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CITY SIZE AND PRODUCTION DIVERSITY:

Patterns of specialisation and diversity in the US cities, 1969-1997

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Abstract

Research on the issue diversity and specialisation of cities over the last decade has shed new light on the "empirical regularity" of a relationship between city size and industrial diversity, identified in the early 1970s. Nevertheless, the results obtained from the theoretical models are not yet conclusive and indeed depend on the assumptions employed. Moreover, empirical research on the topic is relatively undeveloped and the stylised facts are not yet fully understood. In this paper we employ a panel data analysis for a big number (333) of US cities over a period of twenty-nine years (1969-1997), revealing two interesting results. First, time and city effects are highly significant. Second, while a positive relationship between size and diversity is apparent in the cross-sectional analysis, the time series and pooled investigations reveal a negative relationship. This, we interpret as evidence of the existence of a system of cities. In support to that, overall, our results suggest the existence of a complexity of mechanisms, which cannot be attributed simply to an exogenous city size effect. Under this perspective, the current theoretical advances in new economic geography seem to be the most useful tools in understanding the patterns and relationships identified in this paper.

JEL Classification: C23, R12.

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I. Introduction

The hypothesis of the existence of a direct relationship between the size of a city and the (degree of) industrial diversity of its economy is pretty old and rather widespread. A corresponding "empirical regularity" has for a long period been identified, dating back to at least the early 1970s (Clemente and Sturgis, 1971, 1973; Crowely, 1973; Henderson, 1974; Paraskevopoulos, 1975). Despite that, a coherent and sufficiently convincing theoretical explanation was hardly provided in this early empirical literature. The theoretical framework for the conceptualisation of the determinants of this relationship in this early literature was quite loosely related to the notions of spatially variable factor prices (Evans, 1972) and localisation and urbanisation economies (Hoover, 1936). Briefly reviewed, such theoretical understandings were based on the fact that while land and labour prices (rents and wages) increase with city size (at a diminishing rate), the price of business services decreases (at a diminishing rate) with city size and the price of capital (interest rate) remains constant. As different firms and industries use different proportions of factors of production, their production costs will be minimised in different locations. For example, labour-intensive production firms will (other things equal) tend to locate in smaller cities than firms which require a more intensive use of business services. In addition, different industries realise to different extents the benefits of localisation (within industries) economies, while urbanisation (between industries) economies apply equally to all firms from all industries. Large cities, then, attract not only business-oriented industries, but also industries for which urbanisation economies are relatively important. On the other hand, smaller cities tend to be more specialised, due to centripetal forces (the impact of localisation economies).

The regeneration of economists' interest in spatial aspects in recent years has boosted research on the economics of cities and the determinants of city formation and evolution. However, the focus has shifted from the identified "empirical regularity" towards a more structural understanding of the relation between cities' formation and growth and their industrial bases and diversity. This was partially due to the recognition of the existence of a multiplicity of city specialisation and diversity patterns (Duranton and Puga, 1999a), although the "empirical regularity" is still supported by the findings of contemporary research (Begovic, 1992; Henderson, 1997b; Black and Henderson, 1998). A number of theoretical models that have been developed almost at the same period, have proposed different mechanisms relating to the city size – industrial diversity interplay. Abdel-Rahman and Fujita (1990) have introduced Marshallian-type agglomeration economies to the initial Henderson's (1974) theoretical set up, to show that specialisation of cities is the long-run equilibrium condition, with larger cities specialising in industries that are related to bigger externalities (require bigger "critical masses"). In the same line of argument, in a series of papers, Abdel-Rahman (1990a, 1990b, 1994, 1996; see also Kim, 1991 and 1992 and Abdel-Rahman, 1992) has showed that under specific assumptions larger cities tend to be more specialised, in contrast with the stylised facts, implicitly raising an issue of optimality of the existing urban systems. On the other hand, a direct account of urbanisation economies (Begovic, 1992), economies of scope (Abdel-Rahman and Fujita, 1993) and learning-by-doing (Duranton and Puga, 1999b) can alter the predictions of such models so that the equilibrium condition will be larger cities to be more diversified in terms of their industrial base.

