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Related variety and economic development: a literature review

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Abstract: Since the introduction of the related variety in 2007, a number of studies have been undertaken to analyze the effect of related variety on economic development. Our review of 21 studies makes clear that most studies find support for the initial hypothesis that related variety supports employment growth, though some studies suggest that the growth effects of related variety may be specific to knowledge-intensive sectors only. From the review, we list a number of further research questions regarding: methodology, the role of unrelated variety, different forms of relatedness, and the effect of related variety on knowledge production and entrepreneurship.

1. Introduction

In recent research in economic geography, an empirical body of literature has emerged on the role of related variety in regional development. The concept of related variety was put forward by Frenken et al. (2007) as to further specify the common hypothesis that regions may benefit from producing a variety of products and services, as more variety implies more potential for inter-industry knowledge spillovers. Frenken et al. (2007) emphasized that: “one expects knowledge spillovers within the region to occur primarily among related sectors, and only to a limited extent among unrelated sectors” (p. 688). That is, they hypothesized that inter-industry spillovers occur mainly between sectors that draw on similar knowledge: knowledge originating from one sector is most relevant to, and can most effectively be absorbed by, another sector that is related in the sense that firms draw on similar knowledge (about technology, markets, etc.).

The concept of related variety was introduced in an attempt to resolve an earlier empirical question put forward by Glaeser et al. (1992) whether regions benefit most from being specialized or being diversified. This "controversy" is commonly referred to as “MAR versus Jacobs”, referring to the theories of Marshall, Arrow and Romer suggesting spillovers to take place primarily within a single industry versus the theory of Jacobs (1969, p. 59) who argued that “the greater the sheer numbers and varieties of divisions of labor already achieved in an economy, the greater the economy’s inherent capacity for adding still more kinds of goods and services". The theories of MAR view innovation mainly as incremental where firms learn from knowledge and innovation from same-industry firms (otherwise known as "localization economies"), while Jacobs views innovation essentially as a recombinant process that necessarily builds on a pre-existing variety of knowledge and artefacts that are being combined in new ways leading to new products and services, viz. new employment.

As reviewed by De Groot et al. (2015), the many empirical studies on Mar versus Jacobs, which followed on the seminal study by Glaeser et al. (1992), have provided very mixed results (Figure 1).[1] There are almost as many studies that find evidence for the MAR hypothesis, as there are studies that disprove it. And, while a large share of studies finds evidence confirming Jacobs externalities, still a substantial share of studies finds no effect of variety on regional growth, or even opposite effects. It also seems evident from the many studies yielding insignificant results, that the theoretical notions of specialization and variety seem too simplistic to capture the varied effects of an economy's composition on its further development.

FIGURE 1 AROUND HERE

Frenken et al. (2007) agreed with Jacobs that innovation is essentially a recombinant process (what Schumpeter famously called "Neue Kombinationen"), but qualified the notion of recombination arguing that some pieces of knowledge and artefacts are much easier to recombine than other pieces of knowledge and artefacts. Hence, variety is especially supportive for innovation and regional development when variety is *related*, be it in a technological sense or in a market sense. The reasoning here is similar to that of diversified firms, where is has been argued that firms undergoing related diversification outperform firms undergoing unrelated diversification, because only the former profit from economies of scope.[2]

Frenken et al. (2007) specifically hypothesized that related variety would spur employment growth, as new combinations lead to new products or services and, hereby, to new jobs. Localization economies stemming from the spatial

[1] Note that most studies also take into account a competition variable, following Porter's (1990) work on the advantages of competition (in clusters).

[2] Analogously, some authors prefer to speak of *geographies of scope* (Florida et al. 2012) instead of related variety.

concentration of firms in the exact same industry, instead, would enhance process innovation as specialized knowledge is used to optimized production processes in existing value chains. Such innovations spur labour productivity, and do not necessarily lead to more jobs. The related-variety thesis is thus consistent with product lifecycle theory, which poses that young industries with high rates of product innovation create jobs in diverse urban areas, while mature industries with high rates of process innovation spur productivity in specialised peripheral areas (Duranton and Puga 2001; Capasso et al. 2015).

