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Abstract

We investigate the effect of related variety on the entry and exit patterns of domestic and foreign firms in Hungarian city regions from 1996-2012. In order to characterize the archetypes of interaction between domestic and foreign firms, we introduce three alternative models to calculate the related variety. The best fit is provided by the model, in which no interaction among foreign and domestic firms is presumed. Related variety in the foreign subset tends to accelerate firm entry and decelerate firm exit in a much earlier stage of economic transition than related variety across domestic firms.

Key words: related variety, firm entry and exit, foreign-owned firms, panel logistic regression, dual economy.

JEL Classification: F43, F23, L16

1. Introduction

The effect of agglomeration economies and the underlying economic structure of regions have long been considered a major driver behind regional dynamics because new firms may benefit from the specialized local labour market, specialized local value chains and intra-industry knowledge spillovers. Therefore, firms may prefer the locations in which the above externalities are available; this was already emphasized by the classical works of Marshall (1890) Hoover (1948) and North (1955). The size of the region is another factor that drives firm dynamics because huge markets in urban areas, the large scale of public services, advanced infrastructure, and the diversity of available services offer benefits to all entering firms (for an overview of the literature, see Duranton and Puga 2004, McCann 2008). Inter-industry knowledge spillovers in large cities — as it was anticipated by Jacobs (1969) — stem from the diversity of economic activities present in a region, and these urban externalities favour the entry of firms differently according to the life course of industries and firms (Almeida and Kogut 1997, Glaeser et al. 1992, Henderson et al. 1995).

More recently, the role of technological relatedness of economic activities in establishing local knowledge externalities was emphasized in the evolutionary economic geography literature (Boschma and Frenken 2011). The evidence demonstrates that technological relatedness to already-existing industries increases the probability that a new industry enters the country or region (Hidalgo et al. 2007, Neffke et al. 2011) and enhances the survival rate of startups due to the easy access of related knowledge and skills in the region (Boschma and Wenting 2007).

Related variety, which was proposed by Frenken et al. (2007), is the first indicator that has been used to measure the level of technological relatedness in regions. The authors argue that an optimal mix of technological proximity and diversity among co-located actors is important for regional employment growth (Boschma 2005), which has been confirmed by a growing number of papers (Bishop and Gripaios 2010, Boschma and Iammarino 2009, Boschma et al. 2012, Boschma et al. 2014, Brachert et al. 2013, Hartog et al. 2012, Mameli et al. 2012, Wixe and Andersson 2013). Furthermore, Cainelli and Iacobucci (2012) found that the level of technological relatedness among co-located firms correlates with the level of intermediate goods and services in the region; therefore, one can expect related variety to boost the prevalence of agglomeration economies. These findings support our expectation that related variety in a region enhances the number of entries to the region and reduces the number of exits from the region, which we aim to examine as the main empirical goal of the paper.

The specific aim of the paper is to introduce the dimension of foreign ownership into the related variety calculation and analyse its effect on firm entry and exit in regions. This is an important extension of the literature because the role of multinational enterprises in regional development has also gained a significant amount of attention in the last few decades (Iammarino and McCann 2013). Well-established arguments discuss the location behaviour of MNEs (Barrel and Pain 1999, Cantwell 2009, Ledyaeva 2009), the speed of their local embedding (Lorenzen and Mahnke 2002), their spatial effects (Beugelsdijk et al. 2010, Cantwell and Iammarino 2000, Capello 2009, Christopherson and Clark 2007, Phelps 2004, 2008, Young et al. 1994), among other topics. Despite the extensive research in the field of technological relatedness on the one hand and foreign-direct investments on the other, the interaction of foreign-owned firms and relatedness is still underexplored.

This paper makes a novel contribution to the literature by introducing domestic and foreign ownership into the related variety calculation by analysing three alternative assumptions regarding domestic-foreign interactions. We investigate the relationship between the new indicators with the entry and exit patterns of domestic and foreign firms from 1996-2012 in Hungarian city regions.

Our case is especially interesting from an evolutionary point of view because the era in Hungary that is being examined can be characterised by a major transformation from a planned to market economy. Foreign-owned firms became key actors in determining the export and employment levels of regional industries (Kállay and Lengyel 2008; Lengyel 2003, Radosevic 2002); these firms brought new knowledge into the regions offering new sources of dynamics (Halpern and Muraközy 2007, Inzelt 2003). However, previous research showed that despite their central position, the local interactions between foreign- and domestically owned segments evolve slowly (Békés et al. 2009, Lengyel and Leydesdorff 2011, 2015, Lengyel and Szakálné 2013, 2014); thus, it is important to understand how technological relatedness combined with domestic-foreign interactions affected firm dynamics.

In order to fulfil the full scope of the above aims, we introduce the extensions in the related variety calculations and the rationales behind the alternative hypotheses in the next chapter. The third section contains the description of the data and its spatial distribution. Panel logit models focusing on company entries and exits are specified in the fourth section, where we discuss the models with the best fit. In these models, no interactions among foreign and domestic firms are presumed. We also find that related variety in the foreign subset tends to accelerate firm entry and decelerate firm exit at a much earlier stage of economic transition than related variety across domestic firms. The paper closes with a discussion of major findings and questions that can be raised in further research, focusing on the role of technological relatedness in regional dynamics over the economic transition.

2. Methods

We follow the seminal work of Frenken et al. (2007) in the first step of calculating related and unrelated variety indicators. The argument claims that two co-located firms are technologically unrelated when they do not share two-digit NACE codes. Two co-located firms are technologically related when they share the same two-digit NACE codes but do not share the four-digit NACE code. The rationale behind these assumptions is that related firms may share enough knowledge but are not too proximate; therefore, they can not only understand but may also learn new things from one other, whereas unrelated firms may not be able to learn from one other because they exploit different technologies.

In the next step, we develop three alternative models in order to distinguish foreign-owned and domestic companies in the related variety calculation. This development is important in the case of firm-level dynamics in Hungary because the technological proximity and gap between foreign and domestic firms were crucial in regional development as reported by previous research (e.g., Lengyel and Szakálné 2014). Unlike in previous papers, in which related variety was decomposed into subsets of manufacturing and service industries (Mameli et al. 2012) or high-tech manufacturing (Hartog et al. 2012) by technological categories, the introduction of ownership categories requires an additional level of entropy aggregation because we will use a new feature for decomposition.

Ownership categories can be introduced to variety decomposition at three levels: (1) the whole economy in the region, (2) within 2-digit NACE codes, and (3) within 4-digit NACE codes. Furthermore, there are distinct arguments and assumptions regarding the local learning facilities among foreign and domestic companies in these three alternative models. These extended models are the *Dual Economy model*, the *Portfolio model*, and the *Technological Proximity model*, respectively. In all cases, economic variety measured in the region will be equal to the entropy of the employment distribution of the finest bin structure, which is the four-digit NACE code combined with the ownership category, and therefore, $V_{dual} = V_{portfolio} = V_{technological\ proximity}$. For simplicity, we only describe the Dual Economy model and compare it with the Original version because the Dual Economy model had the highest *pseudo*-R^2 values over the 1996-2011 period for firm entry and exit regressions. One can find a detailed description of the Portfolio and Technological Proximity models in *Supporting Information 1* and a discussion of the results of these latter models in *Supporting Information 4*.