A more relevant theoretical contribution on the issue comes from the work of Paul Krugman (Krugman, 1991a, 1991b). Based on this work, a new economic geography literature has attempted a re-statement of the traditional spatial economic analysis of the first half of the twentieth century. Specifically, strong micro-economic foundations have been applied to the theoretical works of Christaller (1933) and Losch (1940). Their work, the central-place theory, combines transportation costs and economies of scale (agglomeration economies) to produce a regular hierarchical landscape of a system of cities, with bigger cities (the central places) being the more diversified and the more dynamic. The models developed by Fujita and Krugman (1995 and 2000), Fujita and Mori (1997) and Fujita et al. (1999) have introduced product variety in non-agricultural production as a source of agglomeration forces and cross-industry differentiation of price elasticities as a source of the formation of a hierarchical system of cities. Under this set-up, the economic behaviour of profit and utility maximising agents leads to an optimal (but very volatile) hierarchical non-regular system of cities where larger cities are more diversified. This later work is for up to date the best and more thorough explanation offered in the literature for the empirically identified relationship between city size and industrial diversity.

Despite, however, the new connections with coherent theoretical insights, the issue of the relation between city size and industrial or production diversity is still yet far from fully understood. Moreover, many misconceptions are potentially around. First, what holds in the dimension of space does not necessarily hold in the dimension of time. As diversity is a relative term, city size cannot be related to it in absolute terms. For example, a city may be growing over time but at the same time declining in terms of population shares. Assume that it becomes more specialised. Is this the outcome of absolute growth, or the outcome of relative decline? To add more ambiguities, assume that this city becomes more specialised in absolute terms, but at the same time the whole country becomes more specialised, so that the city ends up being more diversified in relative terms. What is then the real, structural relationship between city size (growth) and industrial diversity?

In this paper we do not attempt to answer these questions. Nor do we attempt to explain the mechanisms of city formation (which is what much of the literature of the new economic geography is engaged with). Rather, our main objective is to offer some more detailed evidence on what has been long perceived as a common knowledge: that diversity is positively related to city size. In the next section we present our data and methodology and discuss some drawbacks and advantages related to them. Section 3 looks in more detail at the stylised facts as revealed from our data. In sections 4, 5 and 6 we perform the empirical investigation, at the cross-city, time-series and panel dimensions of the data, respectively. Finally, in the last section we summarise our findings and discuss their implications as well as directions for further research.

II. Methodology and Structure of the Analysis

The empirical analysis undertaken here was motivated by the following observation. Despite the fact that a positive relationship between industrial diversity and city size has long been considered to be a well-established "empirical regularity", there is evidence that this relationship is not constant over time.[1] Specifically, in a time-series analysis, city size seems to be negatively related to industrial diversity, implying that diversity is decreasing in time (as population increases with time). If this is really the case, then it is really important to study the time-behaviour of the relationship between diversity and city-size and identify its determinants. This can better be done with a panel of data.

We use a sample of 333 US cities for the years 1969-1997 (29 years; total sample is 9657 observations).[2] The cities considered in the analysis are all large and medium sized cities, of a total population above 50,000 people in 1997 (above 25,000 in 1969). The employment shares refer to 1-digit SIC data, as it was impossible to collect consistent time-series data for a sufficiently big and representative number of cities at a more disaggregate level. Specifically, there are significant inconsistencies accruing from changes in the definition of 2-digit sectors over time and from the lack of data for some specific sectors for some years.[3] The use of 1-digit SIC data is a necessary evil of our analysis, effectively diverting the focus from industries to economic sectors. Nevertheless, it has also a number of advantages. First, the full consistency of the definition of sectors over time. Second, the fact that it allows us to use a very big panel of data and to look at time trends in the relationship that we want to investigate. Because of the fact that we use 1-digit SIC data, we prefer to think of our analysis as an analysis of "diversity in the production base" of the economy, rather than an analysis of "industrial diversity". Such an analysis is not uninteresting, since most of the theoretical formulations that refer to the concept of industrial diversity (agglomeration economies and diseconomies, central place theory, etc) can be applied to the case of production diversity, as well. And all the economic advantages and disadvantages that accrue from industrial diversity can more or less be the outcome of production diversity as well. The economic sectors that we consider are the following: agriculture, mining, construction, manufacturing, transport, wholesale trade, retail trade, finance, services and government.

