Industrial resilience, regional diversification and related variety during times of crisis in the US urban–rural context

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\textbf{ABSTRACT}
This paper evaluates the role of related variety in the industrial resilience of US counties against the 2008 economic shock. We use employment data on six-digit industries and measure industrial resilience by the extent to which a county maintained or improved entry rates of new industrial specializations in the post-crisis period of 2009–14 as compared with 2002–07. We find that metropolitan counties are more resilient than other types of areas. Related variety exhibits a strong positive effect on industrial resilience. This effect appears to be driven by intermediate and rural counties, which particularly benefit from related variety.

\textbf{KEYWORDS}
regional resilience; diversification; related variety; urban–rural divide

\textbf{INTRODUCTION}
The global economic crisis of 2008 constitutes one of the most significant economic crises since the Great Depression of the 1930s. While the nature of the crisis was global, significant subnational disparities in vulnerability to the shock and in recovery have been noted, in both the United States (Chapple & Lester, 2010; Delgado & Porter, 2021; Deller & Watson, 2016; Doran & Fingleton, 2018; Han & Goetz, 2019) and Europe (Cainelli et al., 2019; Capello et al., 2015; Dijkstra et al., 2015; Fagiani et al., 2018). The economic shock first originated in the US housing and financial markets, and thus first impacted metropolitan areas, but from there it spread quickly to more rural and remote counties, which showed less resilience to the crisis (Han & Goetz, 2015). Metropolitan areas may benefit from urbanization economies, which support productivity and innovation, but it is unclear if they are inherently more resilient than rural areas (Giannakis & Bruggeman, 2017; Grabner, 2021). In fact, Fingleton et al. (2012) show that recessionary shocks permanently affect employment in focal regions and their proximate regions in the UK. Giannakis and Bruggeman (2017) show that rural regions are more resilient to recessionary shocks than urban regions in Greece, while Cainelli et al. (2019) underline how advanced and more industrial regions seem to be most affected immediately after an economic shock than the other regions, even if in the long run they experienced higher resiliency than less advanced regions. The mechanism that drove these patterns is firmly linked to the socio-economic characteristics and industrial structures of the regions (e.g., productive specialization, diversification, technological resilience). In this paper we investigate patterns and drivers of industrial resilience across US counties, paying particular attention to the differences among metropolitan and rural counties, with respect to the 2008 global economic crisis.

We define industrial resilience following the evolutionary approach, which highlights that a decisive element of regional resilience is the ability of regions to diversify into new growing industrial activities (Boschma, 2015). Diversification, defined as the development of an industrial specialization that is new to a region’s specialization portfolio, is particularly meaningful during times of rapid change and crisis, as regions that continue to diversify their industrial base, thus show a high industrial resilience, have a higher capacity to adapt to new circumstances and build new development paths (Boschma, 2015; Pike et al., 2010). Indeed, case studies such as Evans and Karecha...
Resilience is driven by an array of factors, but to tackle the question of industrial resilience specifically, an understanding of how regions successfully diversify and create new industrial specializations is required: the literature on regional diversification and innovation has shown that the presence of a diverse set of related industries, a situation called related variety, promotes intersectoral knowledge spillovers and provides better opportunities for recombinations across industries from which new industry specializations may develop (Content & Frenken, 2016; Frenken et al., 2007; Neffeke et al., 2011). However, in a crisis context does related variety make regions more vulnerable to a disruption of their industrial diversification process, as the decline of one crisis-stricken industry may affect the innovation opportunities of other related industries in the region (Boschma, 2015)? Moreover, does the role of related variety differ among metropolitan and rural areas? Rural areas are more specialized, so they may benefit more from added related variety than metropolitan areas. The latter, on the other hand, may profit from possessing a variety of unrelated industries in order to counteract shock contagion among related industries. By addressing these questions, this paper contributes to the literature in three main ways: first, the different patterns and drivers of resilience between metropolitan and rural areas require more empirical evidence, especially with respect to industrial resilience. Contrary to European Union (EU)-based research, the US context allows for a clearer interpretation of the results because EU urban–rural classification change according to historical/geographical/institutional characteristics of the different EU member states (Dijkstra et al., 2015; Modica, 2017; United Nations Department of Economic and Social Affairs (UNDESA), 2018). Furthermore, the United States suffers of a more severe urban–rural political divide than EU. In fact, Gimpel et al. (2020) find for the first time evidence that US urban rural political differences are rooted in geography rather than in the individual characteristics of people. Second, past studies on resilience in US counties applied aggregate measures of resilience (Chapple & Lester, 2010; Delgado & Porter, 2021; Deller & Watson, 2016; Doran & Fingleton, 2018; Han & Goetz, 2019), thus by applying the definition of industrial resilience of Xiao et al. (2018), which focuses on the industrial diversification process with respect to an economic shock, this paper complements existing US studies. Third, empirical research on the role of related variety for regional development is primarily set in European regions, with the exception of Castaldi et al. (2015), who used US state patent data. Thus, an application of the related variety concept in US counties is currently missing.