The concept of related variety is also consonant with the concept of product space introduced by Hidalgo et al. (2007). They argued that countries develop by diversifying their export portfolio over time. They showed that countries typically do so by "branching out", that is, by entering export products that are closely related to the products they already export. The reasoning underlying this phenomenon holds that once a country has developed the capabilities to specialize in exporting particular products, it can easily diversify in related products that require very similar capabilities to produce them. By calculating, for each possible new product, the "proximity" of related products already present in a country's export portfolio, the authors could show that the higher the average proximity of related products vis-à-vis a new potential product (which they called "density"), the higher the chance that a country will diversify into this new product. This idea is in line with related variety, because the more products a country already exports related to a product that it does not yet export, the more likely it will start exporting that product in the future. The difference between the related-variety and the product proximity concepts is that the former is used to explain aggregate regional or national growth, while the latter is used to explain diversification events into specific new products or industries at the regional or national level.

The related-variety hypothesis has motivated a large number of empirical studies on the effect of related variety in sectoral composition on national and regional economic development as indicated by employment, income or productivity, or by diversification measured as a country's or region's entry into a new industry. We

provide a systematic review of empirical studies at the regional and national level in the next section. That means that we focus on the *related-variety* literature following Frenken et al. (2007) analyzing how related variety affects regional/national growth as well as the *branching* literature following Hidalgo et al. (2007) analyzing how related variety vis-à-vis a specific industry affects the probability that a region/nation becomes specialized in that specific industry.[3] We limit our review to papers that have been either published or accepted for publication in scientific journals[4]. Hence, we omit current working papers on the topic.

2. Related-variety studies

Below, we review 16 studies we found that analyzed the effect of related variety on employment growth, or another economic performance indicator, at either national or regional levels. We summarize the set-up and results of each study in table 1.

The first study to associate variety with regional economic growth is Frenken et al. (2007), who looked at employment growth in a study on 40 Dutch regions. They argued that on the one hand related variety is expected to increase employment growth and on the other hand unrelated variety is expected to decrease

[3] Given the macro-scope of the review with a focus on regional and national growth, we do not go into micro-level studies investigating the effect of regional related variety on firm performance. This is, to a large extent, already covered by a recent review by Frenken et al. (2015) on industrial dynamics in clusters. From this review, it became apparent that firms profit most if co-located with firms in other, but related, industries rather than being co-located with firms operating in the same industry. In the latter environments, the benefits from learning from firms in the same industry may well be offset by increased competition as well as knowledge spillovers to direct competitors, especially for the more advanced firms.

[4] We selected papers to review by searching for papers that i. cited Frenken et al. (2007) in case of the related variety studies, or ii. Hidalgo et al. (2007) in case of the branching studies, or iii. contained the keyword 'related variety', or iv. Contained the keywords 'revealed comparative advantage' and 'proximity'.

unemployment growth. Unrelated variety in this respect can be described as a measure of risk-spreading that cushions the effects of an external demand shock in a certain sector. This is explained by the fact that a higher degree of unrelated variety in a region will cause that region overall to be affected just moderately in the case of a sector specific shock in demand. Whereas the specialization in one or few sectors will result in the opposite scenario, as the region is exposed to the probability of a severe slowdown. Empirically, using the Standard Industrial Classification scheme, Frenken et al. (2007) measured related variety as the average entropy across employment in five-digit industries within each two-digit class, while unrelated variety is the entropy in employment across 2-digit classes. They showed that related variety, as hypothesized, enhances employment growth. The results also confirmed the portfolio effect, as they found that unrelated variety is negatively related to unemployment growth.

Using OECD export data on a national level, Saviotti and Frenken (2008) later found related export variety to stimulate GDP growth per capita and labor productivity, while unrelated export variety only promotes growth with a considerable time lag. They explain this finding by the type of innovation that benefits from variety. Related variety means that knowledge is easily recombined in new products causing direct growth effects. Unrelated variety is harder to recombine, but if successful, can lead to complete new industries sustaining long-term growth. This study, however, did not include control variables and calls for more refined follow-up studies.