The analysis is divided into four parts. *First*, we take a look at the time-trends of the indexes of specialisation and diversity (for each of our 333 sample cities). *Second*, we perform cross-city regressions for each year (29 in total) and for each one of our indexes. This provides us with a time-series of (29) estimates of the intensity of the relationship between size and diversity/specialisation. Hence, we analyse the time-trends of these estimates as well. Moreover, we regress this series (of the 29 estimated coefficients) on GDP and its square and reveal a highly significant relationship. Our results seem to imply that there is a negative (or positive but concave) relation between GDP and the relationship between population and diversity. In other words, our results seem to suggest that as national economies develop, population size generates less and less diversity. *Third*, we perform time-series regressions for each sample city (333 in total) and for each one of our indexes. We then analyse the percentage of cities for which (i)a significant positive relation, (ii)an insignificant positive relation, (iii)an insignificant negative relation, and (iv)a significant negative relation is revealed. Further analysis could employ (as a further step) a cross-city regression with the estimated coefficients as the dependent variables and a number of city-specific characteristics as the independent variables, so as to reveal potential determinants for the difference between the estimated effects. Additionally, the same analysis is undertaken, including this time two time-dummies in the original time-series regressions (one linear and one quadratic), in order to control for the aforementioned time-effect. *Fourth*, we finally perform some pooled regressions (using dummy variables least squares), specified as two-way error component models, since the preliminary analysis (but intuition as well) suggests that both time- and city-specific effects are important. Controlling for such effects should produce a single, universal estimate for the relationship between city size and industrial diversity, which would be independent of the cities' specificities and the impact of changes related to time (e.g.: technological change). Hence, this estimate should be showing more precisely the true, structural relationship between city size and industrial diversity.

III. Specialisation and diversity over time

For the analysis we use five indexes in total. Four of these are taken from Duranton and Puga (1999a) and one is calculated as a standardised inverse Hirshman-Herfindahl index of diversity. More specifically, we use an index of absolute specialisation (ZI), an index of relative specialisation (RZI), an index of absolute diversity (DI), an index of relative diversity (RDI) and an index of standardised absolute diversity (BLA). The DI and BLA indexes measure the same thing, with the only difference being that BLA is adjusted for the maximum potential value and, hence, expresses DI in percentage points. The ZI and DI (or RZI and RDI) indexes are not exact opposites, as the specialisation indexes only look at the most important sector (in terms of employment share), ignoring the allocation of employment among the other sectors. The reason to look at relative diversity is the following. Diversity can be the outcome of two very different sets of forces. One set refers to the local or systemic developments that affect the city. Specifically, diversity can increase because of changes in the local economy (labour force composition, demand changes, new raw materials, innovations, etc), or because of changes in the organisation of the system of cities in which this city belongs. Such changes could be related to new developments that affect trading patterns or commuting/shopping journeys, or to changes in the organisation of production (and the division of labour) in the region or in the State.

Figure 1: Specialisation and diversity in the USA

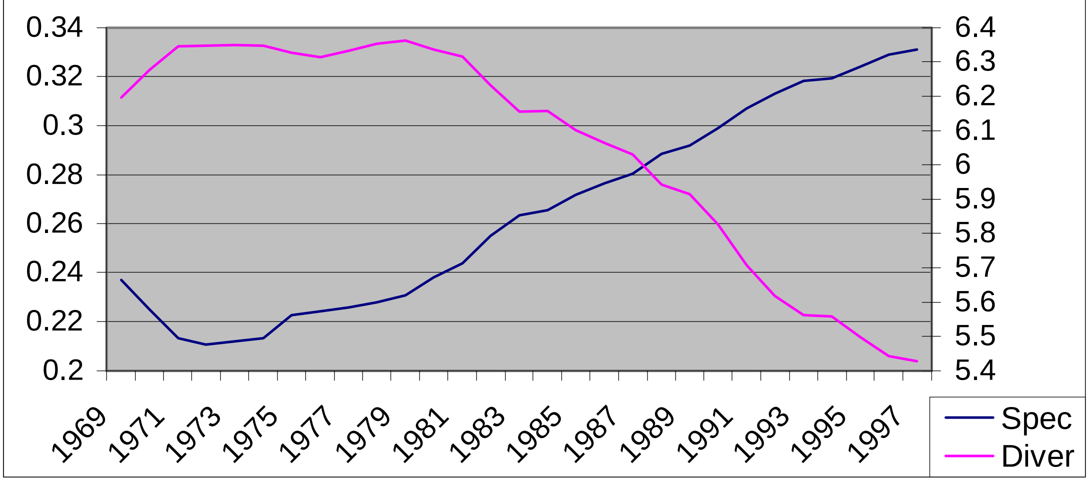
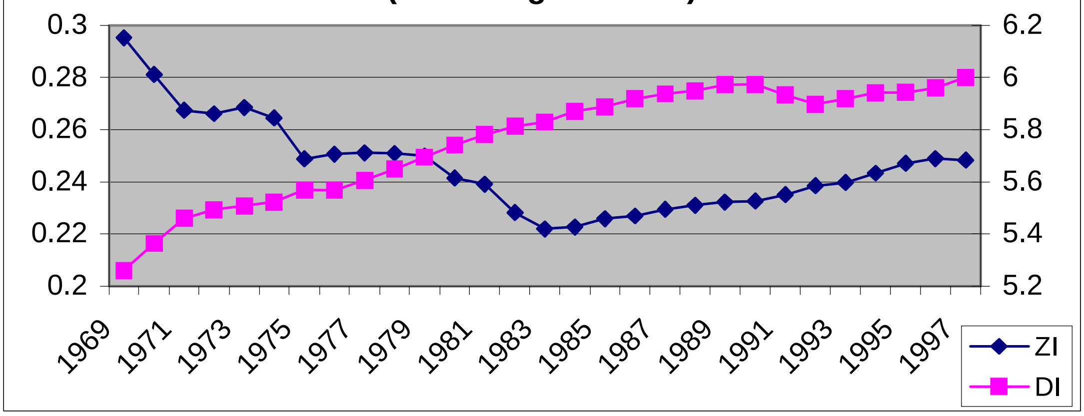