Using employment data on six-digit North American Industry Classification System (NAICS) industries, we find a heterogeneous picture of industrial resilience across US counties underlining deep urban–rural discrepancies. In fact, among of the metropolitan counties, 17% are highly resilient and 47% resilient, whilst of the rural counties, 11% are highly resilient and 2% resilient. Consequently, 87% of the rural counties are classified as non-resilient to the 2008 crisis in terms of industry entry, compared with 36% of metropolitan counties. The regression analysis further reveals that related variety exhibits a strong positive effect on the probability that a county is resilient and highly resilient. This suggests that the 2008 crisis did not undermine the benefits associated with related variety for the diversification of a county. However, as suspected, we find differences along the urban–rural divide, as the positive role of related variety for industrial resilience appears to be driven by rural (and intermediate) counties. Increasing related variety in metropolitan counties on the other hand, impedes industrial resilience, while also unrelated variety does not play a role. Overall, our analysis indicates that regions, in particular rural ones, should foster a diverse profile of related industries in order to create new industrial specializations also during times of crisis.

CONCEPTS OF RESILIENCE

The term ‘resilience’ takes different interpretations according to objects, aims and framework of the analysis, even if it generally refers to the responsiveness of systems to shocks or changes (Rocchetta & Mina, 2019). Consequently, studies on regional economic resilience are fundamentally interested in the capacity of regions to deal with shocks, and what drives that process (Deller & Watson, 2016; Doran & Fingleton, 2018; Martin, 2012).

However, conceptualizations of resilience can be broadly categorized in three perspectives. First, engineering, where resilience refers to a systems’ ability to absorb shocks without experiencing changes and efficiently return to its unique pre-shock equilibrium. The second perspective originates from environmental sciences, the so-called ecological resilience, and focuses on whether a shock is pushing a system from one equilibrium to a new one (Christopherson et al., 2010). The ecological view resembles in many ways the concept of economic hysteresis, which is a situation where a unique disturbance permanently affects the development path of the economy. Finally, the third perspective, the so-called evolutionary or adaptive resilience, focuses on the capacity of regions to continuously reconfigure their economic structure beyond recovery (Boschma, 2015; Christopherson et al., 2010; Simmie & Martin, 2010). The latter approach therefore links resilience to the ability of regions to adapt by diversifying and creating new industrial growth paths despite disruptive crisis or shocks. As a consequence, regional industrial diversification, with the aim of developing distinctive new areas of specialization despite economic shocks, is regarded as a central element for regional
resilience in the evolutionary perspective (Boschma, 2015). This study adopts the evolutionary view and as such defines a region as resilient, if it continues to successfully diversify into new industrial activities when confronted with an economic shock. Following Xiao et al., 2018, we henceforth refer to this process of successful industrial diversification during crisis as industrial resilience.

**DRIVERS OF INDUSTRIAL RESILIENCE**

Resilience in all its shapes is found to be driven by a plethora of factors. Martin and Sunley (2015) argue that resilience is determined by the dynamics of four main regional economic subsystems: the industrial structural subsystem; the labour market; the financial subsystem; and governance. This paper focuses on the first subsystem and contributes to the strand of literature that investigates empirically the role of the local industrial structure. Past empirical studies on this issue with respect to the 2008 global economic crisis in European regions (Cainelli et al., 2019; Martin et al., 2016; Xiao et al., 2018) and US counties and metropolitan areas (Chapple & Lester, 2010; Delgado & Porter, 2018; Deller & Watson, 2016; Doran & Fingleton, 2018; Han & Goetz, 2019; Hill et al., 2010) generally found, that the industrial composition, its diversity and specialization patterns shape regional resilience.

To tackle the question of industrial resilience specifically, an understanding of how regions successfully diversify and create new industrial specializations is required. Diversification is a strongly path-dependent process: regions tend to diversify into new industries that are related to existing local industries (Hidalgo et al., 2018). Two industries are related if they demand similar capabilities, such as knowledge, skills, technologies and institutions (Boschma, 2017). Relatedness supports knowledge spillovers across industries as recombinations are more feasible and effective across activities that share similar capabilities (Frenken et al., 2007). Consequently, the underlying complementarities of local industries are considered a key determinant of diversification. The concept of related variety captures this situation and describes an industrial system where a region possesses a diverse set of industries which are related to each other (Frenken et al., 2007). It can therefore be expected that related variety is also a key factor in driving industrial resilience, thus the diversification of regions during or despite major economic disruptions.

Despite empirical support for the positive impact on regional development in general, theoretically it is not obvious that related variety must be a positive force for diversification during times of major crisis. An economic shock could reverse the effect, as a region with a high level of related variety among its industries is vulnerable to a disruption of its diversification processes: when a crisis causes the decline of one local industry also the innovation opportunities of the related industries in the region are affected (Boschma, 2015). Thus, potentially a high level of unrelated variety, a situation where a region has a diverse set of sectors, which however share little in terms of knowledge and technology, is more beneficial for industrial resilience: since local industries are dissimilar in their required knowledge, the decline of one industry does not hurt the learning and innovation opportunities of other firms in that region (Boschma, 2015). Moreover, since shocks spread more easily in related industries (Acemoglu et al., 2013), unrelated variety may act as a shock container and as a regional portfolio strategy that protects a region from an external demand shock (Frenken et al., 2007).

