1 and 2 assess the price of new export products only. The difference between them is that the second indicator covers the recurring partners, only. Indicators 3 and 4 try to capture the export pricing strategy of firms with respect to the growth, whether there is a difference between the pricing of export products with higher or lower export growth rates. Indicator 5 captures the weighted average of relative price level of each firm. Indicator 6 is an indirect

[2] The concordance was created using the methodology developed by Pierce and Schott (2012).

[3] Product categories are not necessarily the same in the two samples as the concordance procedure created synthetic product categories separately.

measure of price as the share of export products in the highest price quintile. The ability of a firm to produce differentiated product can be in close relationship with its innovation activity. That is what indicator 7 – the share of differentiated export products – is covering with the usual definition initiated by Rauch (1999). Finally, the export product concentration – measured by the usual Herfindalh-Hirschman index – can also be a performance indicator of innovation activity.

In this paper an empirical framework is used to test the effect of innovation on firm performance other than productivity. This is actually the same framework what was used in Halpern (2020) to analyze the impact of innovation on productivity. The same controls are used, namely, TFP, firm size measured by log employment, the share of foreign ownership, the corresponding import indicator and the innovation variables with time and industry fixed effects. TFP is lagged by 5 years, all the other control variables, but innovation are lagged by one year to ease endogeneity. Innovation is lagged by two years due to the nature of the innovation survey as responses refer to the average of the preceding 3 years. As innovation surveys are published biannually, the survey values are used for the *t-1* and *t-2* observations. Combined it implies that the actual value of a performance indicator can be affected by the innovation activity of the preceding period. This lag structure is supposed to mitigate the endogeneity concern between innovation and productivity. The import indicator is constructed in the same ways as the export indicator, the use of lagged valued is intended to alleviate the same endogeneity concern similar to the previous one.

$$s_{jt}^{E} = c + \alpha * TFP_{jt-5} + \beta * s_{jt-1}^{M} + \gamma * d_{jt-2} + \delta * \boldsymbol{X}_{jt-1} + year + industry_t + \epsilon_{jt}, \quad (1)$$

where *j* is firm, *t* is year, **X** includes size (log employment) and the share of foreign ownership. *s* denotes different indicators of firm performance, where superscript *E* denotes exports, *M* imports, respectively. TFP is the total factor productivity and was estimated by ACF-method[4] for two-digit industries separately. This estimation of TFP made necessary to include industry fixed effects. Explanatory variable *d* represents innovation in two versions. It can either be a binary variable or the share of new products in sales. The binary variable is unity for firms pursuing either product or process innovation.

The estimations were made for Prodcom and Manufacturing firms for the first four performance indicators, separately, then for the last four indicators for a larger set of Manufacturing firms with two versions of innovation variables.

Results

The first results are presented in Table 1 and in Table 3 for Prodcom firms; in Table 3 and in Table 4 for Manufacturing firms. The results are quite similar, none of the estimations have explanatory power, most of the coefficient estimates are not significantly different from zero for the first four indicators. The results for indicators 5 to 8 are quite different, the estimated parameters are mostly significant. In case of imports, size and foreign ownership the coefficients are positive, while the TFP is negative, but significant for the share of differentiated products in both samples and the product concentration for Prodcom firms.

[4] See Ackerberg et al. (2015).

The innovation has significant negative effect on the dependent variables for Prodcom firms, what then changes into positive in case of relative price and the share of highest price quintile products for Manufacturing firms.

Table 1. Estimation results for price indicators for Prodcom firms

	new product price all partners	new product price running partners	product price above median	product price below median
tfp (-5)	-0.528 (0.934)	-0.0204 (0.942)	0.0302 (1.132)	-1.401 (1.245)
Import price (-1)	-0.000332 (0.00206)	-0.00158 (0.00716)	0.0780 (0.104)	-0.000790 (0.00578)
size (-1)	-0.0683 (0.603)	0.902 (0.599)	1.050 (0.752)	1.636* (0.840)
foreign capital (-1)	-0.608 (1.290)	0.0880 (1.297)	0.429 (1.580)	-1.122 (1.753)
innovation (-2)	-1.099 (1.238)	-1.465 (1.234)	-0.531 (1.551)	-2.467 (1.712)
Constant	6.489* (3.439)	-0.0856 (3.506)	-2.430 (4.269)	-1.095 (4.293)
Observations	4508	3949	5005	7519
R^2	0.007	0.009	0.069	0.011

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Table 2. Estimation results for price and other indicators for Prodcom firms

	relative price	share of differentiated products	share of highest price quintile products	product concentration
tfp (-5)	-0.0206*** (0.00380)	-0.0171*** (0.00510)	-0.00389 (0.00243)	-0.0163*** (0.00423)
Import (-1)	0.172*** (0.0147)	0.217*** (0.0143)	0.164*** (0.0123)	0.113*** (0.0182)
size (-1)	0.0136*** (0.00253)	0.0220*** (0.00341)	0.00279* (0.00162)	-0.0104*** (0.00283)
foreign capital (-1)	0.0585*** (0.00551)	0.133*** (0.00748)	0.0164*** (0.00349)	0.154*** (0.00609)
innovation (-2)	-0.0196*** (0.00529)	-0.0506*** (0.00711)	-0.00409 (0.00339)	-0.0369*** (0.00591)
Constant	0.0804*** (0.0134)	0.159*** (0.0181)	0.0256*** (0.00858)	0.280*** (0.0153)
Observations	7602	7602	7602	7602
R^2	0.145	0.406	0.084	0.221