Figure 2: Specialisation and diversity in the US (excluding Services)



The second set of factors relates to changes that occur outside the city and the system to which it belongs. For example, changes in national or international demand and in international trade, as well as technological change can be forces that alter the degree of specialisation of the economy as a whole, irrelevant of the specific local conditions of the city. For this reason, looking at relative diversity is useful, in the sense that it controls for the latter set of factors, allowing us to look at changes in diversity that are strictly due to changes in local conditions.

In investigating the patterns of diversity and specialisation, the first thing to do is to look at the evolution of the indexes over time for each city in our sample and for the US as a whole. Figure 1 presents the diversity and specialisation indexes (DI and ZI, respectively) for the US, for the period 1969-1997. As it can be seen, the US is getting constantly more and more specialised since 1975, which coincides with the year where services become the most important sector (overtaking the declining manufacturing sector). Of course, specialisation increases due to the increasing importance of services (and the low level of disaggregation in our analysis). In Figure 2, we show the same plot, but now excluding services from our analysis. This time, diversity seems to be increasing. Nevertheless, one has to notice that the increase is not as big as one should have expected (provided that services are excluded). Diversity has increased over the last 15 years (1983-1997) by 0.03 times (or, as measured by BLA, by 0.6%), while in the period 1969-1983 these figures where 0.11 and 2%, respectively.

Turning our attention to the individual cities, the first observation is that they do not follow one common path. Some cities become more and more specialised (even in a linear fashion) throughout the sample years. Some others become more and more diversified. Some return to their early 70s position, after experiencing a change in diversity/specialisation patterns during the 1980s. A visual investigation of the graphs does not reveal any specific pattern, where -say- bigger cities become more specialised and smaller ones become less diversified. There seems to be a fairly big degree of randomness in the evolution of diversity/specialisation in each city. This suggests that there should be significant city-specific effects that one should take into account when undertaking an econometric analysis. Moreover, if this is true (the existence of city effects), then undertaking simple cross-city regressions becomes very problematic.

It is of course impossible to present here all graphs (for 333 cities and 5 indexes). Nevertheless, in Figures 3 to 7 we present some characteristic plots. Each figure corresponds to a different index and presents plots for nine randomly selected MSAs (Anchorage, Ann Arbor, Anniston, Appleton-Oshkosh-Neenah, Asheville, Athens, Atlanta, Atlantic-Cape May and Augusta-Aikenfour). We believe that the graphs are illustrative enough to support our claim that the cities’ experiences of diversity and specialisation over time are substantially different (and non-linear).