Boschma and Iammarino (2009) used regional trade data of Italy to study the effects of variety in regional exports and found that variety *per se* was not found to explain regional growth. However, related export variety was found to have a positive and significant association with regional growth and employment, in contrast to unrelated export variety. The authors also looked at the similarity between the importing and exporting sectors and found some evidence that it will support regional employment. This finding, however, is not robust in the sense that this effect was not found for regional growth in labor productivity or value added growth.

Other studies looked at the effect of related variety on growth indicators other than employment growth. Boschma et al. (2012) showed that Spanish regions with higher levels of related variety are likely to have higher levels of value-added growth. They did so using two additional measures of related variety in order to overcome some limitation of the entropy measure that is based on the standard industrial classification (SIC), which defined relatedness "ex ante", as Boschma et al. (2012) put it. One of the alternative "ex post" methods they employ is based on Porter's (2003) study on clusters where relatedness is measured on the basis of the spatial correlation of employment between sectors. The other measure is based on the proximity index of Hidalgo et al. (2007), based on the co-occurrence of products in production portfolios. Boschma et al. (2012) found that related variety is positively related with regional growth using any of the three measures, and that the effect is stronger for the cluster (Porter) and proximity (Hidalgo) indicators relative to the entropy (Frenken) measure.

Falcioğlu (2011) looked at productivity growth in Turkish regions, and finds that related variety, rather than variety as a whole, of regional economic activity positively impacts a region's productivity. The author has defined productivity in two ways, as output divided by labor and value added dived by labor. Instead of looking at the industrial structure, Quatraro (2010) also analyzed regional productivity growth, and specifically how knowledge affects regional growth in Italy. The results suggest that, not only the regional knowledge stock affects regional productivity growth rates but also the composition and the variety of the knowledge stock matter. Related knowledge variety seems to positively affect regional productivity, while unrelated knowledge variety was found to be insignificant.

TABLE 1 AROUND HERE

Yet other studies analyzed whether the effect of related variety differs across industries. Bosma et al. (2011) distinguished between total factor productivity growth in manufacturing and in services for 40 Dutch regions. They found that related variety had a positive effect on productivity growth in manufacturing, but a slightly negative effect on productivity growth in services. Mameli et al. (2012) examined the relationship between related variety and regional employment growth in local labor systems of Italy. Without making further distinctions both related and unrelated variety in general have a positive effect on regional employment growth. Distinguishing between manufacturing and services, and contrary to Bosma et al. (2011), related variety positively affected regional employment in services, while unrelated variety positively affects regional employment growth in manufacturing. Hartog et al. (2012) investigated the impact of related variety in Finland, they did not found evidence that related variety in itself influences employment growth. Rather when decomposed into a low/medium-tech sectors and high tech sectors, related variety between high-tech sectors seems to positively impact regional employment growth. The distinction between sectors here is based on the R&D intensity and the share of tertiary educated persons employed.

Bishop and Gripaios (2010) looked at the effect of related variety on regional employment growth *per industry* in Great Britain. They argue that distinguishing between the manufacturing and services industry might be an oversimplification as these sectors themselves are also heterogeneous and thus the mechanisms and extent to which spillovers occur differ between sectors. Motivated by this argument the authors make use of a disaggregated approach, and look at employment growth in each 2-digit sector as dependent variables. Their assumed heterogeneity between sectors is reflected in the results, as related variety has a significant positive impact on employment growth only in 3 out of the 23 sectors (telecom, computing and other business activities), and – surprisingly – unrelated variety has a significant positive impact in 8 out of the 23 sectors.