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Table 3. Estimation results for price indicators for the Manufacturing firms

	new product price all partners	new product price running partners	product price above median	product price below median
tfp (-5)	-0.699	-96.84**	1.256	1.187
	(1.206)	(47.87)	(1.021)	(1.417)
Import price (-1)	-0.000679	0.0138	0.0190	0.0393***
	(0.00345)	(0.413)	(0.0366)	(0.00839)
size (-1)	0.114	-52.80*	1.026	-0.685
	(0.768)	(30.42)	(0.653)	(0.925)
foreign capital (-1)	1.290	60.74	0.979	-3.361*
	(1.695)	(68.15)	(1.426)	(1.997)
innovation (-2)	-0.409	-41.09	-0.208	-2.013
	(1.608)	(63.56)	(1.376)	(1.941)
Constant	5.837	423.2**	-3.700	9.773*
	(4.293)	(174.5)	(3.661)	(5.057)
Observations	7519	6365	7886	9628
R^2	0.011	0.006	0.025	0.008

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

The second round of estimations attempts to get result for the last four indicators. These estimations were made in two versions, that is, the first one used the binary innovation variable, while the second one tested the effect of the share of new products in total sales. These two variables differ not only in their nature, but in their coverage, too. As the binary variable is equal to one in case of either product or process innovation, the share of new products might be the outcome of product innovation, though not necessarily. As our performance indicators are closely related to products, it is to be expected if there is a positive impact, then it might be stronger in case of the latter.

Table 4. Estimation results for price and other indicators for Manufacturing firms

	relative price	share of differentiated products	share of highest price quintile products	product concentration
tfp (-5)	-0.000653	-0.00750***	0.00138	-0.00204
	(0.00135)	(0.00211)	(0.000967)	(0.00181)
Import (-1)	0.205***	0.282***	0.145***	0.282***
	(0.00679)	(0.00650)	(0.00618)	(0.00840)
size (-1)	0.0222***	0.0525***	0.00623***	0.0363***
	(0.000915)	(0.00144)	(0.000648)	(0.00121)
foreign capital (-1)	0.0743***	0.196***	0.0295***	0.185***
	(0.00264)	(0.00420)	(0.00187)	(0.00354)
innovation (-2)	0.00885***	0.00245	0.00556***	-0.00228
	(0.00241)	(0.00376)	(0.00173)	(0.00323)
Constant	-0.0398***	-0.0882***	-0.00918***	-0.0403***
	(0.00389)	(0.00607)	(0.00278)	(0.00520)
Observations	29989	29989	29989	29989
R^2	0.202	0.421	0.087	0.319

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Table 5. Estimation results for price and other indicators for Manufacturing firms with alternative innovation indicator

	relative price	share of differentiated products	share of highest price quintile products	product concentration
tfp (-5)	-0.000464 (0.00135)	-0.00767*** (0.00210)	0.00153 (0.000965)	-0.00242 (0.00181)
Import (-1)	0.206*** (0.00679)	0.282*** (0.00649)	0.146*** (0.00618)	0.283*** (0.00839)
size (-1)	0.0228*** (0.000885)	0.0521*** (0.00139)	0.00665*** (0.000626)	0.0354*** (0.00117)
foreign capital (-1)	0.0742*** (0.00264)	0.196*** (0.00419)	0.0294*** (0.00187)	0.185*** (0.00354)
share of new products (-2)	0.0423*** (0.0105)	0.0739*** (0.0163)	0.0177** (0.00751)	0.0776*** (0.0141)
Constant	-0.0408*** (0.00386)	-0.0872*** (0.00602)	-0.00999*** (0.00276)	-0.0382*** (0.00516)
Observations	29989	29989	29989	29989
R^2	0.202	0.421	0.086	0.320

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Coefficients of four out of five explanatory variables are positive and highly significant in both versions – Table 4 with the binary innovation and Table 5 with the share innovation variable. The only variable which has no effect mostly is the TFP. In two cases – both for the share of differentiated products its coefficient is negative and significant. The binary innovation variable is insignificant for the share of differentiated product and for the product concentration.

These positive results seem to confirm that there is a positive effect of innovation on different performance indicators even if we control for size, foreign ownership and for the effect of imports. It appears that the TFP does not play a role, it has no effect on our selected performance indicators.

Quality estimations

The results presented above raise different concerns. First, our price variables were proxied by unit values. This is the usual approach, however, it is criticized.[5] Second, prices might not always reflect quality, what is our primary goal to achieve. Let us first review the relevant literature, then present our suggestion how to quantify the firm level quality.