Figure 3:
The evolution of ZI in a random selection of US cities

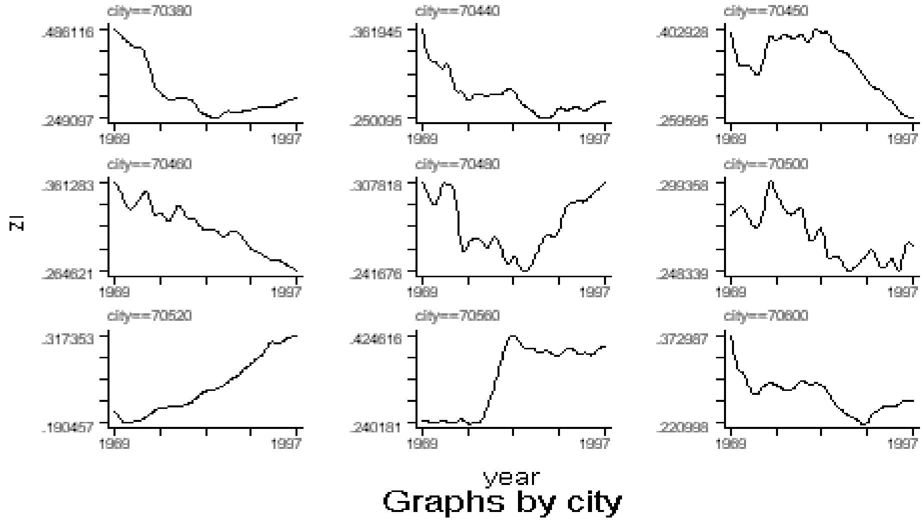


Figure 4:
The evolution of RZI in a random selection of US cities

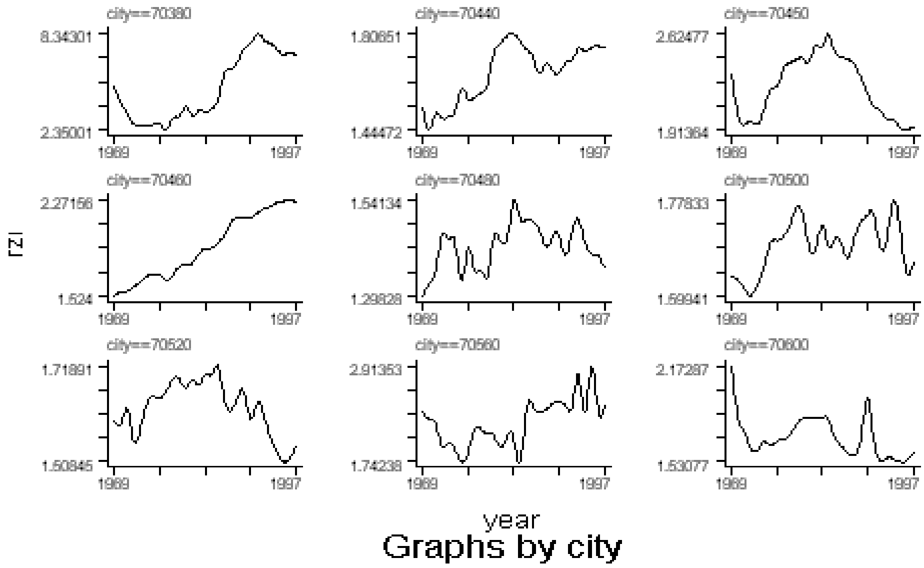


Figure 5:
The evolution of DI in a random selection of US cities

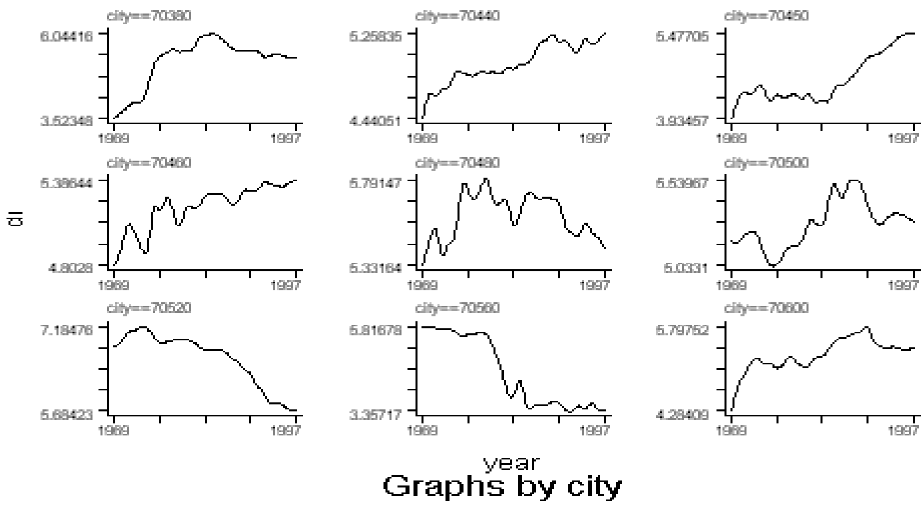


Figure 6:
The evolution of RDI in a random selection of US cities

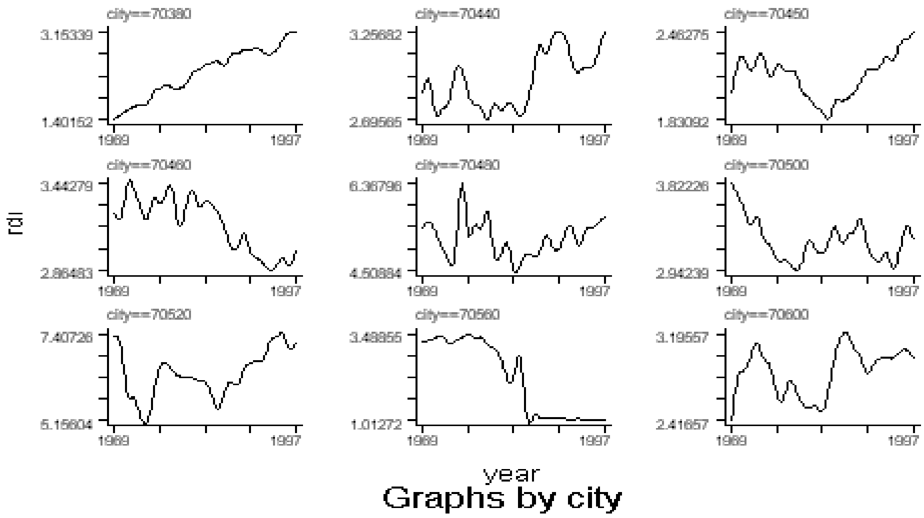
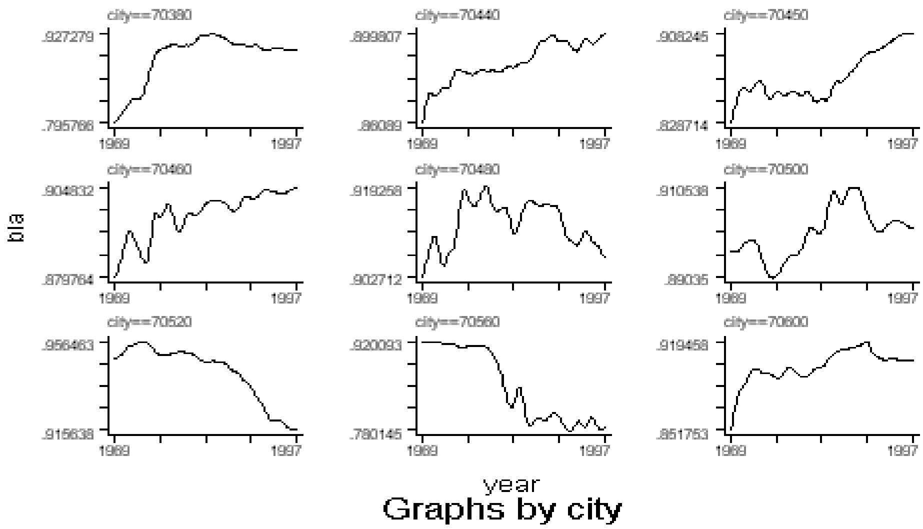


Figure 7:
The evolution of BLA in a random selection of US cities



Before closing this section, in Table 1 we present Spearman's rank correlation coefficients for population and the four indexes of specialisation/diversity, for three year-periods (significance levels in parentheses). The first column shows that cities' ranking in terms of population was quite constant between 1969 and 1997. The second and third columns are simply presented to verify the robustness of the coefficients obtained. Relative diversity (RDI) and relative specialisation (RZI) show some relative stability, as well, but much smaller than in the case of population. In other words, all cities seem to have grown analogously over the 29-year period of our analysis and diversified (specialised) cities relative to the US have in general remained diversified (specialised) relative to the US. On the other hand, the coefficients obtained for the case of absolute diversity (or specialisation) are much smaller in magnitude. Specifically, the ranking of cities according to their absolute specialisation in 1997 has pretty much nothing to do with their ranking in 1969, while the ranking of cities according to their absolute diversity in 1997 has admittedly little to do with that of 1969.

Table 1: Rank correlation coefficients for population, specialisation and diversity

Variable	1969-1997	1969-1995	1995-1997
Population	0.9382 (0.00)	0.9429 (0.00)	0.9997 (0.00)
ZI	-0.0954 (0.08)	-0.0659 (0.23)	0.9416 (0.00)
RZI	0.7224 (0.00)	0.7315 (0.00)	0.9494 (0.00)
DI	0.3633 (0.00)	0.4213 (0.00)	0.9298 (0.00)
RDI	0.6202 (0.00)	0.6684 (0.00)	0.9654 (0.00)

What can be concluded from this, is that production structures per se have not been stable over time. Specialised cities remain specialised only relative to the national figure. In other words, the geography of specialisation relative to the country has changed little over the last three decades. However, the geography of specialisation in absolute terms has changed completely. Intuitively, this seems to suggest that cities that are specialised for local reasons and not because the whole economy is specialised (i.e.: cities with high scores in both the ZI and RZI indexes), have not retained their status as specialised cities: the geography of local factors of specialisation has changed over the last three decades. This is consistent with the view that big changes in the production structure (e.g.: decline of manufacturing and globalisation) are the main determinants of the evolution over time of patterns of specialisation and diversity.

