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Firm characteristics of two-way traders: Evidence from Probit vs. Kernel-Regularized Least Squares regressions

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Firm characteristics of two-way traders: Evidence from Probit vs. Kernel-Regularized Least Squares regressions*

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Abstract

Firm characteristics in empirical models for margins of international trade usually enter these models in linear form. If non-linearities do matter and are ignored this leads to biased results. Researchers, however, can never be sure that all possible non-linear relationships are taken care of. A solution is provided by Kernel Regularized Least Squares (KRLS) that uses a machine learning approach to learn the functional form from the data. While in earlier applications the big picture revealed by standard empirical models and KRLS was identical this note presents a case where results from a standard approach and KRLS do differ considerably.

JEL classification:F14

Keywords: Two-way trading firms, firm level data, BEEPS data, kernel regularized least squares (KRLS)

* The firm level data used in this study are taken from the Business Environment and Enterprise Performance Survey (BEEPS) of the European Bank for Reconstruction and Development (EBRD) and the World Bank conducted in 2018-2020. The data can be downloaded free of charge after registration at https://www.beeps-ebrd.com. Stata code used to generate the empirical results reported in this note is available from the author.

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1 Motivation

Firm characteristics in empirical models for intensive or extensive margins of international trade usually enter these models in linear form, sometimes augmented by quadratic terms (like firm size and firm sized squared), taking logs or using interaction terms, to take care of or test for non-linear relationships. If these non-linear relationships do matter and if they are ignored in the specification of the empirical model this leads to biased results. Researchers, however, can never be sure that all possible non-linear relationships are taken care of in their chosen specifications, because the number of polynomials and interaction effects grows exponentially when the number of firm characteristics included in the empirical models for the trade margins increases.

As a solution for this problem Wagner (2025a) suggests the application of Kernel Regularized Least Squares (KRLS) regression, introduced in Hainmueller and Hazlett (2014) and Ferwerda, Hainmueller and Hazlett (2017), and outlined in section 3.2 below. KRLS uses a machine learning approach to learn the functional form from the data. In doing so, it protects against misspecification that leads to biased estimates. To demonstrate the usefulness of the method for the estimation of intensive and extensive margins of exports Wagner (2025a) presents results from a study that replicates estimates reported in two published papers. In two other applications of KRLS regression Wagner (2024, 2025b) looks at the role of cloud computing and digitalization intensity for extensive margins of exports in manufacturing firms from 27 EU countries.

To summarize the most important results from these papers, KRLS works fine for empirical models with continuous, fractional, and dichotomous endogenous variables and control variables that are continuous, dichotomous, or dummy variables

for industries or countries. Most importantly, in all examples considered in these papers the big picture from the standard parametric models and from the models estimated by KRLS is the same.

This note contributes to the literature by presenting empirical evidence for a case where results from a standard approach, namely Probit regression, and from KRLS do differ considerably. We look at he links between the probability that a firm is active in both exports and imports as a so-called two-way trader and various firm characteristics that can be expected to be linked to this probability. It turns out that due to the misspecification of the functional form used in the empirical model estimated by Probit the application of KRLS regression leads to different conclusions with regard to some firm characteristics.

The rest of the paper is organized as follows. Section 2 introduces the firm level data and variables used in the empirical investigation of firm characteristics of two-way traders. Section 3 presents the results from standard Probit regressions and compares them to the estimations from KRLS regressions. Section 4 concludes.

2 Data and discussion of variables

The firm level data used in this study are taken from the Business Environment and Enterprise Performance Surveys (BEEPS) of the European Bank for Reconstruction and Development (EBRD) and the World Bank conducted in 2018-2020. The data and the questionnaire can be downloaded free of charge after registration at https://www.beeps-ebrd.com. These surveys were conducted in a large number of countries and cover firms from various sectors. In this study we focus on data for manufacturing firms from eight member countries of the European Union: Bulgaria, Czech Republic, Greece, Hungary, Italy, Poland, Portugal, and Romania.

In the survey firms were asked in questions D3 and D13, respectively, whether they exported and imported directly. Firms that answered both questions in the affirmative are classified as two-way traders.

Descriptive evidence on the share of firms that are both exporters and importers in the total sample and by country is reported in in Table 1. While the overall share of two-way trading firms in the sample is 27.21 percent figures differ widely between the eight countries. It is as low as 10.92 percent in Poland and 14.6 percent in Romania, and as high as 42.63 percent in Greece and 51.74 percent in the Czech Republic.