2.1 Original model

The original method of performing the related variety calculation proposed by Frenken et al. (2007) is as follows. Let p_i be the four-digit NACE share of employment and P_g the two-digit level NACE shares of employment that is derived by adding the four-digit shares and g moves from 1 to G, where G is the number of different two-digit level NACE codes. Let S_g be the set of different four-digit level NACE codes within the g^{th} two-digit level NACE code. The variety of economic activity (V) in a region can then be phrased as the sum of the probabilistic entropy of the four-digit level NACE shares (*Eq. 1*). This variety can be decomposed to unrelated variety and related variety (*Eq. 2*). The unrelated variety (UV) is given as the sum of the probabilistic entropy of two-digit level NACE shares (*Eq. 3*). The related variety (RV) is the sum of the probabilistic entropy of four-digit level NACE shares within each two-digit level NACE shares (H_g; *Eq. 5*) aggregated at the regional level (*Eq. 4*).

$$V = \sum_{g=1}^{G} \sum_{i \in S_g} p_i \, log_2 \left(\frac{1}{p_i} \right) \tag{1}$$

$$V = UV + RV \tag{2}$$

$$UV = \sum_{g=1}^{G} P_g \, log_2 \left(\frac{1}{P_g} \right) \tag{3}$$

$$RV = \sum_{g=1}^{G} P_g H_g \tag{4}$$

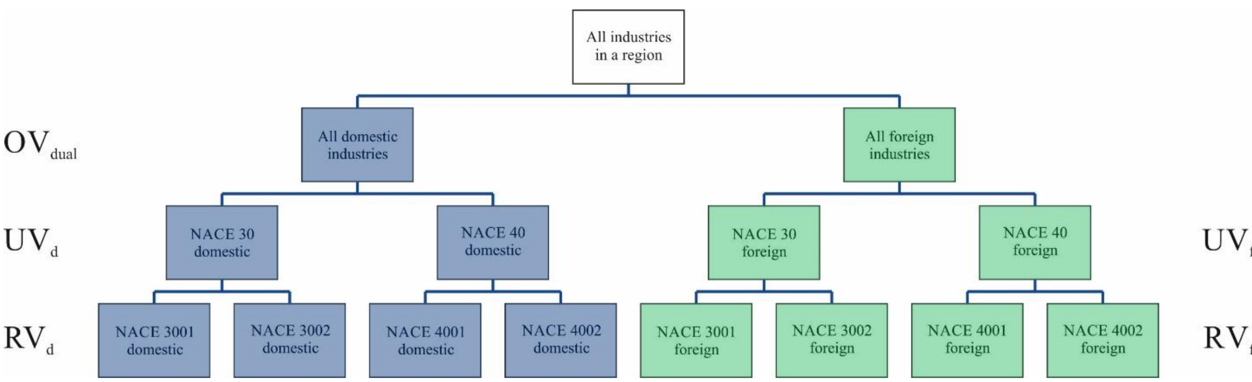
$$H_g = \sum_{i \in S_g} \frac{p_i}{P_g} log_2 \left(\frac{1}{p_i / P_g} \right) \tag{5}$$

2.2 Dual Economy model

Ownership categories (domestic or foreign) can be distinguished throughout the whole economy in the region. This model implies that domestic and foreign firms are not related at all; hence, it is called the Dual Economy model (*Figure 1*).

Formally, let p_{oi} be the share of employment in industries with four-digit NACE codes combined with ownership categories. Let p_{oi} add up to P_{og}, which is the share of employment in two-digit NACE codes combined with ownership categories. Additionally, let the sum of P_{og} be P_o, the share of employment in all industries combined with ownership categories. Finally, let '*d*' indicate domestic set of firms and '*f*' the foreign set of firms.

Figure 1. Variety decomposition in the Dual Economy model.



Note: Blue represents domestic industries and green represents foreign industries.

Economic variety measured in the region will be equal to the entropy of the employment distribution of the finest bin structure, which is the four-digit NACE code combined with the ownership category (*Eq. 6*). The overall variety in a region then equals the variety measured in the ownership distribution (OV_{dual}) plus the weighted sum of domestic and foreign unrelated varieties (UV_d and UV_f) and the weighted sum of domestic and foreign related varieties (RV_d and RV_f) (*Eq. 7-14*).

$$V = \sum_{o=f,d} \sum_{g=1}^{G} \sum_{i \in S_g} p_{oi} log_2 \left(\frac{1}{p_{oi}} \right) \quad (6)$$

$$V = OV_{dual} + UV_{dual} + RV_{dual} \quad (7)$$

$$OV_{dual} = \sum_{o=f,d} P_o log_2 \left(\frac{1}{P_o}\right) \tag{8}$$

$$UV_{dual} = \sum_{o=f,d} P_o \sum_{g=1}^{G} \frac{P_{og}}{P_o} log_2 \left(\frac{1}{P_{og}/P_o}\right) = P_d UV_d + P_f UV_f \tag{9}$$

$$UV_d = \sum_{g=1}^{G} \frac{P_{dg}}{P_d} log_2 \left(\frac{1}{P_{dg}/P_d}\right) \tag{10}$$

$$UV_F = \sum_{g=1}^{G} \frac{P_{fg}}{P_f} log_2 \left(\frac{1}{P_{fg}/P_f}\right) \tag{11}$$

$$RV_{dual} = \sum_{o=f,d} P_o \sum_{g=1}^{G} P_{og} \sum_{i \in S_g} \frac{p_{oi}}{P_{og}} log_2 \left(\frac{1}{p_{oi}/P_{og}}\right) = P_d RV_d + P_f RV_f \tag{12}$$

$$RV_d = \sum_{g=1}^{G} \frac{P_{dg}}{P_d} \sum_{i \in S_g} \frac{p_{di}}{P_{dg}} log_2 \left(\frac{1}{p_{di}/P_{dg}}\right) \tag{13}$$

$$RV_f = \sum_{g=1}^{G} \frac{P_{fg}}{P_f} \sum_{i \in S_g} \frac{p_{fi}}{P_{fg}} log_2 \left(\frac{1}{p_{fi}/P_{fg}}\right) \tag{14}$$

3. Data

We obtained access to a firm-level dataset at the Hungarian Central Statistical Office. The data were collected from the annual census-type data of Hungarian firms, which were compiled from financial statements associated with tax reporting that were submitted to the National Tax Authority in Hungary by legal entities using double-entry bookkeeping. The observation period was from 1996 to 2012 on a yearly basis. The data include all industries and contain basic information for each sample firm, including the LAU2 region (settlement) of company seats, the NACE 4-digit industrial classification codes, the annual average number of employees, the amount of equity capital held by the type of owners, and the major financial indices at the end of the term.

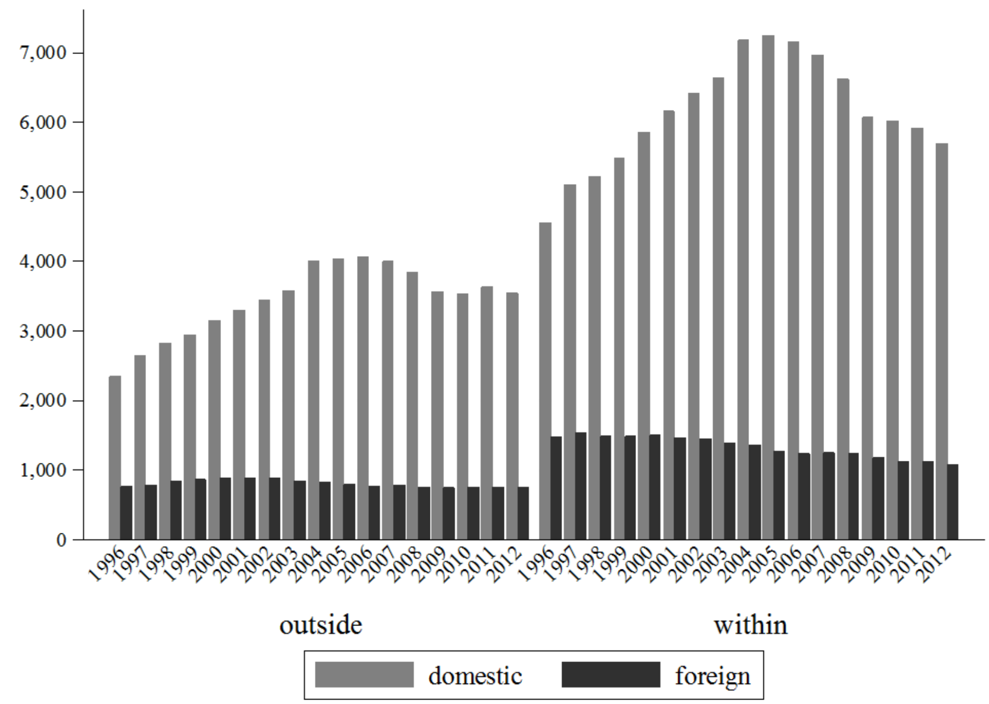
Foreign ownership is attributed to a firm when 10% or more shares of the stocks of a firm are in foreign hands (OECD 2008, HCSO 2007). This standard definition by the Hungarian Statistical Office considers a significant foreign interest in all of the above firms even if the rate of domestic ownership is higher than foreign ownership.