**THE 2008 US ECONOMIC CRISIS ALONG THE URBAN–RURAL DIVIDE**

The 2008 economic crisis in the United States was a significant economic shock, which destroyed more than 6 million jobs and had the slowest job recovery of any previous recession (Sherk, 2013). Thus, it represents an ideal case to investigate industrial resilience. In early 2007 a financial crisis began to brew in a complex series of events when the housing bubble, which was fuelled by complicated new financial instruments, burst. The housing collapse first generated widespread liquidity problems, a decline in the stock market and soaring household debt (Hausman & Johnston, 2014). In December 2007 the financial crisis spread to the real economy and the National Bureau for Economic Research (NBER) officially announced the beginning of a recession. Figure 1 shows the quarterly percentage change of US gross domestic product (GDP), which displays a large decline in the period starting in the last quarter of 2007 until the end of 2008. While GDP recovered quite quickly, the labour market struggled even after the official end of the recession in June 2009.

The 2008 economic shock was a systemic crisis, yet some regions were hit harder than others. Han and Goetz (2015) show that the downturn first affected large metropolitan counties with overheated housing markets. Only then the economic shock hit the more rural counties in the centre of the United States, which showed less resilience. However, there is no consensus if urban areas are indeed fundamentally more resilient than rural areas (Giannakis & Bruggeman, 2017). What is clear, is that urban and rural economies are different in many aspects, ranging from the economic structure to human capital and institutions, which likely affect the determining factors for resilience (Grabner, 2021). In particular, agglomerated areas often experience urbanization economies, which arise from a more diversified economic structure and increased opportunities for interactions and knowledge spillovers (Duranton & Puga, 2004). Urbanization economies likely support industrial resilience, as they are associated with enhanced productivity and innovation. However, they also bring about negative consequences: besides possible issues with congestion, high land rents and pollution (Glaeser, 2012), cities also tend to be specialized in more crisis prone sectors such as finance or real estate and they are more connected to global markets which makes cities more exposed to external economic shocks (Fratesi & Rodríguez-Pose, 2016). On the
contrary, rural areas are specialized in less valuable but often more stable sectors such as agriculture (Giannakis & Bruggeman, 2017) and they experience a more limited exposure to global financial markets, which could make them less vulnerable to adverse shocks (Han & Goetz, 2019). Moreover, there is evidence that the role of related variety for the economy differs between urban and rural areas: Van Oort et al. (2015), who looked at European regions, find that the positive effect of related variety on employment growth is stronger for small and medium size regions in terms of population as compared with larger urban regions. They hypothesize that perhaps due to agglomeration disadvantages, the largest urban regions do not benefit as much from related variety. Similarly, Xiao et al. (2018) found that relatedness is more important for diversification in peripheral regions due to their lower innovation capacity.

MEASURING INDUSTRIAL RESILIENCE

We use data from the County Business Pattern (CBP) programme of the US Census Bureau, which provides annual employment data of all US counties at detailed industrial level according to the NAICS. Unsuppressed data from the WholeData database were generously provided by the UpJohn Institute (Bartik et al., 2018), which is harmonized to the 2012 NAICS codes, and covers the period 2002–14. The data encompass 3125 counties and 675 traded NAICS six-digit sectors on the private non-farm economy. Moreover, we employ the 2013 Rural–Urban Continuum Codes (RUCC) from the US Department of Agriculture (USDA), which distinguishes between nine regional typologies. The RUCC characterize metropolitan counties by the population size of their metro area, and non-metropolitan counties by degree of urbanization and adjacency to a metro area (see Table A1 in the supplemental data online). We aggregate the codes to differentiate between metropolitan (codes 1–3), intermediate (codes 4–7) and rural (codes 8 and 9) counties.

Following the definition of industrial resilience, as a region’s ability to keep diversifying and creating new industrial growth paths (Xiao et al., 2018, p.5), we measure industrial resilience by comparing entry rates of new industrial specializations in US counties before and after the crisis. A resilient place is therefore one that successfully moves its regional economy into new industry specializations despite disturbances such as the 2008 economic crisis (Xiao et al., 2018).