[Table 1 near here]

In the empirical investigation of the difference between firms that are two-way traders and firms that are not a number of firm characteristics are looked at. The selection of these characteristics is not based on a theoretical model – it is motivated by the results of a large number of empirical studies that use firm level data from many countries to investigate the links between firm characteristics and extensive margins of international trade (see Wagner (2012) for a survey). From the results reported in this literature we expect that all these firm characteristics are positively related to the probability that a firm is a two-way trader.

The firm characteristics considered and the way they are measured here are listed below:

Firm size: Firm size is measured as the number of permanent, full-time individuals that worked in the establishment (see question I.1).

Firm age: Firm age is measured based on question B.5 of the survey were firms are asked “In what year did this establishment begin operation?”.

Productivity: Productivity is measured as labor productivity, defined as the amount of total annual sales for all products and services (recorded in question D2) over the number of permanent, full-time individuals that worked in the establishment at the end of the last complete fiscal year at the time of the survey (see question I.1). Given that information on value added and on the capital stock used in a firm is missing in the data, more elaborate measures of productivity at the firm level like total factor productivity cannot be used.[1]

Innovation: In the survey firms were asked whether during the last three years this establishment has introduced new of improved products and services (see question H1). Firms that answered in the affirmative are considered as product innovators. Similarly, firms were asked whether during the last three years this establishment introduced any new or improved process, including methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products or services; or supporting activities for processes (see question H5). Firms that answered in the affirmative are considered as process innovators.

Web site: In the survey firms were asked in question C22b "At present time, does this establishment have its own website or social media page?" Firms that answered "yes" are classified as firm with a web presence.

Descriptive statistics for all variables are reported for the whole sample used in the empirical investigation in Table 2.

[Table 2 near here]

[1] Note that annual sales are recorded in local currencies. Given that only three of the eight countries considered here (Greece, Portugal and Italy) adopted the Euro while the other countries use different local currencies the figures are not directly comparable across countries. In the empirical models this is staken care of by country fixed effects.

3 Characteristics of two-way traders: Probit vs. Kernel Regularized Least Squares (KRLS)

To test for the links between the probability that a firm is a two-way trader and firm characteristics, and to document the size of these differences, an empirical approach is applied that regresses a dummy variable (indicating whether the firm is a two-way trader or not) on a set of variables measuring the firm characteristics (discussed in detail in section 2) and a set of country fixed effects (to control for different currencies used in the computation of labor productivity and other country characteristics).

(1) $\text{Two-way trader}_i = a + ß*\text{firm characteristics}_i + c*\text{country}_i + e_i$

where i is the index of the firm, two-way trader is a dummy variable with a value of 1 if the firm is a two-way trader (that both exports and imports) and zero else, firm characteristics are the characteristics listed in section 2, country are dummy-variables for the country of origin of the firm, and e is an error term.

3.1 Results from Probit regressions

In a first step, the empirical model outlined in (1) above is estimated using Probit, a standard parametric econometric model. Estimated average marginal effects and their p-values are reported in the first column of Table 3.

The big picture revealed by these estimates can be summarized as follows: With one exception all firm characteristics included in the empirical model are positively linked to the probability that a firm is a two-way trader (as expected from the results reported in many empirical studies on the margins of international trade), and the estimated marginal effects are highly statistically significantly different from zero. The

exception is labor productivity – the estimated marginal effect is not statistically different from zero at any conventional level, indicating that according to these results labor productivity is not related to the probability that a firm is a two-way trader.

The missing positive link between labor productivity and the probability of being a two-way trader comes as a big surprise. From the start of the literature that uses firm-level data to investigate the links between margins of international trade and firm characteristics (see Bernard and Jensen (1995, 1999)) a positive link of trade activities and productivity at the firm level is reported in hundreds of studies (see Wagner (2007, 2012) for surveys), and this positive link is at the heart of the “new new trade theory” founded by Melitz (2003), too.