More recently, Cortinovis and van Oort (2015) conducted their research using a pan-European dataset. Following the original set-up of the study by Frenken et al. (2007), they hypothesize that related variety is positively related to employment growth due to knowledge spillovers across sectors, unrelated variety is negatively related to unemployment growth due to portfolio effects associated with a diversified economy and as a result dampened effects of sector-specific shocks. Specialization is positively related to productivity due to cost-reduction and efficiency gains achieved through localization externalities. They fail to find evidence supporting these hypotheses. However, when introducing technological regimes, they found related variety to positively affect employment growth and productivity in regions characterized by high technology. Van Oort et al. (2015) also looked at the pan-European level and make a distinction between smaller and larger regions' urban size in order to account for differences in agglomerative forces. They find that related variety has a positive effect on employment growth, which seems to be stronger for small and medium urban regions compared to large urban regions. No significant effect was found for unrelated variety. In a most recent pan-European study on employment growth at the sectoral level, Caragliu et al. (2016) did not find evidence for the hypothesis that related variety enhanced employment growth. Instead, they found a positive and significant effect of unrelated variety on employment growth. This study is rich in that it looks at 259 NUTS2 regions in the EU and for an extensive period (1990-2007). However, given data limitations, the authors defined unrelated variety as the entropy at the one-digit industry level and related variety as the weighted sum of the entropy at the two-digit level, within each one-digit class. Hence, their results are not fully comparable with studies looking at a more fine-grained industrial level in line with Frenken et al. (2007). Furthermore, their dependent variable was employment growth within a single sector, as only Bishop and Gripaios (2010) did before, rather than overall employment growth in a region as most studies did before.

3. Branching studies

The concept of related variety as introduced by Frenken et al. (2007) associated related variety in a regional economy with total employment growth of that regional economy. A complementary perspective is to analyse whether related variety vis-à-vis a specific industry enhances the growth of that particular industry, because that industry benefits from spillovers from related industries. This research design was first introduced by Hidalgo et al. (2007) and later followed by a number of studies both at national and regional levels. We summarize the set-up and results of each study in Table 2.

Hidalgo et al. (2007) introduce the concept of product space, where each product has a certain proximity to each other product, indicting its relatedness. They measure relatedness of products using a proximity indicator based on how often two products co-occur in countries' export portfolios. The idea here holds that if many countries have a comparative advantage both in product A and in product B, apparently A and B are somehow related, sometimes referred to as "revealed relatedness" (Neffke and Henning 2008). Hidalgo et al. (2007) argue that if a country has a comparative advantage[5] in producing a certain product, chances are high it will also obtain a comparative advantage in products that are related to it in terms of, for instance what kind of skills, institutions, infrastructure, physical factors, or technology is needed. Their study shows that countries indeed generally become specialized in new products which are related to products it already is producing.[6] They also show that some countries are located in the center of this product space exporting products that are related to many other products, while other countries are located more to the periphery with fewer connections to related products. Being located more to the periphery thus means having to "travel" a larger distance to the center, which in turn might help explain that poorer countries are struggling to develop competitive products and therefore might fail to converge as they are

[5] A country has a comparative advantage in a product, if the product's share in a country export portfolio exceeds the product's share in total trade worldwide.

[6] A more extensive study was reported in the working paper Hausmann and Klinger (2007).

located more to periphery of the product space with less connections to related products.[7]

TABLE 2 AROUND HERE

Neffke et al. (2011) ask the same question as the original study by Hidalgo et al. (2007), but at the regional level. Indeed, as for countries, regions are most likely to branch into industries that are technologically related to the preexisting industries in the region. Using data on products being co-produced at the same plants, they were able to measure in detail the relatedness structure between products based on co-occurrences. They then show for 70 Swedish regions during the period 1969-2002 that industries that were technologically related to pre-existing industries in a region had a higher probability to enter the region, as compared to unrelated industries. Furthermore, they show that unrelated industries had a higher probability to exit the region.

Similarly, Boschma et al. (2013) analyzed the emergence of new industries in 50 Spanish regions in the period 1988–2008. A novel element in this study is the inclusion of measure indicating how related a local industry is vis-à-vis the national production profile. In line with Neffke et al. (2011), this study also provides evidence that regions tend to diversify into new industries that use similar capabilities as existing industries in these regions. They show that proximity to the regional industrial structure plays a much larger role in the emergence of new industries in

[7] Hidalgo & Hausmann (2009) later developed a method that captures an economy's complexity and show that higher levels of complexity of an economy are associated with higher levels of income. Their method is based on two dimensions, the first is the ubiquity of the products exported (by how many countries is a product exported?) and the second is the diversification of an economy (how many products does a country export?). They show there is a negative relationship between these two dimensions, i.e. diversified countries tend to export less ubiquitous products. For further refinements, see Tacchella et al. (2012) and Cristelli et al. (2015).

regions than does proximity to the national industrial structure. This finding suggests that capabilities at the regional level enable the development of new industries. This result was further confirmed by a more recent study on 360 U.S. metropolitan areas (Essletzbichler 2015).