Literature review

Piveteau and Smagghue (2019) claim that the endogeneity of prices comes from two sources. Prices are likely to be correlated to quality. It is obvious that high quality varieties are costlier to produce. Firms with higher ability are likely to exert market power that will result in higher mark-up. In both scenarios, final prices charged by firms are correlated with demand, which leads ordinary least squares to underestimate the price-elasticity of demand. Indeed, when a firm increases the quality of its products, the effect of prices on demand is compensated with

[5] See Fast and Fleck (2019).

the greater appeal of the good to consumers. A second source of endogeneity comes from the construction of prices. Unit values as a proxy for prices are obtained by dividing the value of a shipment by the physical quantity shipped. The use of this proxy may generate an attenuation bias due to the measurement error contained in the price variable.

Other authors rely on different variable to address endogeneity. Berry et al. (1995) use competitors' product characteristics, Hausman (1996) and Nevo (2000) use product's price on other markets, while Foster et al. (2008) rely on estimated physical productivities. However, these instruments are not valid in the presence of unobserved vertical differentiation.

Instrumental variables approaches were used by Khandelwal (2010) and Hallak and Schott (2011). Their strategy, however, is not suited to firm-level demand estimation as their instruments vary at the market level, not across firms within a market.

Roberts et al. (2017) and Gervais (2015) use firms' wages and physical productivities as instruments for prices. These instruments are only valid if product quality is constant over time within the firm. For instance, if a firm upgrades its quality, it might need more workers per physical unit of output. In that case physical productivity is (negatively) correlated to quality and IV estimates of elasticity would be biased downward. Khandelwal et al. (2013) construct a firm-level quality measure by calibrating a CES demand system with price-elasticity estimates from Broda and Weinstein (2006). Conceptually, this approach raises two concerns. First, it implicitly inherits the identifying assumptions from Broda and Weinstein (2006). These assumptions are problematic in the presence of vertical differentiation. Second, Broda and Weinstein (2006) estimates are obtained from country-level data. Elasticity may differ at the micro and the macro level, which would generate biases in estimated firm-level quality.

In their final instrument authors interact the import-weighted exchange rate with the share of these imports in the operating costs of the firm.

If individual firms have an effect on the price index of the nest in which they are operating, this mark-up is not constant and firms feature heterogeneous pass-through. In order to capture this potential heterogeneity, an additional instrument was created by interacting market share of exporter in an HS6 product category in a market. In presence of these nested preferences, export prices of firms with larger market share should respond less strongly to the instrument.

A third instrument was created based on the lagged real exchange rates faced by firms. The production of many goods span more than a year. As a consequence, it is expected that cost shocks on imports purchased in the previous year might also generate an increase in the current price charged by an exporter. This instrument used a similar set of weights than the main instrument, but relies on real exchange rates at time $t-1$.

According the above reasoning higher quality firms most likely import from countries with a stronger currency, from where they can source higher quality inputs. Therefore, authors expect the instrument to be positively correlated to quality in the cross-section of firms. If not controlled for, this correlation would induce the price elasticity of demand to be biased upward. In the cross-section of firms, the instrument is likely to be positively correlated to quality. So, provided that higher quality goods are more expensive, an increase in the value of the instrument is associated to an increase in both prices and the demand shifter. Hence the upward bias.

Hornok and Muraközy (2019) do not estimate the price elasticity of the demand function. They do this because, for their database, the instrumental variable estimation produces very imprecise elasticity estimates. Four characteristics of their data are responsible for this: i) the above instrument is missing or does not vary across non-importers; ii) the number of exporters is relatively small; iii) the import structure at the firm level is unstable; iv) most Hungarian manufacturing exporters import from EU countries, yielding relatively small variation in the import-weighted firm-level real exchange rate.

Authors also present evidence for the relevance of the quality channel, using a similar strategy as Bas and Strauss-Kahn (2015). In particular, they show that the importer markup premium is larger when the imported intermediaries arrive from developed countries, which are likely to specialize in higher quality intermediate good production. The first channel is the self-selection. Second, the access to a larger variety of intermediate inputs can increase the firm's physical productivity. Finally, importing intermediate inputs may help firms in upgrading their quality level. In contrast to importing, their results show no robust evidence for a markup premium for exporters.

Estimating demand with varying price elasticities

Our framework to quantify firm level quality makes necessary to estimate the product level demand in the following specification:

$$\log q_{ijnt} = \alpha + \beta_{int} * \log p_{ijnt} + \mu_{nt} + \tau_t + \rho_{jt} + \boldsymbol{U} + \epsilon_{ijnt} \quad (2)$$

where *i* product, *j* firm, *n* partner, *t* time. The same demand function was estimated for exports, imports and for domestic sales separately. The elasticity parameter β was allowed to differ only in one dimension in each estimation, what means, that it was allowed to vary either by time, or by partner or by product. $\boldsymbol{U}$ is the binary variable for unit of quantity: liter, meter, meter^2, piece as for most data kilogram is the usual measure. Time varying fixed effects are estimated for partners and products.