All industries are present in the data, but we concentrate only on manufacturing firms that have at least five employees for three reasons. First, the location decision of manufacturing firms can be expected to be influenced more strongly by local knowledge externalities and related variety than service firms because the latter may be motivated by the presence of customers (Frenken et al. 2007). Second, company seats can be considered as the actual geographical locations of the sample with which we work, unlike in the case of service firms that may have more plants (Békés and Harasztosi 2013). Third, the quality of the data compiled from the balance sheets of Hungarian firms with less than five employees have usually been considered uncertain in previous papers (Békés and Harasztosi 2013).

We further narrowed our attention to firms located in city regions that were identified on the basis of daily commuting trends aggregated from census data by the Hungarian Statistical Office (see *Supporting Information 2* for a visual presentation of city regions). It has been reported repeatedly that the majority of manufacturing industries is concentrated in these 23 agglomeration areas around major towns (Tóth 2014). The territories of these city regions change over time, mostly due to changing commuting patterns. Thus, we use the 2012 classification consistently over the period of the analysis.

The majority of both foreign and domestic firms are located within city regions throughout the whole period of the analysis (*Figure 2*). Interestingly, the number of foreign firms decreases from 2000 onwards, whereas one finds the maximum of domestic firms in the sample in 2005.

Figure 2. Number of manufacturing firms in Hungarian regions with at least 5 employees, 1996-2012.



Note: “Outside” denotes firms located outside of city regions and “within” denotes firms located within city regions.

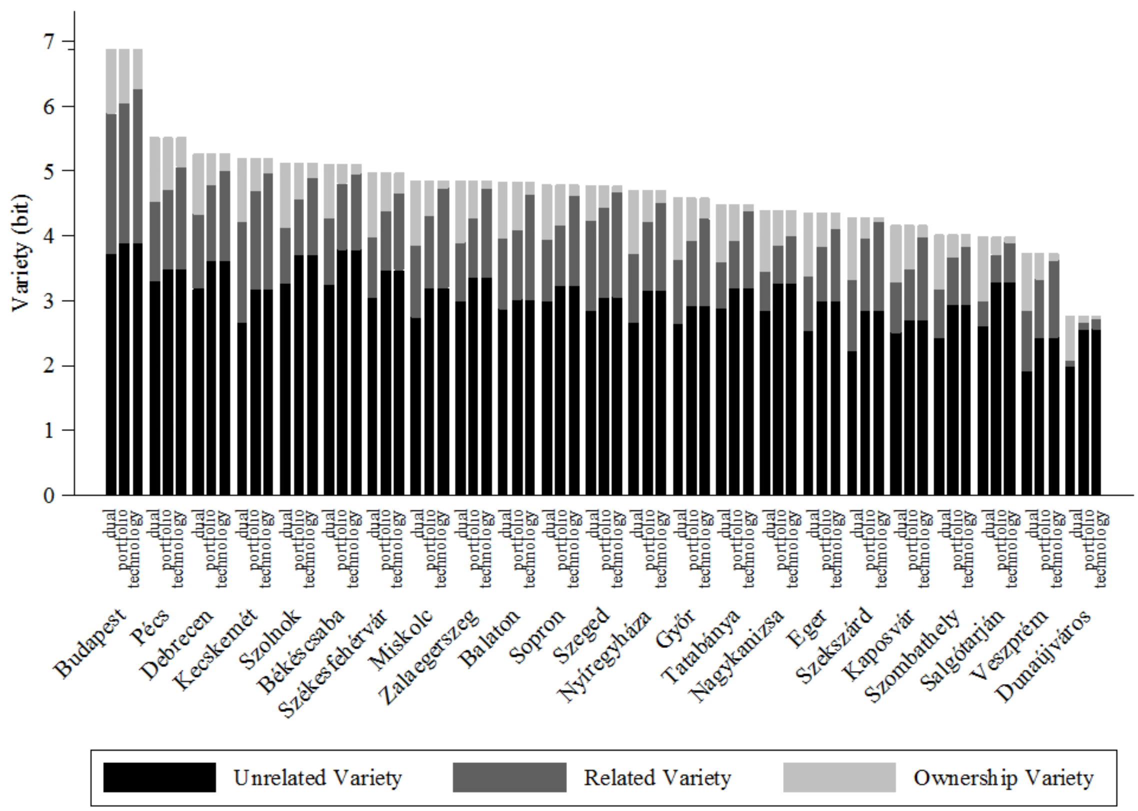
4. Results

In *Figure 3*, we sorted Hungarian city regions according to extent of variety in a descending order and plotted the decomposed variety measures into ownership-, unrelated-, and related variety values. The capital and its suburban area (Budapest) has the highest variety value and a heavily industrialized region (Dunaújváros) has the lowest. Interestingly, one can observe a much more defined difference in the composition of variety indicators computed by the Dual Economy, Portfolio, and Technological Proximity models in the least diverse regions than in the most diverse regions. Ownership variety has the highest value in the Dual Economy model in every region, and it is especially true in the least diverse regions.

We illustrate the decomposed indicators of the Dual Economy model specified in Section 2.2 for every city-region over the full period of our investigation in Supporting Information 3.

In the remainder of this section, we first specify the regression models describing firm entry and exit and the control variables. In the next step, we compare the results of the Dual Economy model with the Original model. Finally, we demonstrate the effect of the varieties in the domestic and foreign subsets on the entry and exit of domestic and foreign firms.

Figure 3. Ownership, Unrelated and Related variety index values for city regions in the case of Dual Economy, Portfolio, and Technological Proximity models for 2012.



4.1 Specification of the regression models

A previous paper found the dynamically changing effect of related variety on employment growth in the regions (Lengyel and Szakálné 2013). In order to identify such changes in the effect of the varieties on firm entry and exit, we divide the analysis into four equal time periods, each of which can be associated with significantly different eras in the post-socialist transition of the Hungarian economy. A fast liberalization and dynamic economic growth characterized the first period (1996-1999). Following this period, the country prepared for EU accession in the second period (2000-2003), which was followed by an economic slowdown in the third period (2004-2007) and a more dramatic downturn in the fourth period (2008-2011). We used the 2012 year data to compute the exit of firms in 2011.

We run panel logit models for every period, in which *ENTRY* and *EXIT* of firms are binary dependent variables. *ENTRY* is defined equal to 0 if the firm was present in the former year and 1 if firm entered the economy in the given year. Similarly, *EXIT* is equal to 0 if the firm is present in the data in the next year and 1 if the firm was not.

$$\text{logit}(\Pr(ENTRY \neq 0|\boldsymbol{x_{it}})) = \boldsymbol{x_{it}}\boldsymbol{\beta^T} + \varepsilon_i\text{, where}$$

$$\text{logit}(p) = \ln\left(\frac{p}{1-p}\right) \quad (15)$$

All four models have been tested; the results of Original and Dual Economy models can be found in *Tables 2-5* and these results are discussed in the main text, and the results of the Portfolio and Technological Proximity are presented and discussed in *Supporting Information 4*. Related variety (*RV*) and unrelated variety (*UV*) are used in the Original model as explanatory variables. The Dual Economy model consists of five explanatory variables: ownership variety (OV_{dual}) and related and unrelated variety measured in the two subsets (UV_d, UV_f, RV_d, RV_f). We use three explanatory variables in the Portfolio ($UV, OV_{portfolio}, RV_{portfolio}$) and three explanatory variables in the Technological Proximity models (UV, RV, OV_{tech}).