3.2 Results from Kernel Regularized Lest Squares (KRLS) regressions

In the standard parametric model used in section 3.1 the firm characteristics that explain the participation of a firm in two-way trade enter the empirical model in linear form. This functional form which is used in hundreds of empirical studies for margins of international trade, however, is rather restrictive. If any non-linear relationships (like quadratic terms or higher order polynomials, or interaction terms) do matter and if they are ignored in the specification of the empirical model this leads to biased results. Researchers, however, can never be sure that all possible relevant non-linear relationships are taken care of in their chosen specifications. Therefore, this note uses the Kernel Regularized Least Squares (KRLS) estimator to deal with this issue. KRLS is a machine learning method that learns the functional form from the data. It has been introduced in Hainmueller and Hazlett (2014) and Ferwerda, Hainmueller and Hazlett (2017), and used to estimate empirical models for margins of trade for the first time in Wagner (2025a).

While a comprehensive discussion of the Kernel Regularized Least Squares (KRLS) estimator is far beyond the scope of this applied note, a short outline of some of the important features and characteristics might help to understand why this estimator can be considered as an extremely helpful addition to the box of tools of empirical trade economists (se Wagner (2025a)). For any details the reader is referred to the original papers by Hainmueller and Hazlett (2014) and Fernwerda, Hainmueller and Hazlett (2017).

The main contribution of the KRLS estimator is that it allows the researcher to estimate regression-type models without making any assumption regarding the functional form (or doing a specification search to find the best fitting functional form). As detailed in Hainmueller and Hazlett (2014) the method constructs a flexible hypothesis space using kernels as radial basis functions and then finds the best-fitting surface in this space by minimizing a complexity-penalized least squares problem. Ferwerda, Hainmueller and Hazlett (2017) point out that the KRLS method can be thought of in the “similarity-based view” in two stages. In the first stage, it fits functions using kernels, based on the assumption that there is useful information embedded in how similar a given observation is to other observations in the dataset. In the second stage, it utilizes regularization, which gives preference to simpler functions (see Ferwerda, Hainmueller and Hazlett (2017), p.3).

KRLS works well both with continuous outcomes and with binary outcomes. It is easy to apply in Stata using the `krls` program provided in Ferwerda, Hainmueller and Hazlett (2017). Instead of doing a tedious specification search that does not guarantee a successful result, users simply pass the outcome variable and the matrix of covariates to the KRLS estimator which then learns the target function from the data. As shown in Hainmueller and Hazlett (2014), the KRLS estimator has desirable statistical properties, including unbiasedness, consistency, and asymptotic normality

under mild regularity conditions. An additional advantage of KRLS is that it provides closed-form estimates of the pointwise derivatives that characterize the marginal effect of each covariate at each data point in the covariate space (see Ferwerda, Hainmueller and Hazlett (2017), p. 11). These estimates can be used to examine the heterogeneity of the marginal effects.

Therefore, KRLS is suitable to estimate empirical models when the correct functional form is not known for sure – which is usually the case because we do not know which polynomials or interaction terms matter for correctly modelling the relation between the covariates and the outcome variable.

Results for an application of KRLS to the model for participation of a firm in two-way trade are reported in the second to fifth columns of Table 3.

While the results are rather similar in the estimations that use Probit and KRLS for the three firm characteristics that enter as dummy variables (i.e. web site, product innovation, and process innovation) they differ considerably for the firm characteristics that are measured by continuous variables (firm age, firm size, and labor productivity). Most importantly, and in line with what we expect from earlier empirical studies (and theoretical models), labor productivity and participation in two-way trade are positively related, and the marginal effect is statistically significantly different from zero at a conventional level. On the other hand, the positive link between firm age and participation in two-way trade that we found in the model estimated by Probit is no longer there – in the model estimated by KRLS the marginal effect is zero. Furthermore, the average marginal effect of firm size on participation in two-way trade estimated by KRLS is much larger (by a factor of three) than the average marginal effect estimated by Probit.

These differences in the sign, size and statistical significance of the average marginal effects between the results from Probit and KRLS regression can be

explained by the fact that the parametric model in column 1 inappropriately imposes a restrictive functional form in the shape of the estimated relationships, while KRLS estimated this relationship without imposing such a functional form.