Time varying partner fixed effects represent the demand in case of exports, while they represent the supply for imports. More precisely in case of exports it is the demand of the partners, while for the imports it is the demand of the Hungarian firms what is commonly called demand.

Variable ρ represents the firm fixed effect what can change in time. It collects the firm level information from the product level demand estimations. Firms may sell larger quantities of the same product due to higher quality or for any other reason. As markups are interpreted at the firm level, this effect is also part of the estimated fixed effect. Our working assumption is that no Hungarian firm represents important share in any relevant market, domestic markets in case of domestic sales are excepted. If this assumption is valid, then our estimated firm fixed effect reflects the average revealed quality what partners reveal in case of exports and Hungarian firms in case of imports.

In this approach it is allowed that firms may have different average quality at imports, exports and domestic sales. For Prodcom firms there are quality estimates for exports and domestic sales, while for Manufacturing firms the quality is quantified for exports and imports, separately.

The novelty of our approach is, that some degree of flexibility is allowed in the estimation. It can be interpreted as a robustness check, too. For each demand function there are at least three different versions. In case of Prodcom firms two additional versions were estimated beside the base version. First, the aggregate price elasticity was allowed to change over time. Second, the flexibility was introduced across products, each product category could have different price elasticity. For the Manufacturing firms five different versions were estimated. The base version was supplemented by two product versions, one partner version and one version similar to the Prodcom in which annual flexibility of the elasticity was allowed. Due to computational constraints the number of products for which flexibility was allowed had to be constrained. Two versions were chosen; one by the number of observations, and the other one by the share in trade. In both cases the number of products for which the elasticity could change was set at 250 with the largest number of observations or the largest share of the products in the overall trade. Finally, as partners are known for each transaction, this dimension of flexibility was also tested.

The estimated price elasticities of export and domestic sales for Prodcom firms are presented in Table 6. It includes the aggregate estimation and the mean, the minimum and the maximum value. Means seem to differ quite a lot across different estimations and one can observe quite large differences between the two extreme values in case of product elasticity estimations.

Table 6. Estimated price elasticities for Prodcom firms

	Aggregate	Product	Year
Domestic sales	-0.755		
Mean		-0.684	-0.859
Minimum		-3.219	-0.924
Maximum		21.201	-0.822
Prodcom export	-0.727		
Mean		-0.641	-0.723
Minimum		-4.595	-0.856
Maximum		20.784	-0.656

The estimated price elasticities for Manufacturing firms are presented in Table 7. There is a significant difference between export and import elasticities, import elasticities are higher in absolute value. The range is much wider for the product varying estimation for the turnover share criterion. These values are more or less in line with the values obtained by Piveteau and Smagghue (2019) in their first stage. It is an open question how the second stage might affect the estimated values of the firm fixed effect, as the difference between the estimated elasticities in the first and in the second stage is around threefold. The factors which drive away the estimated elasticities in the first and the in the second stage seem to be significantly less relevant for our data, than for what is used in Piveteau and Smagghue (2019). In spite of this difference their elasticities estimated by 2SLS will also be used in the next section.

Table 7. Estimated price elasticities for Manufacturing firms

	Aggregate	Product/obs	Product/turnover	Partner	Year
Exports					
Price elasticity	-0.851	-0.899	-0.937		
Mean		-0.901	-0.802	-0.805	-0.853
Minimum		-1.210	-1.206	-0.940	-0.924
Maximum		-0.609	5.095	-0.688	-0.822
Imports					
Price elasticity	-1.004	-0.997	-1.035		
Mean		-1.029	-0.925	-1.003	-1.007
Minimum		-1.217	-1.149	-1.124	-1.025
Maximum		-0.816	0.517	-0.840	-0.986

Our variable of interest is the firm fixed effect from the demand functions. Altogether there are 26 varieties of them. There are three estimation groups: Prodcom, Prodcom with exports and imports from the foreign trade data, and Manufacturing firms. Within each group there are two subgroups, namely exports and domestic sales for the Prodcom and exports and imports for the other two other groups. Within each subgroup there are different estimations according to the number of allowed time varying variable versions. There are three different versions for the Prodcom estimations each, as beside the base version, elasticities could vary annually and by products. For the other two groups five versions can be found in each subgroup as beside the base version elasticities might change annually, by partners and by products with the first 250 largest number of observations or share in total trade.

The most important descriptive statistics for the estimated firm level quality indicators are presented in Table A1. We can see the largest coefficients of variation in Prodcom exports and Manufacturing imports, they exceed 4, while the lowest values are estimated for Prodcom with foreign trade exports. The mean and median are rather close to each other, what reflects that the distribution seems to be symmetric. As our ultimate goal is to estimate the effect of innovation on these quality indicators it is important to consider the number of observations or the share of missing values. This latter is the largest for the Prodcom exports; only about 1/3 of the observations remain, while all the other cases it varies between 45 and 70 percent.