Table 1. Description of the control variables

POPDENS	Population density of the city region.
LQ	Location quotient of the firms' NACE 2-digit industry in the city-region.
EMP	Number of employees in the firm.
CAPTOT	Amount of total equity capital of the firm in 1000 HUF.
AVGSIZE	Average number of employees in firms of the same 2-digit industry in a city-region.
WASTE	Dummy that equals 1 if the net result of the firm was negative in the previous year.

The same set of control variables are introduced to each model (*Table 1*). The *location quotient* (*LQ*) controls for the specialization level of a city region and the 2-digit industry of the given firm. The *number of employees* (*EMP*) and *total equity capital* of a given firm (*CAPTOT*) controls for different aspects of firm size. The *average firm size* in the 2-digit industry of the firm in a city region (*AVGSIZE*) controls for the level of internal economies of scale. *Population density* (*POPDENS*) is used as a control for the size of agglomerations. In exit models, we used the additional dummy variable *WASTE* that is set to 1 if the net result of the firm was negative in the previous year.

In case of the entry models, we applied fixed effects because these omit firms that are incumbent for the whole period and therefore have 0 entry values in every year. Random effects are applied in the case of the exit models because the firms that do not exit the economy over the investigated time period and therefore have 0 exit values in every year are also important in the regression.

4.2 Comparison of the Original and the Dual Economy models of firm entry and exit

In order to clarify the model of technological relatedness that best describes the data, we first estimated the probability of firm entry and exit with the Original model (*Table 2*). We then estimated the probability of firm entry and exit with the Dual Economy model (*Table 3*) and with the portfolio and Technological Proximity models (*Supporting Information 4*, *Table 1 and Table 2*, respectively). A separate regression was run for each of the periods examined.

One can expect that related variety in the region enhances the probability that a new firm will enter and decreases the probability of firm exit because there is a higher level of intermediate goods and services in the region, and technological relatedness boosts the prevalence of agglomeration economies (Cainelli and Iacobucci 2012). This expectation is also relevant in the case of unrelated variety because the diversity without technological proximity involved also increases the variety of locally available intermediate products and services.

However, one can observe a change in the sign of the explanatory variables over time (*Table 2*). *RV* in the region has a significant negative effect on firm entry in 1996-1999; the sign changes at a later period and becomes significant for 2008-2011. In a similar manner, *UV* has a negative significant effect on firm entry in 1996-1999, but the effect becomes positive at later periods. On the contrary, both *RV* and *UV* have positive significant effects on firm exit in the 1996-1999 period, which becomes negative in later periods. These findings suggest that a major turn occurred over the transition period of the Hungarian economy in the way technological relatedness affected regional dynamics. This finding is in line with previous observations regarding the changing effect of related variety on employment growth in Hungarian regions (Lengyel and Szakálné 2013) and further supports the idea that the fully restructured input-output relations due to the economic transition had a footprint on agglomeration economies as well.

Next, we made a split in the set of explanatory variables by introducing firm ownership. No relatedness among domestic and foreign firms is assumed in the *Dual Economy model*, and therefore, we can distinguish between the effects of related and unrelated varieties in both foreign and domestic subsets (*Table 3*). Interestingly, a similar pattern can be seen as above: UV_f and RV_f influence firm entry negatively in 1996-1999, but their effect becomes positive after 2000. Even more interestingly, the effect of RV_d on firm entry remains significantly negative until the last period. This latter finding means that technological relatedness among domestic companies have started to contribute to agglomeration economies only at a later stage, but technological relatedness among foreign firms was a quicker enhancing factor. The effect of OV_{dual} does not seem to be either stable or follow the above pattern over time.

Looking at the control variables, one can observe a systematic effect only in the case of employment and the total registered capital of the firm; the entering firms are mostly smaller firms with fewer employees and lower total capital.

Table 2. Firm entry and firm exit, 1996-2011, Original Model.

	FIRM ENTRY				FIRM EXIT			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
RV	–7.357***	0.516	–2.975***	5.780***	6.698***	0.316	3.628***	–7.796***
	(–15.12)	(0.94)	(–5.19)	(4.59)	(14.82)	(0.47)	(4.80)	(–8.58)
UV	–8.826***	2.895***	–0.486	6.798***	7.572***	–2.956**	–3.193***	–9.873***
	(–12.79)	(3.89)	(–0.73)	(5.82)	(8.95)	(–3.00)	(–3.63)	(–10.49)
POPDENS	0.879***	–0.103	0.0542	2.368	–0.573***	0.0909	–0.0499	0.413***
	(10.72)	(–1.33)	(0.76)	(1.90)	(–9.44)	(1.46)	(–0.91)	(5.22)
LQ	–53.69	15.54	–24.19	–55.20	19.68	20.06	23.83	–3.626
	(–0.73)	(0.54)	(–0.43)	(–1.19)	(0.57)	(0.76)	(0.53)	(–0.16)
ln *EMP*	–1.795***	–1.418***	–1.705***	–1.365***	–0.591***	–1.154***	–0.675***	–0.997***
	(–10.95)	(–10.12)	(–10.99)	(–6.38)	(–3.69)	(–7.75)	(–5.04)	(–5.67)
ln *CAPTOT*	–1.914***	–1.021***	–0.903***	–0.815**	0.719***	0.278*	0.696***	0.0602
	(–6.73)	(–4.65)	(–3.41)	(–2.59)	(3.49)	(2.24)	(3.46)	(0.31)
ln *AVGSIZE*	0.475*	2.210***	0.814***	–1.183**	–0.481*	–1.528***	–0.269	0.339
	(2.31)	(8.67)	(3.89)	(–2.94)	(–1.97)	(–5.85)	(–1.20)	(1.68)
WASTE					0.697***	0.772***	1.049***	0.812***
					(4.76)	(7.46)	(9.67)	(7.25)
N	3876	3604	3793	1345	2302	2837	2680	2875
pseudo R^2	0.45106	0.10935	0.09249	0.17987	0.36226	0.10428	0.09868	0.18187
Ll	–753.5	–1134.8	–1214.0	–389.4	–518.2	–899.9	–854.6	–829.7
P	3.69e-263	2.16e-56	9.67e-50	1.70e-33	6.29e-122	6.19e-41	3.29e-36	8.46e-75

Note: t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Firm entry and firm exit, 1996-2011, Dual Economy model.

	FIRM ENTRY				FIRM EXIT			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
OV_{dual}	-3.493^{*}	10.08^{***}	-6.093^{**}	-12.03^{**}	4.034^{*}	–1.904	5.334^{*}	13.90^{***}
	(–2.45)	(6.41)	(–2.63)	(–2.95)	(2.51)	(–1.19)	(2.19)	(4.00)
UV_d	-5.050^{***}	2.896^{***}	-5.337^{***}	2.973^{**}	4.187^{***}	-2.613^{***}	0.418	-4.981^{***}
	(–9.48)	(5.16)	(–6.13)	(3.11)	(6.93)	(–4.33)	(0.47)	(–7.00)
RV_d	-3.515^{***}	-5.034^{***}	-12.42^{***}	7.428^{***}	2.987^{***}	4.278^{***}	12.40^{***}	-10.08^{***}
	(–8.99)	(–7.46)	(–18.43)	(9.08)	(7.70)	(5.91)	(15.89)	(–15.43)
UV_f	-3.550^{***}	2.732^{***}	3.244^{***}	2.995^{***}	2.962^{***}	-1.855^{***}	-3.082^{***}	-2.409^{***}
	(–7.46)	(6.76)	(6.41)	(4.25)	(5.38)	(–4.08)	(–4.97)	(–4.55)
RV_f	-4.852^{***}	6.260^{***}	7.151^{***}	0.423	4.054^{***}	-5.316^{***}	-4.900^{***}	-2.601^{***}
	(–10.03)	(12.50)	(11.35)	(0.45)	(8.45)	(–9.89)	(–7.68)	(–3.96)
POPDENS	1.039^{***}	-0.181^{*}	0.294^{***}	1.979	-0.647^{***}	0.188^{*}	-0.195^{**}	0.558^{***}
	(10.89)	(–2.05)	(3.32)	(1.94)	(–9.98)	(2.07)	(–2.68)	(6.66)
LQ	–83.13	37.53	–91.46	–35.43	31.23	18.98	–25.55	6.231
	(–0.89)	(1.13)	(–1.44)	(–0.62)	(0.96)	(0.63)	(–0.46)	(0.22)
ln *EMP*	-1.757^{***}	-1.362^{***}	-1.764^{***}	-1.369^{***}	-0.599^{***}	-1.122^{***}	-0.596^{***}	-1.033^{***}
	(–10.51)	(–9.03)	(–9.63)	(–6.00)	(–3.66)	(–7.36)	(–3.91)	(–5.58)
ln *CAPTOT*	-1.790^{***}	-0.856^{***}	-0.798^{**}	-0.889^{**}	0.607^{**}	0.266	0.596^{**}	0.194
	(–6.34)	(–4.00)	(–2.91)	(–2.88)	(3.13)	(1.85)	(2.65)	(0.87)
ln *AVGSIZE*	0.437^{*}	1.931^{***}	1.128^{***}	-1.062^{*}	-0.565^{*}	-1.339^{***}	–0.280	0.246
	(1.99)	(7.60)	(4.00)	(–2.54)	(–2.16)	(–5.39)	(–1.03)	(1.16)
WASTE					0.725^{***}	0.755^{***}	1.020^{***}	0.840^{***}
					(4.88)	(6.93)	(8.07)	(7.02)
N	3876	3604	3793	1345	2302	2837	2680	2875
pseudo R^2	0.47296	0.23324	0.36792	0.26165	0.37987	0.19001	0.32502	0.29986
Ll	–723.4	–977.0	–845.5	–350.6	–503.9	–813.8	–640.0	–710.0
P	8.36e-273	2.84e-121	4.46e-205	1.14e-47	2.77e-125	4.44e-75	4.52e-125	2.49e-123