Another question holds whether certain countries or regions are better capable of diversifying into unrelated industries compared to other countries or regions. Boschma and Capone (2015) took up this question at the national level, and hypothesized that certain types of institutions enable unrelated diversification more than other types of institutions. In particular, following the distinction made by Hall and Soskice (2001), they found that liberal-market institutions (e.g., United States) are more flexible than coordinated-market institutions (e.g., Germany) in reallocating labour and capital from one sector to another unrelated sector. This can be explained by the actors in coordinated-market economies being primarily oriented towards collaboration and stability. Hence, they will tend to diversify into related industries as to maximally leverage existing knowledge, institutional arrangements and collaborative relationships. In liberal-market economies, this is less so, as both firms, suppliers, employees and other stakeholders are relatively more self- interested and driven by opportunities rather than on preserving existing arrangements and relationships *per se*.

A final topic that has been addressed building on the original study by Hidalgo et al. (2007) is the question of spatial spillovers. If a region or country lacks a certain local capability rendering it difficult to diversify into related products, it may still be able to do so if it can leverage the spatial proximity to such capabilities through spillovers. Bahar et al. (2014) address this question and show that a country is more likely to start exporting a product when a neighboring country is already exporting the product. In addition, they find that having a neighboring country with a strong comparative advantage in a certain product, has positive predictive power on future growth in the country's own comparative advantage of that same product. Their results furthermore indicated that, regardless of size, income level, cultural and

institutional dimensions, and factor endowments, the variety of products exported by countries is remarkably similar to their neighbors.

Boschma et al. (2014) extended this line of research by analyzing the effect of neighboring regions and the probability a region develops a new industry for US states. They show that a region has a higher probability to develop a certain industry if the neighboring region is specialized in it. This might be explained by knowledge spillovers that are more easily absorbed at small distances, that is, the strong distance-decay effect of knowledge spillovers over spatial distance. In addition they find that neighboring states show a high similarity in the variety of exported products, suggesting a convergence process. A more recent study by Boschma and Capone (2015b) looked more specifically at import profiles at the country level. Here, they found that a country tends to enter into a new product not only when its own product portfolio is close to this new product ("density") but also when its import portfolio is close to this new product ("import density").

4. Future research

The review of related variety research made clear that – although the evidence base is still rather small with 21 studies – most studies find support for the initial hypothesis by Frenken et al. (2007) that related variety supports some form of regional growth. Those who looked at inter-industry differences found that the effects of related variety on growth may be specific to certain industries only, especially manufacturing and knowledge-intensive ones (Bishop and Gripaios 2010; Bosma et al. 2011; Hartog et al. 2012; Cortinovis and van Oort 2015). Concerning the studies looking how countries or regions develop new industries following Hidalgo et al. (2007), it was also found that if a region or countries already hosts industries that are related to a specific industry, it is much more likely to become specialized in that industry.

A number of follow-up research questions come to mind that can be taken up in future research:

1. Though evidence is generally in support of the related variety thesis, the possibility of publication bias is not inconceivable given a more general tendency to under-report negative results, especially in the emerging stage of a new topic area. Future research would benefit from more standardized research designs as well as more comprehensive reporting of possible model specifications. In particular, various dependent variables indicating economic development are being used including employment growth, productivity growth and GDP growth, and sometimes measured in different ways. Future research could follow the original related-variety theory arguing that related variety spurs product innovation and, hereby, employment growth. Hence, ideally, any empirical analysis includes an analysis of the effect of related variety on employment growth, possibly next to other dependent variables. Regarding the measurement of related variety with entropy measures or density as the average proximity of products to a new product, authors do use standardized measures. However, the empirical data on which the measures are applied can be different, for example, different digit levels or a different population of products. Again, in so far as possible, standardization is needed.