It seems that descriptive statistics do not differ within subgroups. This is confirmed by the correlations coefficients, what are presented in Table A2. In general, the quality indicators are highly autocorrelated; the minimum value of AR1 is above 0.75, AR15 never goes below 0.47.

The pairwise correlation coefficients are very high within each group, their minimum value by years never goes below 0.97 for the Manufacturing firms (see Table A3). The quality indicators for exports and imports differ to some extent. The maximum pairwise correlation coefficients are around 0.3.

Pairwise correlation coefficients between different quality indicators for Prodcom firms show more or less the same results (Table A4). Within group pairwise correlation coefficients are larger than 0.86 within each group and never smaller than 0.2 between groups. There is one exception; there is a very high connection between the quality indicators obtained for the demand estimation for domestic sales with varying coefficients for product categories and exports taken from trade data with varying elasticities for the largest 250 product categories.

Innovation and quality

Large variety of different quality measures was derived from the demand equations. It turned out that they differ mostly in whether they were derived from the exports or imports demand, the relaxation of the elasticities did not yield significant differences. The final stage of this analysis is to investigate whether innovation has impact on these quality measures. The framework is similar to what was used in case of price, concentration and differentiated product measures in equation (1). The only modification is that the imports is left out.

Firm level aggregated quality indicators distilled from product level demand functions are positively and significantly explained by lagged TFP, size and foreign ownership for Prodcom firm in case of exports and domestic sales (see Table 8. Quality estimations for Prodcom firmsTable 8). Lagged innovation does not have any impact on quality for domestic sales, while it has significantly negative effect on quality. The message is quite straightforward; innovative firms perform worse compared to non-innovative peers when controlling for productivity, size and foreign ownership. The sample is limited to those exporting firms which are present in both the Prodcom and in the CIS sample.

These results seem not to be affected by the different quality indicators, their closeness assessed by the descriptive statistics are reflected in the estimated coefficients, too.

Table 8. Quality estimations for Prodcom firms

	export			domestic sales		
	base	year	product	base	year	product
tfp (-5)	0.402*** (0.0407)	0.402*** (0.0410)	0.542*** (0.0486)	0.558*** (0.0374)	0.559*** (0.0374)	0.538*** (0.0435)
size (-1)	0.883*** (0.0284)	0.882*** (0.0286)	0.736*** (0.0339)	0.425*** (0.0256)	0.426*** (0.0257)	0.331*** (0.0298)
foreign capital (-1)	1.307*** (0.0618)	1.317*** (0.0622)	1.382*** (0.0737)	0.388*** (0.0578)	0.392*** (0.0579)	0.326*** (0.0672)
innovation (-2)	-0.484*** (0.0611)	-0.485*** (0.0615)	-0.365*** (0.0729)	0.0168 (0.0532)	0.0167 (0.0533)	-0.0205 (0.0619)
Constant	-4.466*** (0.154)	-4.465*** (0.155)	-3.906*** (0.184)	-1.902*** (0.138)	-1.910*** (0.138)	-1.256*** (0.160)
Observations	4071	4071	4071	3988	3988	3988
R^2	0.411	0.409	0.378	0.484	0.486	0.352

year/product: price elasticities are allowed to change over time/product categories
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

The previous results are confirmed if quality fixed effects taken from Prodcom exports demand are replaced by that of exports from foreign trade data (Table 9).

Table 9. Quality estimations for Prodcom firm fixed effect from export demand with varying price elasticities

	base	year	partner	kn_obs	kn_to
tfp (-5)	0.101*** (0.0280)	0.102*** (0.0281)	0.0981*** (0.0280)	0.115*** (0.0273)	0.0929*** (0.0269)
size (-1)	0.192*** (0.0189)	0.192*** (0.0190)	0.192*** (0.0189)	0.173*** (0.0185)	0.154*** (0.0182)
foreign capital (-1)	0.106*** (0.0401)	0.109*** (0.0403)	0.106*** (0.0402)	0.183*** (0.0392)	0.169*** (0.0386)
innovation (-2)	-0.225*** (0.0392)	-0.227*** (0.0394)	-0.219*** (0.0393)	-0.208*** (0.0383)	-0.182*** (0.0377)
Constant	0.00202 (0.102)	0.00910 (0.102)	0.00319 (0.102)	0.102 (0.0995)	0.234** (0.0981)
Observations	6599	6599	6599	6599	6599
R^2	0.205	0.210	0.204	0.188	0.189

year/partner: price elasticities are allowed to change over time/partners. Kn_obs/kn_to: price elasticities are allowed to change over product for the largest 250 categories according to the observation numbers or share in total turnover, respectively.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Quality fixed effects derived from export and import demand estimations seemed to be different. This is not reflected in the estimation results for imports (Table 10) if these results are compared with those of the previous table; the sign, the magnitude and the significance level of the coefficients are more or less the same.