Note: t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Logistic regressions that look at firm exit as dependent variable and ownership-extended variety calculations result in very similar conclusions as those seen in the case of firm entry (*Table 3*). There is a strong switch in the effect of variety indicators on firm exit over time. The sign of almost all indicators change from positive in 1996-1999 to negative in later periods, suggesting that agglomeration economies may have transformed over the post-socialist transition and developed into a stage where the diversity of and technological proximity across economic activities can prevent firms from exiting the region. The exception is again RV_d in the *Dual Economy model*. This indicator has a positive effect on the probability of firm exit, which further strengthens the argument that technological relatedness among domestic companies have only started to contribute to agglomeration economies at a later stage.

In some cases, the control variables also have a systematic influence on the exit of firms. The variables *EMP* and *WASTE* have significant effects: exiting firms tend to be smaller and have negative net results in the previous year.

4.3 Entry and exit of foreign and domestic firms in the Dual Economy model

With the introduction of firm ownership, we were also looking for the effects of different variety indices on the two sets of firms separately. As the *Dual Economy model* was the best model for explaining both entry and exit, in this section, we exclusively focus on these results (*Table 4* and *Table 5*).

We have better explaining power in every case compared to the models where the firms were analysed in one group, and we obtain slightly different patterns for the effect on domestic and foreign firms. In case of domestic firms, UV_d, UV_f, RV_d and RV_f influence firm entry negatively in 1996-1999, but their effect becomes positive after 2000 except for RV_d, which remains negative until 2008, and UV_d that has an alternating sign over the full period.

Table 4. Firm entry, 1996-2011, Dual Economy model.

	DOMESTIC FIRMS				FOREIGN FIRMS			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
OV_{dual}	–4.386*	9.560***	–7.344**	–11.62*	7.429	15.18**	6.014	–2.121
	(–2.37)	(5.51)	(–3.03)	(–2.38)	(1.87)	(3.17)	(0.39)	(–0.22)
UV_d	–5.202***	3.086***	–4.732***	3.696**	–10.55***	2.612*	–13.32**	0.720
	(–8.51)	(4.64)	(–5.28)	(3.19)	(–4.89)	(2.17)	(–2.90)	(0.29)
RV_d	–3.482***	–5.885***	–12.42***	6.101***	–1.109	–0.648	–12.16***	11.08***
	(–7.74)	(–7.73)	(–17.60)	(6.07)	(–1.05)	(–0.33)	(–3.58)	(4.62)
UV_f	–3.939***	2.629***	3.191***	2.648**	–5.991***	6.396***	2.880	1.048
	(–6.98)	(6.24)	(5.98)	(3.18)	(–4.14)	(3.51)	(1.18)	(0.66)
RV_f	–4.816***	6.974***	7.112***	0.553	–5.967***	3.480**	7.156*	0.0684
	(–8.75)	(12.00)	(10.82)	(0.52)	(–4.25)	(2.96)	(2.37)	(0.03)
POPDENS	22.98***	–0.112	0.287**	9.565**	0.788**	0.408	9.323	–0.430
	(7.05)	(–1.22)	(3.17)	(2.94)	(2.84)	(0.32)	(0.83)	(–0.35)
LQ	–80.81	2.597	56.46	–180.0	–263.1	196.7	–343.6	–156.5
	(–0.80)	(0.08)	(0.44)	(–0.39)	(–0.87)	(1.78)	(–0.87)	(–1.58)
ln *EMP*	–1.697***	–1.352***	–1.810***	–1.321***	–2.134***	–1.763***	–2.769***	–0.933
	(–8.51)	(–7.55)	(–8.78)	(–4.71)	(–5.51)	(–5.40)	(–4.44)	(–1.50)
ln *CAPTOT*	–1.728***	–2.126***	–0.727*	–0.600	–2.010***	–0.295	–1.169	–1.199*
	(–4.76)	(–4.49)	(–2.34)	(–1.28)	(–4.05)	(–1.28)	(–1.40)	(–2.12)
ln *AVGSIZE*	0.273	2.151***	1.111***	–0.694	–0.266	1.045*	0.744	–5.272**
	(1.04)	(7.31)	(3.74)	(–1.50)	(–0.46)	(2.02)	(0.68)	(–2.67)
N	3194	2968	3419	1086	581	559	289	219
pseudo R^2	0.50172	0.25129	0.36366	0.26111	0.56257	0.25596	0.49839	0.34638
Ll	–563.5	–785.2	–767.0	–283.1	–89.96	–147.5	–51.51	–50.73
P	1.59e-237	7.14e-107	6.93e-182	1.57e-37	4.38e-44	2.73e-17	1.83e-17	5.37e-08

Note: *t* statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5. Firm exit, 1996-2011, Dual Economy model.