An entry of a new industry in a county is defined as a situation where a region becomes specialized in an industry in which it was not previously specialized in. We divide our dataset into two six-year periods: pre-crisis 2002–07 and post-crisis 2009–14. Following Xiao et al. (2018) we set four criteria to identify a new specialization. First, the location quotient of industry \( i \) in county \( c \) must be greater than 1, meaning that the concentration of six-digit NAICS industry \( i \) in county \( c \) is higher than the average concentration in the United States.

\[
LQ_{ci} = \frac{E_{ci}}{E_{c}} > \frac{E_{ni}}{E_{n}} \tag{1}
\]

Second, employment (\( E \)) in industry \( i \) in county \( c \) has to be larger than the average industrial employment in county \( c \). Thus, industry \( i \) is a major sector in county \( c \).

\[
E_{ci} > \text{avg}(E_{i}) \tag{2}
\]

Third, employment in industry \( i \) in county \( c \) has to be larger than average employment in industry \( i \) in the whole of United States. That would mean that county \( c \) is an important area for industry \( i \).

\[
E_{ci} > \text{avg}(E_{ni}) \tag{3}
\]

Lastly, industry \( i \) in county \( c \) has to experience absolute employment growth.

\[
E_{ci} - E_{ci-6} > 0 \tag{4}
\]

All industries that fulfil these four criteria are identified as a specialization in county \( c \). Accordingly, we define an entry of a new industry if the industry is found to be specialized in county \( c \) at year \( t \) but not at year \( t - 6 \).
which are then summed up for each county and each period. Figure 2 shows the entry numbers of new specialized industries in five quantiles, while Table 1 displays the median pre- and post-crisis across the three different typologies. Overall, median entry number has decreased from seven before the crisis (2002–07) to five after (2009–14), but there are substantial spatial differences visible in the map. The median entry number in metropolitan areas has decreased from 15 before the crisis to 11 after, intermediate areas experienced a decrease from seven to five, while rural areas had a median of only two industry entries in both periods.

To define resilient counties, we adopt a slightly modified procedure derived from Xiao et al. (2018). We perform a transition probability analysis to identify counties that show a high rate of entry over both periods as well as regions that shift from a state of lower rate of entry in the pre-crisis period to a state of higher rate of entry after the crisis.

First, we rank counties based on their industry entry numbers for both periods. Xiao et al. (2018) rank counties in three quantiles; however, we decided to use five quantiles for two related reasons: first because of the different sample size (3125 US counties versus 168 EU regions) and, second, because we are able to capture smaller changes in industry entry between the two periods. We apply Xiao et al.’s classification and estimation strategy as a robustness check. Second, we divide counties in very low, low, medium, high and very high groups based on their rank. Third, a transition probability matrix shows the probability that a county transitions from one group x to another group y between the two periods:

\[
P_{xy} = P(q_{02-07} = x | q_{09-14} = y)
\]

Table 2 reports the transition matrix for all industries: the cells in the diagonal represent counties with persistently very low, low, medium, high and very high entry numbers, which is the most likely case.

Following this, we define counties in three resilience types: resilient, highly resilient or non-resilient. Counties that remain in the top three groups (very high, high and medium) are defined resilient because they showed continuity in their good performance in terms of industry entry. Counties that remain in the lowest two groups (low and very low) or transitioned to a lower group are defined as non-resilient because they either were unable to improve already low entry rates or show a deteriorating performance. Contrary, those counties that transitioned from a

**Table 1.** Median entry numbers of newly specialized industries.

|          | 2002–07 | 2009–14 |
|----------|---------|---------|
| Total    | 7       | 5       |
| Metropolitan | 15     | 11      |
| Intermediate | 7      | 5       |
| Rural    | 2       | 2       |

**Figure 2.** Entries of newly specialized industries (quantiles) before and after 2008.
lower group to a higher one, excluding transitions from the group very low to low, are then defined as highly resilient because they were able to improve their rank group despite the crisis.

Figure 3 shows the distribution of the three resilience types in percentage. Based on industry entry dynamics, 29% of all counties are classified as resilient, 18% as highly resilient and 51% as non-resilient. However, there are large differences among regional typologies: 47% of metropolitan counties are resilient and 17% are highly resilient, while only 2% of rural counties are resilient and 11% are highly resilient. Intermediate areas host the largest share of highly resilient counties, as 23% of intermediate areas are highly resilient. While Han and Goetz (2015) measure resilience by observing drop and rebound of a county’s aggregate employment, they find similar patterns regarding the resilience of counties among the urban–rural divide, that support the high resilience performance of agglomerated areas. However, intermediate area hosting the largest percentage of highly resilient counties hints, that they may be at the advantage of enjoying some benefits of urbanization economies, while escaping its dis-economies. Dijkstra et al. (2015) makes this argument with respect to European regions.

Figure 4 displays the geographical distribution of resilient (R), highly resilient (HR) and non-resilient (N) counties. The pattern of the resilience types resembles that of Figure 2: the Far-, South-West, the Great Lakes region, New England and the Mideast concentrate many resilient and highly resilient counties. Also, regions in the Rocky Mountains cluster many (highly) resilient counties.

In summary, we observed a heterogeneous picture of industrial resilience in the United States counties and the following section aims to investigate the factors which influence a county’s resilience.

**METHOD AND VARIABLES**

We estimate the influence of related and unrelated variety on the probability that a county is resilient and highly resilient with respect to the 2008 economic crisis and further interact these variables with typology dummies coming from the urban–rural continuum classification.