Table 10. Quality estimations for Prodcom firm fixed effect from imports demand with varying price elasticities

	base	year	partner	kn_obs	kn_to
tfp (-5)	0.101*** (0.0197)	0.103*** (0.0196)	0.104*** (0.0195)	0.106*** (0.0190)	0.100*** (0.0189)
size (-1)	0.138*** (0.0132)	0.139*** (0.0131)	0.141*** (0.0130)	0.159*** (0.0127)	0.150*** (0.0126)
foreign capital (-1)	0.0981*** (0.0277)	0.0986*** (0.0276)	0.104*** (0.0275)	0.134*** (0.0267)	0.122*** (0.0266)
innovation (-2)	-0.0966*** (0.0272)	-0.0958*** (0.0271)	-0.0926*** (0.0269)	-0.0949*** (0.0262)	-0.0836*** (0.0261)
Constant	-0.144** (0.0717)	-0.157** (0.0714)	-0.181** (0.0710)	-0.295*** (0.0690)	-0.261*** (0.0688)
Observations	6789	6789	6789	6789	6789
R^2	0.167	0.166	0.164	0.179	0.156

year/partner: price elasticities are allowed to change over time/partners. Kn_obs/kn_to: price elasticities are allowed to change over products for the largest 250 categories according to the observation numbers or share in total turnover, respectively.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

The results for the Manufacturing sample differ slightly from the Prodcom results. The TFP coefficient of exports derived quality estimation is significant in one version out of five; only for the observation number version of price elasticities for products (Table 11).

Finally, the estimations with the firm level aggregate quality indicator derived from the import demand reconfirm the previous results, all the coefficients, but that of the innovation are positive and significant, while the innovation affects the quality negatively (Table 12).

Table 11. Quality estimations for Manufacturing using firm fixed effect from export demand

	base	year	partner	kn_obs	kn_to
tfp (-5)	0.0240 (0.0233)	0.0237 (0.0233)	0.0215 (0.0233)	0.0451** (0.0225)	0.0262 (0.0223)
size (-1)	0.124*** (0.0151)	0.125*** (0.0152)	0.124*** (0.0151)	0.120*** (0.0146)	0.106*** (0.0145)
foreign capital (-1)	0.113*** (0.0333)	0.116*** (0.0334)	0.112*** (0.0333)	0.169*** (0.0321)	0.156*** (0.0319)
innovation (-2)	-0.244*** (0.0325)	-0.247*** (0.0326)	-0.241*** (0.0325)	-0.239*** (0.0314)	-0.228*** (0.0312)
Constant	0.140* (0.0803)	0.144* (0.0806)	0.144* (0.0803)	0.219*** (0.0775)	0.321*** (0.0770)
Observations	10664	10664	10664	10664	10664
R^2	0.192	0.197	0.191	0.180	0.181

year/partner: price elasticities are allowed to change over time/partners. Kn_obs/kn_to: price elasticities are allowed to change over products for the largest 250 categories according to the observation numbers or share of turnover, respectively.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Table 12. Quality estimations for Manufacturing using firm fixed effect from import demand

	base	year	partner	kn_obs	kn_to
tfp (-5)	0.0726*** (0.0157)	0.0742*** (0.0157)	0.0755*** (0.0156)	0.0754*** (0.0152)	0.0734*** (0.0152)
size (-1)	0.140*** (0.00997)	0.141*** (0.00995)	0.142*** (0.00990)	0.156*** (0.00963)	0.149*** (0.00961)
foreign capital (-1)	0.101*** (0.0220)	0.100*** (0.0219)	0.104*** (0.0218)	0.141*** (0.0212)	0.121*** (0.0212)
innovation (-2)	-0.120*** (0.0216)	-0.119*** (0.0215)	-0.117*** (0.0214)	-0.116*** (0.0208)	-0.108*** (0.0208)
Constant	-0.195*** (0.0535)	-0.204*** (0.0534)	-0.221*** (0.0531)	-0.309*** (0.0517)	-0.282*** (0.0516)
Observations	11938	11938	11938	11938	11938
R^2	0.153	0.152	0.150	0.163	0.146

year/partner: price elasticities are allowed to change over time/partners. Kn_obs/kn_to: price elasticities are allowed to change over products for the largest 250 categories according to the observation numbers or share of turnover, respectively.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

Finally, our results are to be compared with three other quality measures, which are estimated by using price elasticities taken from Piveteau and Smagghue (2019) and Gervais (2015). The results for the quality indicators from the export demand are presented in Table 13 and the same from the imports demand in Table 14. There are four elasticities used in this exercise for the Manufacturing sample only. The value in column 1 is what was obtained by our aggregate estimation. The value in column 2 is from Gervais (2015) which is the median of estimates for 504 products. The last two values are the 2SLS estimates of Piveteau and Smagghue (2019) where the difference is whether the selection bias is taken into account, that is, value in column 3 is without and in column 4 is with control for selection bias.

Our main focus was the estimated coefficient for the innovation variable. Price elasticities are ranked from the least to the most elastic one what is mirrored in the innovation coefficient which spans from significant negative to significant positive for both quality indicators. The other explanatory variables are positive and significant for the estimations with the imports demand quality indicator. The estimated TFP and size coefficients are larger in more price elastic versions. TFP is insignificant in each version with quality indicators from export demand, while the size is always positive, but loses its significance in the 2SLS versions. The share of foreign capital goes from significant positive to significant negative, just the opposite what is observed for the innovation coefficient.