	DOMESTIC FIRMS				FOREIGN FIRMS			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
OV_{dual}	4.910**	–1.517	6.391*	11.21**	–2.852	–4.701	4.442	37.44**
	(2.71)	(–0.83)	(2.39)	(2.96)	(–0.80)	(–1.16)	(0.63)	(2.74)
UV_d	4.319***	–2.757***	–0.358	–5.170***	2.129	–2.602*	7.334*	–3.499
	(6.16)	(–3.72)	(–0.37)	(–6.43)	(1.48)	(–2.32)	(2.38)	(–1.64)
RV_d	3.027***	4.978***	12.78***	–9.034***	2.615*	1.598	9.936***	–12.94***
	(7.00)	(5.70)	(14.66)	(–11.57)	(2.36)	(0.97)	(4.56)	(–5.83)
UV_f	3.047***	–1.698***	–2.961***	–1.861**	1.405	–2.758*	0.104	–0.0470
	(4.84)	(–3.30)	(–4.31)	(–3.12)	(1.09)	(–2.09)	(0.06)	(–0.03)
RV_f	3.792***	–6.224***	–4.990***	–2.113**	3.074*	–1.954	–1.768	–4.878*
	(7.14)	(–9.68)	(–7.13)	(–2.89)	(2.13)	(–1.59)	(–0.87)	(–2.35)
POPDENS	–0.627***	0.184	–0.200*	–15.84***	–61.32***	–12.61**	–27.60***	–2.979*
	(–8.69)	(1.81)	(–2.56)	(–6.90)	(–4.52)	(–2.70)	(–3.79)	(–2.39)
LQ	116.5*	38.74	92.44	–1.746	–67.79	–104.6	–31.90	52.47
	(2.46)	(1.28)	(1.03)	(–0.02)	(–0.99)	(–1.29)	(–0.40)	(1.43)
ln *EMP*	–0.604**	–1.163***	–0.530**	–0.933***	–0.525	–0.637*	–0.813	–3.273***
	(–3.24)	(–6.56)	(–3.22)	(–4.25)	(–1.12)	(–2.04)	(–1.86)	(–4.40)
ln *CAPTOT*	0.596*	0.567*	0.579*	0.541	0.284	0.0646	0.543	–0.375
	(2.55)	(2.56)	(2.39)	(1.24)	(0.57)	(0.34)	(0.70)	(–0.68)
ln *AVGSIZE*	–0.560	–1.831***	–0.209	0.172	0.182	0.159	0.0994	1.522*
	(–1.84)	(–5.91)	(–0.69)	(0.75)	(0.28)	(0.30)	(0.14)	(1.97)
WASTE	0.734***	0.842***	1.034***	0.891***	0.493	0.531*	0.998**	0.967*
	(4.43)	(6.69)	(7.36)	(6.53)	(1.03)	(2.05)	(2.92)	(2.54)
N	1820	2224	2217	2421	367	499	361	376
pseudo R^2	0.37911	0.22912	0.33471	0.35428	0.48938	0.11692	0.34866	0.40113
Ll	–398.9	–606.3	–521.7	–551.1	–66.30	–156.8	–83.06	–79.80
P	1.72e-97	1.50e-70	1.52e-105	1.35e-122	6.76e-22	0.0000195	2.71e-14	7.58e-18

Note: t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In the starting period, the same effect for foreign firms exists. However, the related and unrelated variety of foreign firms (UV_f, RV_f) and the unrelated variety of domestic firms (UV_d) affected foreign firms more intensely, and the change in sign and significance is also different: UV_d and RV_d are not significant in later periods and the impacts of UV_f and RV_f become positive, but these are significant only in the second period (2000-2003). This means that the contribution to agglomeration economies of technological relatedness among foreign firms started after 2000 and the impact was stronger on domestic firms. The effect of OV_{dual} is not stabilized even after the division into domestic and foreign sets of firms.

For models in which the exit of firms is the dependent variable, it turns out that every mentioned effect measured for the whole set of firms stems from the domestic set of firms, and there are no remarkable significant effects of the variety indices on the foreign set except for RV_d in the third and fourth periods, and these effects are the same, as they were in case of the domestic subset.

5. Conclusions and further research

The aim of this paper was to identify a relationship between the related variety and firm dynamics and show that in a country with an open economy such as Hungary, the dual economy pattern that formed during the period of economic transition prevails. Technological differences between domestic- and foreign-owned firms give us an environment in which to test hypotheses about related variety and technological relatedness, which is different from environments of previous international studies. We found that the effects of related and unrelated variety levels of regions on firm entry and exit are different from expected ones based on former papers on the topic. We tested several panel logit models and found evidence for dual economy patterns, especially in the early transition period.

A number of conclusions can be drawn from our findings. First, we provided additional support for the claim that a technological gap is present between domestic- and foreign-owned companies, which prevails throughout the period between 1996 and 2011. Second, the role of agglomeration economies and inter-industry spillovers in particular as a driving force of regional firm dynamics changed during the period in question. The variety of the industry structure in the region became an important source of agglomeration economies after 2000. Furthermore, the related variety of regions started to affect firm dynamics at a later phase than the unrelated variety. These findings may suggest that technological proximity became important as cooperation among co-located actors slowly evolved after the major economic transition. Third, this late appearance of related variety as a source of regional dynamics is due to the domestic set of firms. The relatedness among domestic companies became beneficial for firm entry in the last period, while the relatedness of foreign firms has shown this effect since 2000. These findings point towards the formative role of FDI and MNEs in the earlier stages of the economic transition.

As for further research on foreign ownership and related variety, the next step should be linking the entry and exit of individual firms to the regional economic portfolio in terms of technological relatedness. This can be done by a direct measurement of relatedness, either through the relatedness of the products produced (*e.g.*, Neffke et al. 2011) or the labour mobility between industries (*e.g.,* Boschma et al. 2014). An interesting question is, for example, whether the regional portfolios of foreign industries are more or less cohesive than those of domestic industries. Answers to such questions could improve our understanding of the embeddedness of foreign firms in host economies. Furthermore, it is also important to see whether relatedness to the foreign or domestic industrial portfolio of regions is more important for entry and exit of firms. In other words, the push or pull effect of foreign firms and the host economy can be assessed, especially by also differentiating between foreign and domestic entry and exit. Finally, one may investigate the cohesion of foreign and domestic industries that co-evolve in regions over time to shed further light on the role of foreign firms in the evolution of the host economies of regions.

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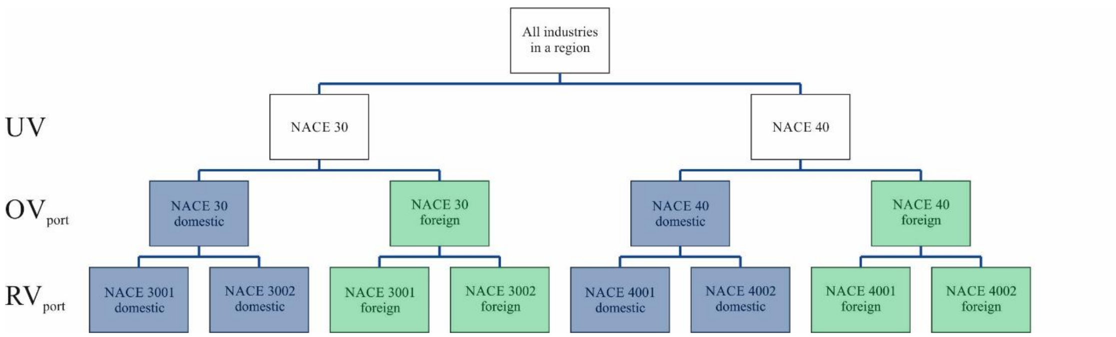
Supporting Information 1. Portfolio model and Technological proximity model

Portfolio model

Ownership categories can be distinguished at the two-digit NACE code level. This model implies that domestic and foreign firms are not totally separated, but technological relatedness occurs only among firms that are from the same ownership category. The variety of foreign and domestic firms in the region enhances the portfolio of firms; hence, it is called the Portfolio model (*S1.Figure 1*).

Supporting Information 1. Figure 1. Variety decomposition, Portfolio model.



Note: Blue represents domestic industries and green represents foreign industries.

Let p_{oi} be the share of employment in industries with four-digit NACE codes combined with ownership categories. Let p_{oi} add up to P_{og}, which is the share of employment in the two-digit NACE codes combined with the ownership categories. Finally, let the sum of P_{og} be P_g, the share of the two-digit NACE code employment, regardless of ownership categories. Variety in the region (*V*) equals unrelated variety (*UV* as specified in *Eq. 3* in the Original model) plus ownership variety measured at the two-digit NACE level ($OV_{portfolio}$) and related variety capturing institutional and technological proximities ($RV_{portfolio}$).

$$V_{portfolio} = UV + OV_{portfolio} + RV_{portfolio} \quad (1)$$

$$OV_{portfolio} = \sum_{g=1}^{G} P_g \sum_{o=f,d} \frac{P_{og}}{P_g} log_2 \left(\frac{1}{P_{og}/P_g} \right) \quad (2)$$