An additional advantage of KRLS compared to the Probit model is that it provides closed-form estimates of the pointwise derivatives that characterize the marginal effect of each covariate at each data point in the covariate space (see Ferwerda, Hainmueller and Hazlett (2017), p. 11). The last three columns of Table 3 report the marginal effects estimated by KRLS at the 1st quartile, at the median, and at the 3rd quartile. We can clearly see the heterogeneity in the marginal effects. The estimated marginal effects differ widely over the quartiles and tend to increase considerably for all variables considered here. This shows the nonlinearity and heterogeneity of the relationship between the covariates and participation in two-way trade.

4 Cocluding remarks

In empirical models for margins of international trade firm characteristics usually enter these models in linear form. If non-linear relationships do matter this leads to biased results. Researchers, however, can never be sure that all possible non-linear relationships are taken care of. A solution is provided by Kernel Regularized Least Squares (KRLS) that uses a machine learning approach to learn the functional form from the data. While in earlier application the big picture revealed by standard empirical models and KRLS was identical this note presents a case where some of the results from a standard approach and KRLS do differ considerably.

While the results are rather similar in the estimations that use Probit and KRLS for the three firm characteristics that enter as dummy variables (i.e. web site, product innovation, and process innovation) they differ considerably for the firm characteristics

that are measured by continuous variables (firm age, firm size, and labor productivity). Most importantly, and in line with all we expect from earlier empirical studies (and theoretical models), labor productivity and participation in two-way trade are positively related, and the marginal effect is statistically significantly different from zero at a conventional level in the model estimated by KRLS, while this is not the case in the model estimated by Probit.

These differences in the sign, size and statistical significance of the average marginal effects between the results from Probit and KRLS regression can be explained by the fact that the Probit model inappropriately imposes a restrictive functional form in the shape of the estimated relationships, while KRLS estimated this relationship without imposing such a functional form.

The take-home message (that extends well beyond the estimation of empirical models for extensive and intensive margins of international trade), then, is: Whenever you estimate an empirical modelt hat links an outcome variable to a set of potential determinating factors take care of non-linear relatonships and interaction terms in investiagting the sign, size and statistical significance of the marginal effects of these variables on the outcome – and let kernel regularized least squares (KRLS) do this job in a both conviniant and convincing way.

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Table 1: Descriptive statistics – Countries covered, number of firms, share of two-way traders

County	Number of firms	Share of two-way traders (percent)
Bulgaria	354	24.86
Czech Republic	288	51.74
Greece	312	42.63
Humgary	466	37.98
Italy	433	21.02
Poland	513	10.92
Portugsl	717	29.15
Romania	507	14.60
All counties	3,90	27.21

Table2: Descriptive statistics – Variables used in estimation

Variable	Mean	Std. dev.	Min	Max
Two-way trader (Dummy; 1 = yes)	0.2721		0	1
Firm age (years)	25.18	18.25	1	202
Firm size (Number of employees)	89.27	180.13	1	3500
Web site (Dummy, 1 = yes)	0.7669		0	1
Product innovation /Dummy; 1 = yes)	0.2623		0	1
Process innovation (Dummy; 1 = yes)	0.1618		0	1
Number of cases	3,590			

Note: Productivity is not included because total sales are measured in local currencies and these differ between countries.

Table 3: Empirical results

Dependent variable: Two-way trading firm (Dummy; 1 = yes)

Method	Probit Average marginal effects	KRLS Average marginal effect	P25	P50	P75
Firm age (years)	0.0011 (0.005)	4.7e-07 (0.999)	-0.0010	0.0002	0.0012
Firm size (Number of employees)	0.00041 (0.000)	0.0013 (0.000)	0.00088	0.00126	0.0017
Web site (Dummy, 1 = yes)	0.1160 (0.000)	0.1008 (0.000)	0.0374	0.8700	0.1556
Product innovation /Dummy; 1 = yes)	0.1148 (0.000)	00995 (0.000)	0.0461	0.1008	0.1622
Process innovation (Dummy; 1 = yes)	0.1127 (0.000)	0.0982 (0.000)	0.0276	0.0974	0.1543
Labor Productivity (total sales / employee)	1.19e-11 (0.496)	6.9e-11 (0.049)	4.5e-11	5.3e-11	7.1e-11
Country dummies	included	included			
Number of cases	3,590				

Note: Probit reports average marginal effects from a model estimated by ML Probit. KRLS reports average marginal effects and marginal effects at the 25th, 50th and 75th percentile estimated by kernel-based regularized least squares. P-values are reported in parentheses. For details, see text.

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