2. Findings that suggest that related-variety effects on growth are confined to certain sectors (Bishop and Gripaios 2010; Hartog et al. 2012; Mameli et al. 2012; Cortinovis and van Oort 2015) deserve further theoretical and empirical elaboration. A common thread among these studies point to the role of knowledge intensity. Indeed, one theoretical line of argument may build on the idea that more knowledge spills over across related industries, when these industries are knowledge-intensive in the first place.

3. Methodologically, the key question at present holds: what is the best method and data source to capture related variety? Frenken et al. (2007) relied entirely on the pre-given hierarchical classification as provided by the Standard Industrial Classification scheme. This has the advantage of being amenable to entropy decomposition into related and unrelated variety, yet

has the disadvantage that relatedness is defined ex ante from a hierarchical classification scheme that was never intended to capture technological relatedness viz. spillovers. Hidalgo et al. (2007) derive relatedness from the co-occurrences of products in countries' portfolios. This method derives relatedness ex post from data rather than ex ante from a classification scheme, yet only measures relatedness indirectly and remains agnostic about the exact source of relatedness causing industries to co-locate in countries. As an alternative to Frenken et al. and Hidalgo et al., the work by Neffke and Henning (2013) seems promising. They measure relatedness by the number of people changing jobs between two industries, thus capturing directly "skill-relatedness". Alternatively you could explore, at least for the industries that patent large parts of their knowledge base, the relatedness of patents by looking at patent classes, citations and inventor mobility. The best results are probably obtained by a smart triangulation of these approaches.

4. Theoretically, there are many reasons to expect that regions or countries generate product innovation from related variety (Frenken et al. 2007) and diversify into related industries (Hidalgo et al. 2007). However, this leaves unexplained why, and under what conditions, regions/countries with unrelated variety can also yield product innovation (especially radical ones), and also leaves unexplained why some regions/countries manage to diversify into unrelated industries. To break with path dependence and create new growth paths through true new recombinations, regions will have to rely more on knowledge and resources residing in other regions. Hence, (policies attracting) multinationals, immigrant entrepreneurs and mobile scientists may well underlie new path creation. Some evidence on this thesis is already available but more research would be needed to come to a more comprehensive understanding (Binz et al., 2014; Dawley, 2014; Neffke et al., 2014).

5. Another question concerns the geographical sources of spillovers through related variety. Rather than solely looking at a region's internal structure, the

relatedness vis-à-vis other regions with which a regions intensively interacts, may also matter. That is, most studies did not pay attention to knowledge spillovers originating from extra-regional activity. These type of spillovers can occur in numerous ways, for instance the trading of goods and services, foreign direct investment, and global value chains are relations that may cause otherwise tacit knowledge to spillover between regions. The extent to which a region can benefit from foreign knowledge inflows trough these types of relationships depends also on the region's own knowledge and knowhow, i.e. its absorptive capacity. In addition to that they suggest that the inflow of knowledge needs to exhibit complementarities to the existing knowledge. It should be related, however not similar. More research along these lines would highlight the role of trade, and global value chains in particular, in generating spillovers between related industries.

6. A natural extension of the current research – both theoretically and empirically – is to look at relatedness in other dimensions than those related to technological knowledge. For example, Tanner (2014) developed a market relatedness indicator and has showed how this indicator predicts quite well regions' technological development in fuel cell technology. A similar argument can be made regarding institutional relatedness. Regions are more likely to diversify into industries that are institutionally related to the industries already present, not only as actors can build on existing institutional arrangements and practices, but also as actors are likely to face less resistance moving into institutionally relate industries than into institutionally unrelated industries.