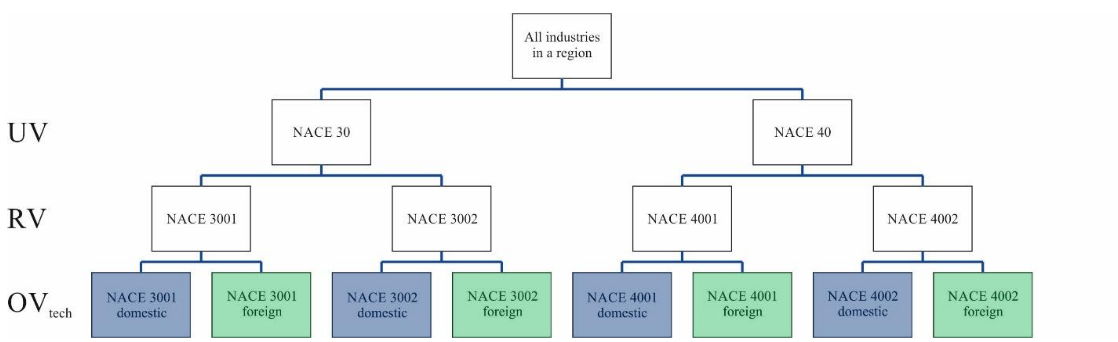
$$RV_{portfolio} = \sum_{g=1}^{G} \sum_{o=f,d} P_{og} \sum_{i \in S_g} \frac{p_{oi}}{P_{og}} log_2 \left(\frac{1}{p_{oi}/P_{og}} \right) = RV_{dual} \quad (3)$$

The *Portfolio model* implies that domestic and foreign firms are not totally separated, but technological relatedness occurs only among firms that are from the same ownership category. However, it is not possible to decompose related variety to foreign and domestic subsets. Therefore, we can estimate the effect of unrelated variety and RV_{port} indicators, which reveals a very similar picture that we have already seen in the Original model of *Table 2*. Both the UV and RV_{port} indicators change from negative to positive in the beginning of the 2000s and become significant for the 2008-2011 period. OV_{port} has a positive effect on entry through the 2000-2011 period, which means that the higher the variety of foreign and domestic firms within the 2-digit NACE industries is, the higher the probability that firms enter the region (*S4. Table 1* and *S4. Table 2*).

Technological Proximity model

Ownership can be distinguished at the four-digit NACE code level. This model implies that domestic and foreign firms may learn from one other when they are technologically related; hence, this model is called the technological proximity model (*S1.Figure 2*).

Supporting Information 1. Figure 2. Variety decomposition, Technological Proximity model.



Note: Blue represents domestic industries and green represents foreign industries.

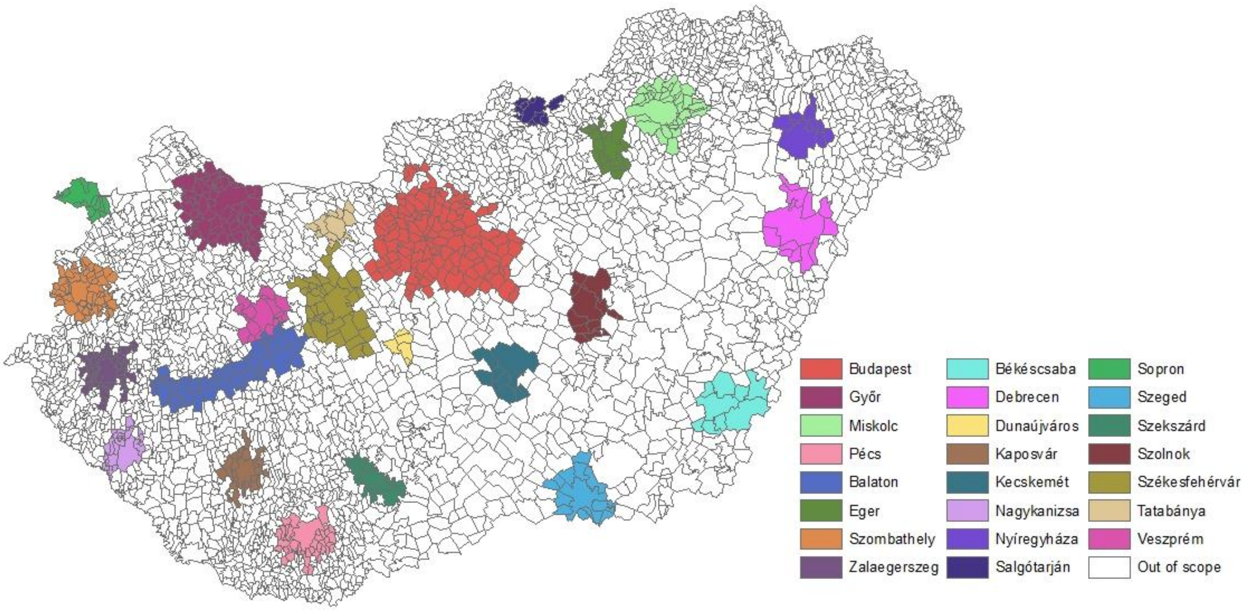
Let p_{oi} be the share of employment in industries with four-digit NACE codes combined with ownership categories. Let p_{oi} add up to p_i, which is the share of employment in four-digit NACE codes without ownership categories. Finally, let the sum of p_i be P_g, the share of the two-digit NACE code employment. Variety in the region (*V*) then equals unrelated variety (*UV* as specified in *Eq. 3* in the Original model) plus related variety (*RV* as specified in *Eq. 4* in the Original model) and plus ownership variety capturing technological proximities (OV_{tech}).

$$V_{tech} = UV + RV + OV_{tech} \tag{4}$$

$$OV_{tech} = \sum_{g=1}^{G} \sum_{i \in S_g} p_i \sum_{o=f,d} \frac{p_{oi}}{p_i} log_2 \left(\frac{1}{p_{oi}/p_i} \right) \tag{5}$$

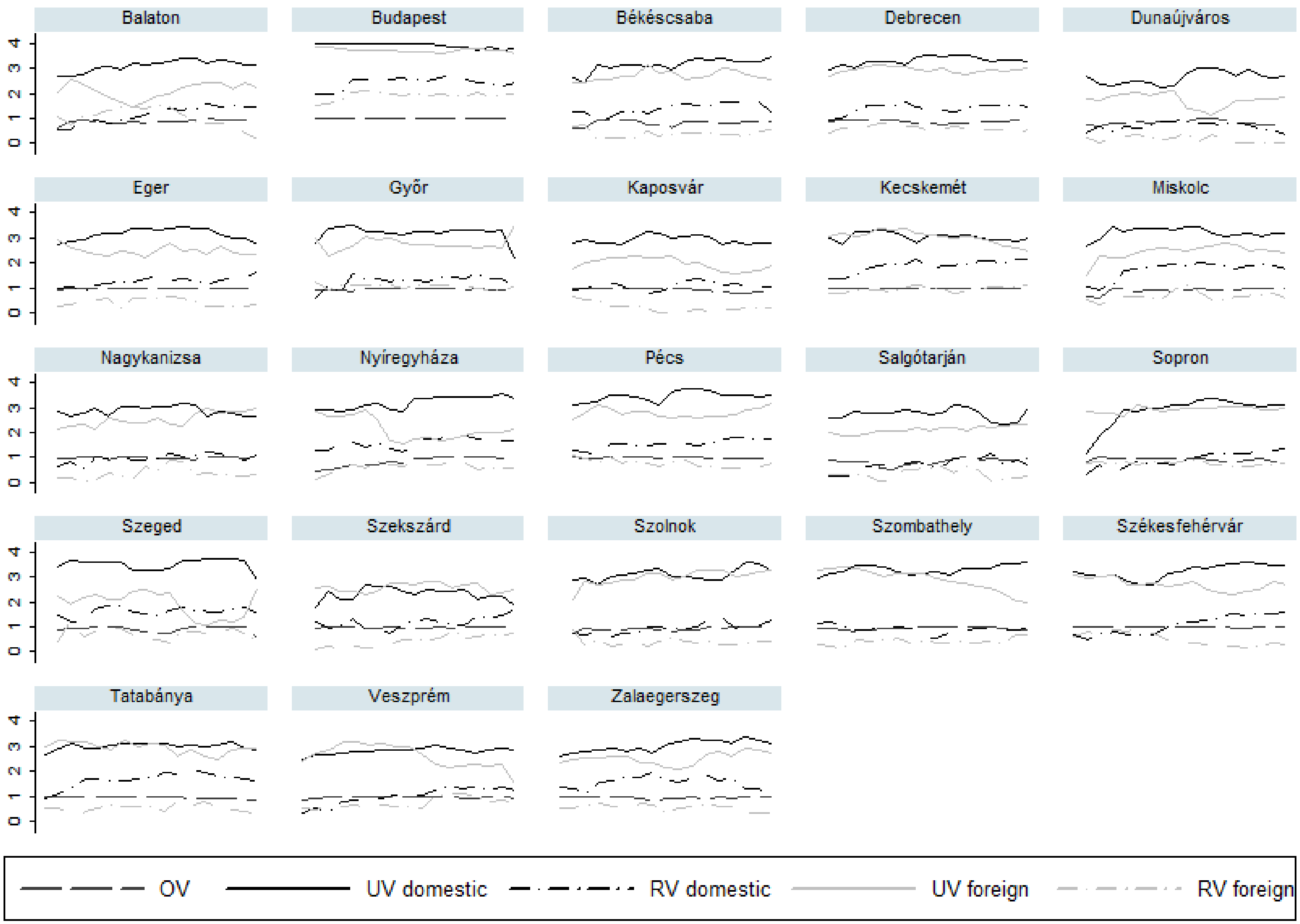
The *Technological proximity model* assumes that technological proximity intensifies interactions across foreign and domestic firms and company ownership is just another layer when measuring similarities. Therefore, this model resembles the original related variety calculations the most. Indeed, the effect of UV and RV follows the patterns already found in *Table 2*. However, OV_{tech} has a very strong positive and significant effect on entry in 2000-2003, meaning that the higher variety is within the 4-digit NACE industries, the higher probability is that firms enter the region. The positive effects of OV_{port} and OV_{tech} over the 2000-2007 period suggests that the local interaction among foreign and domestic companies intensified to a level that can already boost the prevalence of agglomeration economies (*S4. Table 1* and *S4. Table 2*).