To assess the likelihood that a county is resilient, we estimate a multinomial logit model, where the dependent variable is categorical with the three resilience types identified in the previous section: resilient, highly resilient and non-resilient.

\[
P(y = m|x) = \frac{e^{x\beta_{m,NR}}}{\sum_j e^{x\beta_{j,NR}}} \tag{6}
\]

Equation (6) expresses the probability of a county of belonging to a certain group, relative to belonging to a base group, as a function of characteristics summarized by the \(x\) vector.

To compute related and unrelated variety we use 675 traded six-digit sectors in 3125 US counties. Following

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**Table 2. Transition probability matrix.**

|          | 2009–14 |
|----------|---------|
|          | Very low | Low | Medium | High | Very high |
| 2002–07  | 0.57     | 0.30 | 0.11   | 0.01 | 0         |
| Low      | 0.32     | 0.39 | 0.23   | 0.05 | 0.01      |
| Medium   | 0.11     | 0.26 | 0.37   | 0.23 | 0.03      |
| High     | 0.01     | 0.07 | 0.24   | 0.43 | 0.26      |
| Very High| 0        | 0.01 | 0.05   | 0.27 | 0.68      |
Frenken et al. (2007) unrelated variety (UV) is defined as the diversity across 19 two-digit NAICS groups in a county. Related variety (RV) is measured as the weighted sum of six-digit variety within a given two-digit group.

\[
UV = \sum_{s=1}^{S} P_s \log_2 \frac{1}{P_s} \\
RV = \sum_{s=1}^{S} P_s (7)
\]

where the subscript \( s \) denotes a two-digit group and \( i \) a six-digit sector, which exclusively belongs to one \( s \). \( P_s \) denotes the employment share of two-digit groups, which is calculated as the sum of the employment share of six-digit sectors \( (P_i) \). \( H_s \) refers to the six-digit variety within each two-digit group \( S \).

Additionally, we control for several other local economic factors as summarized in Table 3. The following control variables are based on county employment data (Bartik et al., 2018): the Los index, which proxies localization economies; \(^5\) pre-crisis employment growth suggests general labour market performance before the economic shock; The share of supply chain (SC) industries, which are especially important for innovation and growth and thus, may influence industrial resilience. Delgado and Mills (2020) identified SC sectors as those that sell more than two-thirds of their goods and services to other industries. Moreover, commuting, education and inequality (proxied by the Gini index) may impact a county’s industrial resilience. These variables originate from the 2010 US Census. For a correlation matrix, see Appendix A2 in the supplemental data online. We also include state dummies to control for other state specific confounding factors as well as typology dummies (for the USDA RUCC, see Appendix A1 online) to account for population and a counties’ urbanity or remoteness.\(^6\)

**RESULTS**

Table 4 provides the results of the multinomial regression, where the non-resilient group acts as the base category. We find that the estimated coefficient of related variety

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**Table 3. Summary statistics.**

| Variable             | Definition                                                      | Mean  | SD    | Minimum | Maximum |
|----------------------|-----------------------------------------------------------------|-------|-------|---------|---------|
| Entry 02–07          | Entry of new industrial specializations                         | 9.23  | 7.48  | 0       | 37      |
| Entry 09–14          | Entry of new industrial specializations                         | 7.16  | 5.96  | 0       | 34      |
| Unrelated Variety    | Variety within two-digit industries, 2007                       | 16.85 | 10.56 | 0       | 46.98   |
| Related Variety      | Variety across two-digit industries, 2007                       | 2.17  | 0.68  | 0.16    | 3.66    |
| Lox Index            | Localization economies, 2007                                     | 0.07  | 0.07  | 0.01    | 1.01    |
| Employment Growth    | Average employment growth, 2002–07                              | 0.02  | 0.04  | −0.12   | 1.01    |
| Commuting            | Number of in-commuters per capita, 2011                         | 0.39  | 0.13  | 0.08    | 2       |
| Education            | % of the local population with bachelor’s degrees or above, 2010| 21.20 | 9.25  | 5       | 78      |
| Gini Index           | Income inequality, 2010                                         | 0.43  | 0.04  | 0.31    | 0.64    |
| Share of SC Sectors  | Employment share of supply chain industries, 2007               | 0.25  | 0.12  | 0       | 0.88    |
| GDP per Capita       | Gross domestic product per capita                               | 45.14 | 298.90| 7.82    | 16,164.24|

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\(^5\) Bartik et al., 2018.

\(^6\) Delgado and Mills, 2020.
is positive and statistically significant meaning that we observe a positive association with the probability that a county is resilient (R) and highly resilient (HR). This result indicates that related variety has likely increased the degree of industrial resilience with respect to the 2008 crisis, rather than making counties more vulnerable. Unrelated variety on the other hand, does not seem to play a role for industrial resilience, as the estimated coefficient is statistically insignificant. Moreover, the coefficient of related variety is larger on the probability that a county is resilient than highly resilient. Related variety thus appears to be more important for regions that continue to be successful in terms of entry rates than for those regions that make a shift from a pre-crisis state of lower rate of entry towards a state of higher rate of entry after the crisis. Xiao et al. (2018), who conduct a similar analysis of industrial resilience in European regions, also conclude that related variety is positively associated with industrial resilience, but contrary to our analysis find a larger effect for the probability that a region is highly resilient.