7. Since most studies focus on the effect of related variety on either employment growth or the emergence of a new export specialization as dependent variable, the mechanism *how* related variety leads to growth and export specializations remains rather implicit. What can be done in future studies is to analyze directly the impact of related variety on entrepreneurship, knowledge and innovation, which in turn are expected to

lead to employment and exports. Quite some studies already analyzed the effects of related and unrelated variety on patents as dependent variable (Kogler et al. 2013; Tavassoli and Carbonara 2014; Castaldi et al. 2015; Rigby 2015; Tanner 2015), but fewer of such studies exist looking at scientific publications (Boschma et al. 2014; Heimeriks and Balland 2015) or new firm formation (Colombelli and Quatraro 2013; Guo et al. 2015; Colombelli 2016) as dependent variables.

8. Finally, related-variety studies hitherto focuses on how related variety affects economic development, while research on the geography of knowledge recombination processes at the micro-level remains rather unconnected to the related-variety literature. A challenge for future research will be to combine the macro-level work reviewed here with the emerging micro-level work on related variety, both theoretical (Strambach and Klement 2012; Davids and Frenken 2015), and empirical (Antonietti and Cainelli 2011; Aarstad et al. 2016), as to come to a better multi-scalar understanding how regional conditions and constraints as well as various forms of proximity affect recombination processes of knowledge among related and unrelated domains.

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Figure 1. Overview of outcomes of empirical studies on the effect of MAR (specialization) vs. Jacobs (diversity) externalities on regional growth. Note that competition is often taken as a third explanatory variable. Taken from: De Groot et al. (2015).

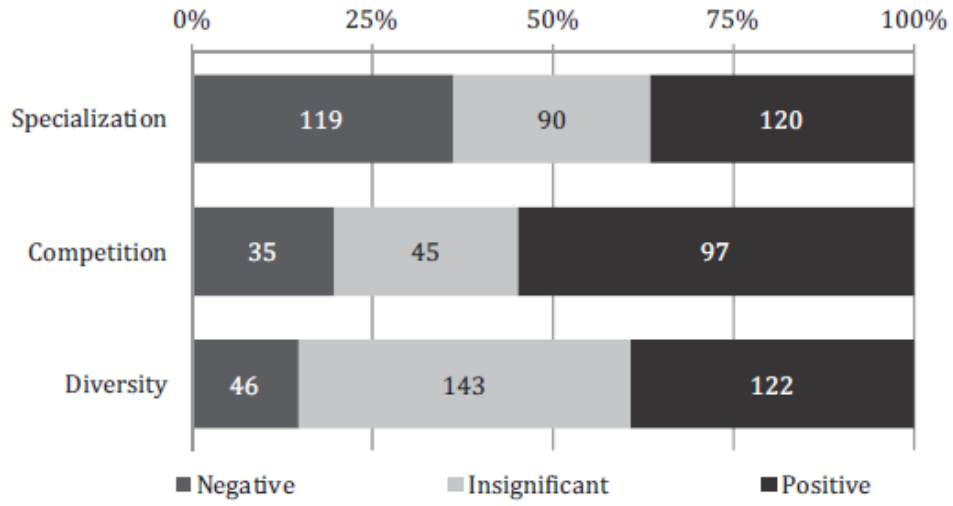

Table 1: Related-variety studies. iV stands for independent variable; dV stands for dependent variable. The columns RV and UV show the significance of related- and unrelated variety on the dependent variables shown in the column dV(s). + and –indicate significant positive or negative effects, respectively, whereas 0 and M indicate no significant- or mixed results, respectively.