Supporting Information 2. Hungarian city regions based on census data in 2011.



Source: Tóth (2014)

Supporting Information 3. Decomposed variety index values for city regions in the Dual Economy model between 1996 and 2012.



Supporting Information 4.Table 1. Firm entry, 1996-2011, Portfolio and Technological Proximity Models.

	PORTFOLIO MODEL				**TECHNOLOGICAL PROXIMITY MODEL**			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
UV	–8.723***	4.001***	–0.419	6.013***	–8.761***	2.067*	–0.313	5.439***
	(–12.78)	(4.97)	(–0.62)	(5.13)	(–12.55)	(2.34)	(–0.47)	(4.34)
OV_{port}	–0.688	6.580***	0.422	7.383***				
	(–0.67)	(7.08)	(0.50)	(3.35)				
RV_{port}	–7.607***	1.985***	–1.941**	8.050***				
	(–15.68)	(3.33)	(–3.22)	(6.22)				
RV					–7.408***	–0.0187	–2.482***	7.060***
					(–14.91)	(–0.03)	(–4.17)	(5.28)
OV_{tech}					–0.643	21.36***	2.963**	15.60***
					(–0.53)	(11.71)	(3.14)	(5.15)
POPDENS	0.861***	–0.279***	0.0334	2.445	0.884***	–0.286***	0.00779	2.834
	(10.56)	(–3.39)	(0.46)	(1.93)	(10.70)	(–3.34)	(0.11)	(1.50)
LQ	–56.15	24.76	–31.61	–37.27	–54.41	23.06	–31.47	–18.65
	(–0.74)	(0.86)	(–0.57)	(–0.83)	(–0.74)	(0.75)	(–0.56)	(–0.42)
ln *EMP*	–1.811***	–1.406***	–1.680***	–1.359***	–1.794***	–1.420***	–1.686***	–1.358***
	(–11.04)	(–9.87)	(–10.84)	(–6.29)	(–10.94)	(–9.73)	(–10.87)	(–6.24)
ln *CAPTOT*	–1.902***	–1.025***	–0.907***	–0.849**	–1.911***	–0.877***	–0.892***	–0.852**
	(–6.95)	(–4.63)	(–3.40)	(–2.60)	(–6.73)	(–4.25)	(–3.38)	(–2.60)
ln *AVGSIZE*	0.440*	2.307***	0.793***	–1.174**	0.480*	2.538***	0.866***	–1.199**
	(2.12)	(8.79)	(3.82)	(–2.81)	(2.32)	(9.11)	(4.07)	(–2.80)
N	3876	3604	3793	1345	3876	3604	3793	1345
pseudo R^2	0.45771	0.13349	0.08665	0.20148	0.45117	0.18791	0.09632	0.20994
Ll	–744.4	–1104.1	–1221.8	–379.1	–753.4	–1034.7	–1208.8	–375.1
P	5.81e-266	1.13e-68	1.21e-45	4.29e-37	4.42e-262	2.44e-98	4.02e-51	8.72e-39

Note: t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Supporting Information 4.Table 2. Firm exit, 1996-2011, Portfolio and Technological Proximity Models.

	PORTFOLIO MODEL				TECHNOLOGICAL PROXIMITY MODEL			
	1996-1999	2000-2003	2004-2007	2008-2011	1996-1999	2000-2003	2004-2007	2008-2011
UV	8.149***	–3.561***	–2.984***	–9.389***	7.619***	–1.940	–3.235***	–9.933***
	(9.22)	(–3.55)	(–3.34)	(–10.04)	(8.97)	(–1.82)	(–3.65)	(–10.54)
OV_{port}	2.916*	–4.829***	–1.899	–7.375***				
	(2.39)	(–4.30)	(–1.81)	(–5.55)				
RV_{port}	7.220***	–1.710*	2.922***	–10.61***				
	(15.05)	(–2.41)	(3.87)	(–11.46)				
RV					6.937***	0.568	3.175***	–8.597***
					(14.54)	(0.74)	(4.05)	(–9.31)
OV_{tech}					2.633	–19.48***	–2.455*	–18.61***
					(1.63)	(–9.52)	(–2.26)	(–8.81)
POPDENS	–0.677***	0.263***	–0.0235	0.595***	–0.618***	0.297***	–0.0000190	0.691***
	(–10.45)	(3.88)	(–0.39)	(7.00)	(–9.12)	(4.14)	(–0.00)	(8.05)
LQ	16.55	7.510	11.98	–9.778	20.39	14.84	21.16	–17.90
	(0.49)	(0.27)	(0.27)	(–0.40)	(0.60)	(0.60)	(0.46)	(–0.69)
EMP	–0.607***	–1.163***	–0.691***	–0.986***	–0.597***	–1.101***	–0.680***	–0.950***
	(–3.81)	(–7.75)	(–5.12)	(–5.51)	(–3.72)	(–7.19)	(–5.06)	(–5.35)
CAPTOT	0.666***	0.293*	0.725***	0.0542	0.701***	0.280*	0.690***	0.0816
	(3.36)	(2.35)	(3.58)	(0.27)	(3.44)	(2.17)	(3.43)	(0.40)
AVGSIZE	–0.432	–1.536***	–0.228	0.353	–0.467	–1.720***	–0.285	0.395
	(–1.77)	(–6.10)	(–1.02)	(1.71)	(–1.91)	(–6.75)	(–1.27)	(1.88)
WASTE	0.698***	0.775***	1.033***	0.805***	0.697***	0.770***	1.054***	0.789***
	(4.75)	(7.43)	(9.56)	(7.04)	(4.75)	(7.18)	(9.69)	(6.86)
N	2302	2837	2680	2875	2302	2837	2680	2875
pseudo R^2	0.36730	0.11571	0.09918	0.21945	0.36394	0.16773	0.10140	0.22684
Ll	–514.1	–888.5	–854.1	–791.6	–516.8	–836.2	–852.0	–784.1
P	9.74e-123	4.87e-45	1.04e-35	3.19e-90	1.45e-121	3.55e-67	1.37e-36	1.99e-93

Note: t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$