Table 4. Probability (relative risk ratio) of being resilient (R) and highly resilient (HR).

|                      | HR          | R           | HR          | R           |
|----------------------|-------------|-------------|-------------|-------------|
| Related.Variety      | 2.039***    | 3.959***    | 1.766***    | 4.165***    |
|                      | (0.098)     | (0.096)     | (0.115)     | (0.116)     |
| Unrelated.Variety    | 0.993       | 0.879*      | 1.053       | 1.038       |
|                      | (0.073)     | (0.075)     | (0.081)     | (0.086)     |
| Los.Index            | 0.824**     | 0.733***    |             |             |
|                      | (0.080)     | (0.112)     |             |             |
| Employment.Growth    | 0.895       | 1.049       |             |             |
|                      | (0.071)     | (0.062)     |             |             |
| Commuting            | 1.051       | 0.872       |             |             |
|                      | (0.074)     | (0.090)     |             |             |
| Education            | 1.106       | 0.906       |             |             |
|                      | (0.085)     | (0.083)     |             |             |
| Gini.Index           | 0.902       | 0.886*      |             |             |
|                      | (0.066)     | (0.072)     |             |             |
| Share.of.SC.Industries| 1.027      | 1.127*      |             |             |
|                      | (0.060)     | (0.068)     |             |             |
| GDP.per.capita       | 1.288       | 1.072       |             |             |
|                      | (0.186)     | (0.497)     |             |             |
| Constant             | 0.719       | 0.539       | 0.417       | 0.313       |
|                      | (0.567)     | (0.801)     | (0.598)     | (0.832)     |
| Observations         | 3125        | 3125        | 3125        | 3125        |
| Pseudo-R²            | 0.208       | 0.208       | 0.215       | 0.215       |

Note: Base group: non-resilient. Includes rural-urban continuum codes and states as dummies. *p < 0.1; **p < 0.05; ***p < 0.01.

In Table 5 we additionally include dummies for intermediate and rural counties in the regression, keeping metropolitan as the base category, and interact them with related and unrelated variety. The interaction terms help us to understand if and how these regional typologies mediate the role of related and unrelated variety. Based on theory and past empirical evidence, we expect that related variety may be particularly important for industrial resilience in more rural, less agglomerated contexts, as it can provide counties not only with economic diversity, but also with enhanced knowledge spillovers through complementarities among local industries. More urban and agglomerated areas on the other hand, unrelated variety may provide a much-needed portfolio strategy to diminish shock contagion from international markets and spread the risk, which could enhance industrial resilience. The regression results firstly indicate, that, relative to metropolitan areas, being intermediate and rural increases the likelihood that a county belongs to the highly resilient group. This effect is larger for rural areas than for intermediate ones. However, both typology dummies are insignificant with respect to predicting if a county is classified as resilient.

The interaction terms with related variety further reveal, that increased related variety enhances the likelihood of being resilient and highly resilient in both typologies, intermediate and rural areas. Again, the size of the coefficient reveals, that especially rural areas benefit from related variety. These differentiated roles of related variety among metropolitan, intermediate and rural areas confirm our expectations, and patterns which have been found in previous literature (Van Oort et al., 2015; Xiao et al., 2018). The interaction terms with unrelated variety, however, do not have any statistical significance, which further reinforces to the idea that variety per se is not enough to
support regional economies and complementarities among local industries are essential.

**ROBUSTNESS CHECKS**

One potential concern of this analysis is related to simultaneous causality issue. In fact, one might argue that higher levels of resilience may drive high levels of relatedness. In trying to underline this issue, we conduct several robustness checks to test the sensitivity of our results. For the results of robustness checks, see the Appendix in the supplemental data online.