IV. The cross-city regressions

Despite the fact that the (positive) relationship between diversity and population is considered to be a well established empirical regularity, our cross-city analysis seems to cast some doubt on that. The estimated coefficients from the cross-city regressions are positive and statistically significant at least at the 5% level for all of the 29 years of our sample and for all three diversity measures (absolute, standardised and relative). The relationship between (log) population and relative specialisation is always negative, while for absolute specialisation it only becomes positive in the 1990s. Nevertheless, the overall fit of the regressions is sometimes terribly low (it varies around 0.03 and 0.3, the latter usually for the RDI-regressions). Hence, even if there is a positive relationship between diversity and city size, the latter seems to be only a minor determinant of the former.

Figure 8: The effect of log population on ZI

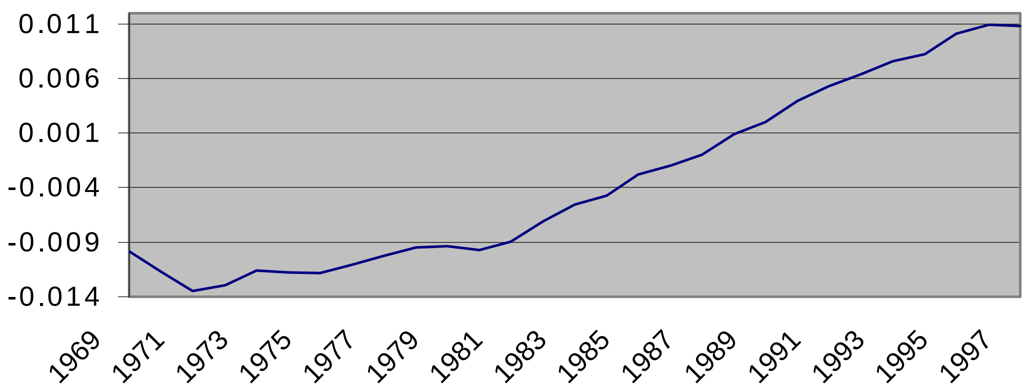
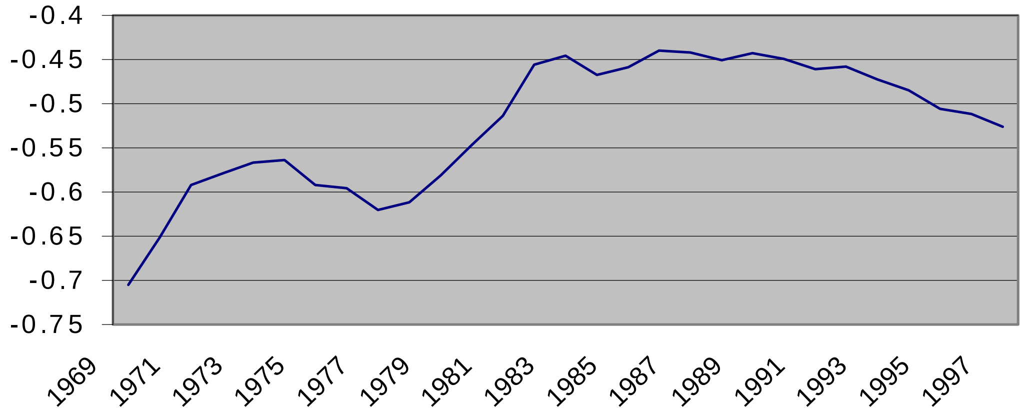


Figure 9: The effect of log population on RZI



As our main objective here is not a cross-city analysis, we will not present the results from the 29 (times 5) cross-city regressions here. After all, the discussion in the previous sub-section suggested the existence of specific time and city effects, so the main focus should be on the results from the pooled regressions (which will be presented later). In this section we will discuss the behaviour over time of the estimated coefficients. In other words, our focus here is on the changes in the intensity of the relationship between population and diversity/specialisation. Figures 8 to 12 present the plots of the estimated coefficients for each of the five indexes. Figure 8 shows the time-trend of the intensity of the relationship between log population and absolute specialisation (ZI). As it can be seen, the intensity of this relationship exhibits an upward trend, especially since 1982. More strikingly, the negative relationship of the 1970s reverses to a positive one in the 1990s. Hence, while larger cities used to be less specialised in the past, the contemporary picture is of large cities being more specialised (apparently, in services).