Author(s)	Unit	Coverage	Period	Data source	Main iv(s)	Digits	dv(s)	RV	UV
Frenken, van Oort & Verburg (2007)	NUTS3	Netherlands	1996-2002	CBS	Related variety Unrelated variety	RV = 5 in each 2 UV = 2	Employment growth Productivity growth Unemployment growth	+ - 0	0 0 -
Saviotti & Frenken (2008)	National	OECD	1964-2003	OECD trade data	Unrelated export variety Semi related export variety Related export variety	UV = 1 SV = 2 in each 1 RV = 3 in each 2	GDP per cap Labor productivity	+ +	- -
Boschma & Iammarino (2009)	NUTS3	Italy	1995-2003	ISTAT	Export variety Related export variety Unrelated export variety Import variety Related trade variety	Variety = 3 RV = 3 in each 2 UV = 1	Employment growth Value-added growth Labor-productivity growth	M + M	0 + 0
Bishop & Gripaios (2010)	Sub-national	Great Britain	1995-2002	NOMIS	Related variety Unrelated variety	RV = 4 in each 2 UV = 2	Employment growth at 2-digit industry-level	M	M
Quatraro (2010)	NUTS2	Italy	1981-2002	ISTAT EPO	Total variety Unrelated variety Related variety	RV = 3 in each 1 UV = 1 TV = 3	Productivity growth	M	0
Bosma, Schutjens & Stam (2011)	NUTS3	Netherlands	1990-2002	CBS Chambers of Commerce	Related variety	RV = 5 in each 2	Productivity growth	M	
Falcioğlu (2011)	NUTS2	Turkey	1980-2000	Turkish statistical institute	Variety Related variety	Variety = 3 RV = 3 in each 2	Productivity growth	+	

Boschma, Minondo & Navarro (2012)	NUTS3	Spain	1995-2007	INE, Ivie, and Agencia Tributaria	Related variety Unrelated variety Porter relatedness measure Hidalgo relatedness measure	RV = 6 in each 2 UV = 1	Value-added growth	+	0
Hartog, Boschma & Sotarauta (2012)	NUTS4	Finland	1993-2006	Statistics Finland	Related variety RV-HiTech RV-LowTech Unrelated variety	Variety = 5 RV = 5 in each 2 UV = 2	Employment growth	+	0
Mameli, Iammarino & Boschma (2012)	Local labor market	Italy	1991-2001	ISTAT	Variety Related variety Unrelated variety	Variety = 3 RV = 3 in each 2 UV = 1	Employment growth	+	+
Cortinovis & van Oort (2015)	NUTS2	Europe	2004-2012	ORBIS, Bureau van dijk	Unrelated variety Related variety Specialization Technological regime	UV = 1 RV = 4 in each 2	Employment growth Unemployment growth	+ M	0 M
van Oort, de Geus & Dogaru (2015)	NUTS2	Europe	2000-2010	Amadeus	Related variety Unrelated variety	RV = 4 in each 1 UV = 2	Employment growth Productivity growth Unemployment growth	+ 0 0	M 0 0
Caragliu, de Dominicis & De Groot (2016)	NUTS2	Europe	1990-2007	Cambridge Econometrics	Related variety Unrelated variety	RV = 2 in each 1 UV = 1	Employment growth at industry-level	0	+

Table 2: Branching studies. iV stands for independent variable; dV stands for dependent variable. All studies showed a significant effect of density or closeness on the probability of entry into a new product or industry, or a rise of the RCA

Author(s)	Unit	Coverage	Period	Data source	Digits	Main iv(s)	dv(s)
Hidalgo, Klinger, Barabási & Hausmann (2007)	National	132 countries	1990-1995	NBER	SITC-4	Density	Entry
Neffke, Henning & Boschma (2011)	A-region	Sweden	1969-2002	Statistics Sweden	SNI69-6	Closeness	Membership Entry Exit
Boschma, Minondo & Navarro (2013)	NUTS3	Spain	1988-2008	NBER World Trade Agencia Tributaria	SITC-4	Density at country level Density at province level	Entry
Bahar, Hausmann & Hidalgo (2014)	National	World	1962-2008	World Trade Flows UN & COMTRADE & WDI & UNCTAD	SITC-4	Density RCA neighbor	Entry
Boschma, Martin & Minondo (2014)	State	US	1997- 2007	US Census Bureau Comtrade	HS-4	Density RCA neighbor	RCA Growth
Boschma & Capone (2015a)	National	23 countries	1970-2010	World Trade Flows and CEPII	6-digits	Density Institution indicator	Entry
Boschma & Capone (2015b)	National	EU27 ENP16	1995-2000	BACI	4-digits	Density Import density	Entry
Essleztbichler (2015)	Metropolitan areas	US	1975-1997	Bureau of Economic Analysis	SIC-4	Closeness	Membership Entry Exit