The first check regards potential inter-industry differences. Counties may differ in their ability to develop various types of sectors and there is evidence that the effects of related variety may be specific to knowledge-intensive industries (Bishop & Gripaios, 2010; Cortinovis & Van Oort, 2013; Hartog et al., 2012). However, we could also argue that more resilient regions are those with a large share of knowledge-intensive industries. Thus, we employ Delgado and Mills’s (2020) industry classification which distinguishes between SC industries and business-to-consumer (B2C) industries (i.e., those that sell primarily to consumers). According to Delgado and Mills, SC industries account for the majority of patents and science, technology, engineering and math (STEM) jobs, making them more knowledge-intensive than B2C industries. We then re-calculate the dependent variable to account separately for entries in SC and B2C industries and repeat the regression analysis, in the case of endogeneity we might observe dramatic change in the estimation of the results. Table A4 in the supplemental data online shows that the results for related and unrelated variety do not change between industrial resilience based on the entry dynamics of SC or B2C industries, thus we argue that endogeneity might be not severe. Second, we apply Xiao et al.’s (2018) resilience classification and binomial logit estimation strategy. They rank European regions in three industry quantiles and define type A resilient regions as those that stay in the second or third quantile (similar to what we have labelled a ‘resilient county’) and type B resilient regions which transition from the second to the third quantile (similar to what we have labelled a ‘highly resilient county’). Table A5 online shows that related variety only has a statistically significant effect and positive sign with respect to predicting whether a county is type A + B resilient and type A resilient, whereas it is insignificant with respect to type B resilience alone. Unrelated variety continues to be insignificant. Third, we check whether our main results are sensitive to the time period, as the onset and end of the crisis is not well defined. To do so, we re-calculate our dependent variable and consider industry entries only between 2002 and 2005 and 2011 and 2014 (see Table A6 online). The results are confirmed in this check. Lastly, we use different estimation strategies to repeat the regression analysis: binomial logit, binomial probit, ordered logit and ordinary least squares (OLS) (see Tables A7–A10 online). The results do not depend

### Table 5. Probability (relative risk ratio) of being resilient (R) and highly resilient (HR): typology interactions.

|                      | R      | HR     | R      | HR     |
|----------------------|--------|--------|--------|--------|
| Related.Variety      | 1.472*** | 3.442*** | 1.397*** | 3.266*** |
|                      | (0.127) | (0.122) | (0.144) | (0.133) |
| Unrelated.Variety    | 1.023   | 1.034   | 1.107   | 1.115   |
|                      | (0.082) | (0.086) | (0.133) | (0.117) |
| Intermediate         | 1.575*** | 1.030   | 1.565*** | 1.015   |
|                      | (0.142) | (0.138) | (0.143) | (0.139) |
| Rural                | 3.175*** | 0.901   | 3.110*** | 0.884   |
|                      | (0.334) | (0.410) | (0.339) | (0.418) |
| Related.Variety*Intermediate | 1.506**  | 1.988*** | 1.631*** | 2.172*** |
|                      | (0.165) | (0.167) | (0.190) | (0.190) |
| Related.Variety*Rural | 5.953*** | 11.194*** | 6.011*** | 11.509*** |
|                      | (0.349) | (0.550) | (0.385) | (0.625) |
| Unrelated.Variety*Intermediate | 0.874   | 0.870    | 0.154   | 0.141   |
|                      | (0.220) | (0.381) | (0.154) | (0.141) |
| Unrelated.Variety*Rural | 0.978   | 0.951    | 0.022   | 0.381   |
|                      | (0.220) | (0.381) | (0.220) | (0.381) |
| Constant             | 0.441   | 0.363   | 0.440   | 0.363   |
|                      | (0.588) | (0.822) | (0.588) | (0.825) |
| Control variables    | Yes     | Yes     | Yes     | Yes     |
| Observations         | 3125    | 3125    | 3125    | 3125    |
| Pseudo-R²            | 0.220   | 0.220   | 0.220   | 0.220   |

*Note: Base group: non-resilient. Includes rural–urban continuum codes and states as dummies and control variables.

*p < 0.1**p < 0.05***p < 0.01.
on the estimation strategy as the roles of related and unrelated variety and their interactions with the typology dummies are consistent across the checks. It is worth mentioning that in the OLS regression, the interaction term between related variety and rural is significant and negative with respect to predicting if a county is resilient, while in all other models this effect is positive.

**DISCUSSION AND CONCLUSIONS**

Industrial diversification, or the creation of new industrial specializations, fosters innovation and growth, while offsetting processes of stagnation, decline and lock-in (Boschma, 2015). Diversification, therefore, is a pivotal element in a local economies' recovery after an economic shock such as the 2008 global financial crisis or the Covid-19 pandemic. This idea is embedded in the definition of industrial resilience: the capacity of a regional economy to keep diversifying and create new industrial activities in response to a major crisis (Xiao et al., 2018). In this paper, we provided empirical evidence on the pattern of industrial resilience across US counties in the context of the 2008 Global Economic Crisis. Measuring industrial resilience by comparing entry rates of new industrial specializations before and after 2008, the paper shows, that US counties differ significantly in their capacity to develop new industries in response to the crisis. Metropolitan areas were much more successful in terms of industry entry than intermediate and rural counties. Indeed, 64% of metropolitan counties are resilient or highly resilient, while the same holds only for 13% of rural counties. Previous work by Han and Goetz (2015) on employment resilience demonstrates similar spatial patterns across US counties. Yet the question if urban areas are inherently more resilient than rural ones due to potential benefits from urbanization economies remains largely elusive (Giannakis & Bruggeman, 2017; Grabner, 2021).