All in all, these results show that the estimated effect of innovation on quality is changing with the price elasticity of demand used for assessing firm level quality measure. If the demand is highly sensitive to the prices, then the innovation has significant positive effect on quality. Productivity, size and foreign capital have the positive effect, too, when the quality indicator is derived from the import demand. When the quality indicator is obtained from the export demand, then these three explanatory variables yield mixed results, two of them become insignificant, while the share of foreign capital is significant negative.

Table 13. Quality estimations for Manufacturing using firm fixed effect from export demand with different aggregate price elasticities

price elasticity	1 (-0.85)	2 (-2.11)	3 (-3.03)	4 (-4.26)
tfp (-5)	0.0240 (0.0233)	-0.00283 (0.0302)	-0.0224 (0.0446)	-0.0486 (0.0670)
size (-1)	0.124*** (0.0151)	0.0556*** (0.0196)	0.00543 (0.0289)	-0.0616 (0.0435)
foreign capital (-1)	0.113*** (0.0333)	-0.00323 (0.0432)	-0.0878 (0.0637)	-0.201** (0.0958)
innovation (-2)	-0.244*** (0.0325)	-0.0566 (0.0422)	0.0805 (0.0623)	0.264*** (0.0936)
Constant	0.140* (0.0803)	0.230** (0.104)	0.296* (0.154)	0.383* (0.231)
Observations	10664	10664	10664	10664
R^2	0.192	0.096	0.185	0.241

Table 14. Quality estimations for Manufacturing using firm fixed effect from import demand with different aggregate price elasticities

price elasticity	1 (-1.00)	2 (-2.11)	3 (-3.03)	4 (-4.26)
tfp (-5)	0.0726*** (0.0157)	0.253*** (0.0178)	0.403*** (0.0279)	0.603*** (0.0444)
size (-1)	0.140*** (0.00997)	0.237*** (0.0112)	0.317*** (0.0177)	0.424*** (0.0281)
foreign capital (-1)	0.101*** (0.0220)	0.107*** (0.0248)	0.112*** (0.0389)	0.120* (0.0620)
innovation (-2)	-0.120*** (0.0216)	-0.00299 (0.0243)	0.0945** (0.0382)	0.225*** (0.0608)
Constant	-0.195*** (0.0535)	-1.172*** (0.0603)	-1.985*** (0.0947)	-3.071*** (0.151)
Observations	11938	11938	11938	11938
R^2	0.153	0.142	0.209	0.239

Conclusions

Innovation is the main driver of productivity. Though, innovation may have positive effect on other performance indicators, too. It was found that controlling for lagged productivity, size and foreign ownership innovation boosts prices, the share of differentiated products and the product concentration.

Wide range of product level demand equations were used to distill firm level quality indicators. The demand equations were estimated on transaction level where the country of origin or destination was also known. Prices and quantities are jointly determined, that is, why the demand equation requires instrumental variables estimation methods. Unfortunately, none of the suggested instruments offer viable solution, therefore elasticities estimated for other countries were also used to assess firm level quality.

It was found that the effect of innovation has a negative impact on firm level quality when the quality was derived from our product level OLS demand estimations. These results seem to contradict to each other if one accepts the usual assumption that our performance indicators are positively correlated with quality. When higher price elasticities were used to estimate quality, then the innovation coefficient becomes positive and significant.

There are different ways to interpret these mixed results. There is a possibility that the goal of innovation is mostly cost reduction what might be accompanied with some degree of quality downgrading. It can be in line with our previous results that innovation enhances productivity.

One should not rule out the possibility that our measure of quality is biased as there might be other factors affecting demand which are left out from our specifications or the endogeneity between prices and quantities drives down the estimated elasticities using OLS what then distorts our quality measures.

Due to the nature of data this assessment is mostly confined to exporting firms which are present in the innovation survey, too. Our results for domestic sales were different from what we obtained for trading firms, but due to the low coverage they are not sufficient to invalidate the results for the latter.

Further research is to be pursued, better understanding and assessment of quality are needed, deeper knowledge of innovation is necessary in order to give a reliable and quantifiable framework for its impact on firm performance.