A multifarious process such as regional resilience is driven by an array of local socio-economic factors. Industrial resilience in particular may be driven the industrial structure and complementarities among local industries: related variety, a situation where diverse set of local industries share similar skills and technologies, supports knowledge spillovers, innovation and thus the creation of new industries in general (Frenken et al., 2007). Yet, during an economic crisis, this positive role of related variety could turn negative, as the decline of one crisis-stricken industry could hurt innovation opportunities of related industries in the region and thus negatively affect resilience (Boschma, 2015). Unrelated variety on the other hand could provide regions a portfolio effect, protecting the regional economy from crisis contagion and supporting resilience. The latter might be particularly important in metropolitan areas, which a more open to international markets, while related variety may be more essential in rural areas, that tend to be more specialized.

Our results show that related variety in general exhibits a positive effect on the probability that a county is resilient and highly resilient. Thus, the diversity and complementarities of local industries that related variety captures appear to strengthen a county’s diversification process during times of crisis. As a general pattern we find that related variety is more important for the probability of being a resilient county than a being a highly resilient one. Unrelated variety on the other hand does not have a statistically significant impact on a counties’ resilience. This further reinforces the idea that variety per se is not enough to support regional economies and complementarities among local industries are essential. We further find that the insignificant role of unrelated variety appears identical in intermediate and rural counties, but the effect sizes of related variety are different: related variety supports the likelihood that a county is resilient and highly resilient in both typologies, but the effects are larger in rural areas. Consequently, the diversification process in rural areas with respect to the 2008 crisis profited from diversity and knowledge spillovers that increased related variety can provide. Agglomerated areas on the other hand, may already suffer some negative externalities of diversity, such that additional related variety actually decreases their industrial resilience.

While these differentiated effects are interesting, future research has to further investigate the mechanisms and causes of the diverging role of related variety across the urban–rural divide. According to this, as underlined by Xiao et al. (2018), a multiscalar approach to assess the relative importance of capabilities is necessary. Regional policies, then, have to incorporate not only the fact that relatedness is an important factor enabling diversification in regions but also the fact that diversification plays different roles while stimulating the innovative capacity of urban or rural regions reducing lock-in effects especially for peripheral regions. In fact, rural regions show high potential in developing economic growth when the degree of related variety increases. Nonetheless, the empirical analysis of this paper yields some policy directives to strengthen regional industrial resilience: regional policies should not only focus on promoting growth and competition but should explicitly entail elements of adaptability to ensure resilience. As such, policies should be defined to contain stimulation for adaptation to a changed context, as caused by systemic crisis, through continued renewal of the productive structure. To support such a diversification process during crisis periods, the results of this paper reinforce policy directives of smart specialization strategies especially in strengthening the capacity of regions to resist to a shock in the light of the urban–rural divide. In fact, regional policies should foster industrial diversity by leveraging existing strengths but pay specific attention to the complementarity of target sectors. Moreover, smart specialization strategies denounce top-down ‘one-size-fits-all’ measures, and instead emphasize the importance of place-based policies (Foray, 2015). This papers’ findings add to the latter element, by suggesting the smart specialization policies for resilience also ought to take into consideration the urban–rural context in which they should operate.
Industrial resilience, regional diversification and related variety during times of crisis in the US urban–rural context

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NOTES

1. See https://www.nber.org/research/data/us-business-cycle-expansions-and-contractions/.

2. Source: FRED, https://fred.stlouisfed.org/series/A191RP1Q027SBEA/.

3. See https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx/.

4. We excluded 2008 because it is the only full year within the recession period announced by the NBER (December 2007–June 2009). Since the onset and end of the crisis is not clearly defined in all counties, we consider a more generous timeframe in the robustness checks.

5. Localization economies refer to the economies of agglomeration associated with specialization and are measured by means of the Los index (Los, 2000), which takes into consideration the technological proximity of industries. We use Hidalgo et al.’s (2007) co-occurrence analysis to infer proximity from the probability of co-specializations of two industries in the same county. By doing so, we obtain a $675 \times 675$ proximity matrix $\varphi$. Equation (8) shows the mathematical notation of the Los index, where $i$ and $j$ refer to a pair of industries in a county $c$, $\varphi$ is based on the minimum of the pairwise conditional probability that a county has a specialization of one industry $(x_i)$ given its co-specialization of another $(x_j)$ (Hidalgo et al., 2007):

$$\text{Los}_c = \sum_{i=1}^{675} \sum_{j=1}^{675} E_{ci}E_{cj} \phi_{ij} \sum_{i=1}^{675} \sum_{j=1}^{675} E_{ci}E_{cj}, \quad \phi_{ij} = \min[p(x_i|x_j), p(x_j|x_i)]$$

6. Since we are applying a multinomial logit estimation strategy, we tested if the independence from irrelevant alternatives (IIA) assumption holds for our regressions. A Hausman test confirms that the odds are not affected by omitting one outcome category in the regression, which suggests that the IIA holds. The results are available from the authors upon request.

7. For the full regression table, see Table A3 in the supplemental data online.

8. Nonetheless, we are aware that a more formal method should be applied. A Bartik strategy might solve any further doubts.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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