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Annex

Table A1. Descriptive statistics of firm level quality estimations

			Mean	coeff of variation	1. percentile	median	99. percentile	Obser-vation	Share of missing
Prodcom	exports	base	0.514	4.348	-4.567	0.490	6.156	12402	0.649
		year	0.514	4.347	-4.546	0.492	6.174	12402	0.649
		kn	0.592	4.844	-4.856	0.480	7.065	12402	0.649
	dom. sales	base	0.706	2.770	-4.086	0.732	5.238	16017	0.547
		year	0.706	2.770	-4.080	0.732	5.239	16017	0.547
		kn	0.787	2.933	-3.577	0.745	5.528	16017	0.547
Prodcom with foreign trade	exports	base	0.864	1.877	-2.639	0.762	5.050	23259	0.343
		year	0.865	1.874	-2.644	0.765	5.078	23259	0.343
		partner	0.864	1.876	-2.621	0.758	5.050	23259	0.343
		kn_obs	0.916	1.715	-2.501	0.840	4.998	23259	0.343
		kn_to	0.925	1.684	-2.460	0.846	4.861	23259	0.343
	Imports	base	0.570	2.104	-2.123	0.509	3.807	24439	0.309
		year	0.569	2.105	-2.120	0.508	3.803	24439	0.309
		partner	0.559	2.129	-2.141	0.498	3.787	24439	0.309
		kn_obs	0.546	2.135	-2.107	0.495	3.632	24439	0.309
		kn_to	0.530	2.172	-2.103	0.479	3.564	24439	0.309
Manufacturing	Exports	base	0.510	3.305	-2.961	0.397	4.834	41112	0.534
		year	0.510	3.298	-2.944	0.397	4.859	41112	0.534
		partner	0.511	3.295	-2.939	0.394	4.828	41112	0.534
		kn_obs	0.592	2.758	-2.836	0.500	4.794	41112	0.534
		kn_to	0.596	2.721	-2.839	0.506	4.704	41112	0.534
	Imports	base	0.299	4.422	-2.597	0.235	3.820	53243	0.396
		year	0.299	4.417	-2.594	0.234	3.822	53243	0.396
		partner	0.291	4.517	-2.598	0.230	3.803	53243	0.396
		kn_obs	0.280	4.598	-2.592	0.229	3.669	53243	0.396
		kn_to	0.272	4.684	-2.577	0.220	3.650	53243	0.396

Table A2. Autocorrelation coefficients of firm level quality estimations

	Autocorrelation	max AR1	min AR1	AR15
Export	base	0.885	0.780	0.546
	year	0.887	0.776	0.539
	partner	0.885	0.778	0.541
	kn_obs	0.883	0.778	0.535
	kn_to	0.888	0.772	0.529
Import	base	0.875	0.754	0.483
	year	0.875	0.754	0.484
	partner	0.874	0.751	0.480
	kn_obs	0.873	0.747	0.473
	kn_to	0.863	0.743	0.477
Prod. export	base	0.954	0.902	0.713
	year	0.954	0.902	0.706
	kn	0.968	0.921	0.747
Dom. sales	base	0.955	0.874	0.652
	year	0.955	0.875	0.656
	kn	0.951	0.889	0.665

Table A3. Correlation coefficients between different quality estimations for Manufacturing firms

		Export					Import			
		base	year	partner	kn_obs	kn_to	base	year	partner	kn_obs
Export	year	1.000								
	partner	0.999	0.999							
	kn_obs	0.977	0.977	0.977						
	kn_to	0.970	0.970	0.970	0.987					
Import	base	0.294	0.296	0.294	0.307	0.300				
	year	0.294	0.295	0.294	0.307	0.299	1.000			
	partner	0.293	0.294	0.293	0.306	0.298	0.999	0.999		
	kn_obs	0.291	0.293	0.292	0.308	0.298	0.990	0.990	0.990	
	kn_to	0.285	0.287	0.286	0.302	0.294	0.986	0.986	0.986	0.991

Table A4. Correlation coefficients between different quality estimations for Prodcom firms

		Export trade					Import		
		base	year	partner	kn_obs	kn_to	base	year	partner
Export trade	year	1.000							
	partner	0.999	0.999						
	kn_obs	0.977	0.977	0.976					
	kn_to	0.972	0.971	0.972	0.987				
Import	base	0.311	0.314	0.313	0.319	0.313			
	year	0.311	0.314	0.313	0.319	0.313	1.000		
	partner	0.310	0.313	0.312	0.319	0.313	0.999	0.999	
	kn_obs	0.308	0.310	0.309	0.320	0.313	0.990	0.990	0.990
	kn_to	0.305	0.307	0.306	0.318	0.312	0.986	0.986	0.986
Export	base	0.365	0.363	0.365	0.381	0.358	0.276	0.276	0.278
	year	0.359	0.361	0.358	0.375	0.353	0.262	0.262	0.264
	kn	0.298	0.299	0.298	0.318	0.315	0.244	0.244	0.245
Dom sales	base	0.265	0.260	0.265	0.277	0.256	0.327	0.327	0.325
	year	0.268	0.259	0.268	0.280	0.259	0.324	0.324	0.322
	kn	0.212	0.217	0.210	0.232	0.223	0.250	0.250	0.248
		Import		Export			Dom. sales		
		kn_obs	kn_to	base	year	kn	base	year	
Import	kn_to	0.991							
Export	base	0.283	0.276						
	year	0.278	0.267	1.000					
	kn	0.251	0.245	0.870	0.868				
Dom. sales	base	0.332	0.316	0.417	0.411	0.354			
	year	0.329	0.313	0.417	0.411	0.354	1.000		
	kn	0.254	0.245	0.348	0.355	0.912	0.908	0.907	