Figure 10: The effect of log population on DI

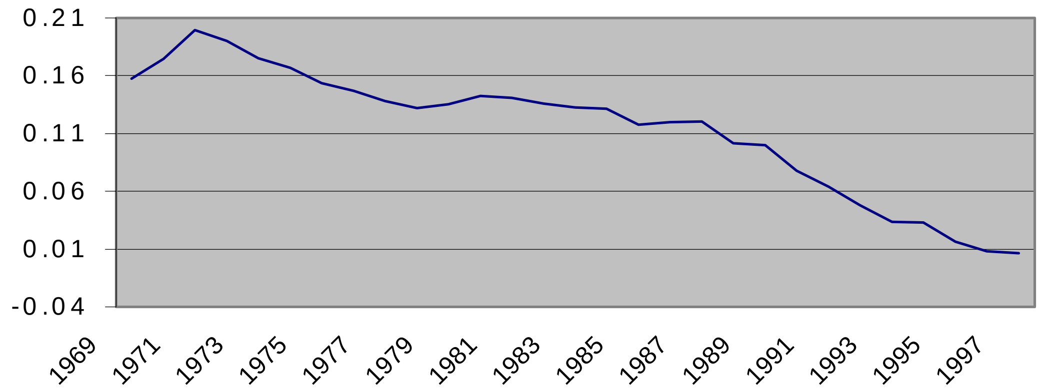
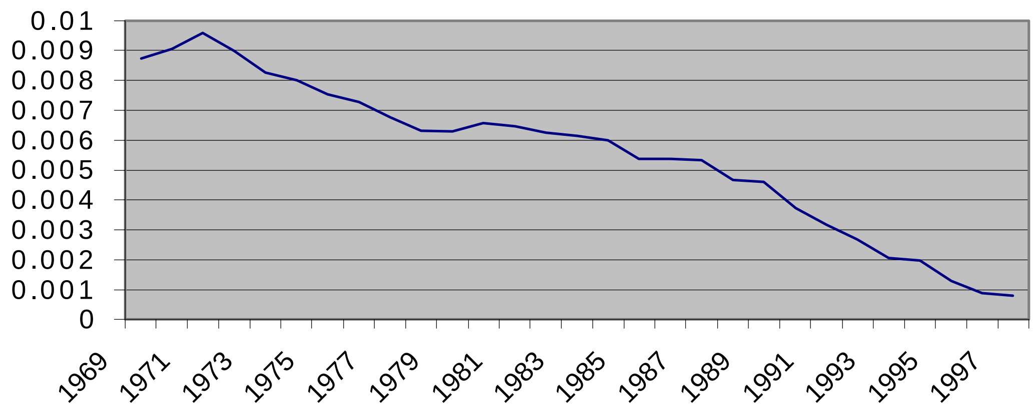


Figure 11: The effect of log population on BLA

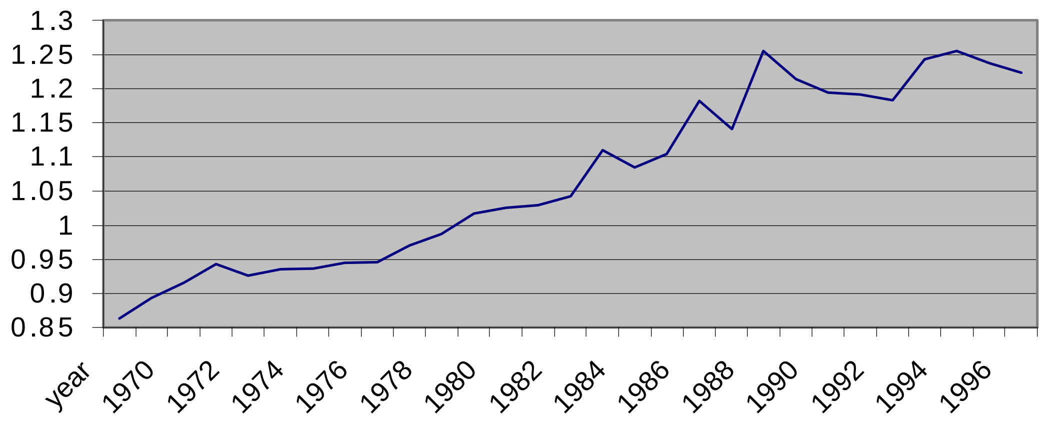


Nevertheless, when one considers specialisation in relative terms (i.e.: relative to the national pattern), the picture is quite different. Again, the relationship between size and specialisation is weaker (less intense) in the 1980s and 1990s than in the 1970s. However, in this case the negative relationship (implying that larger cities are more diversified) shows a high consistency throughout the sample and -if anything- tends to intensify in the last years.

We now turn to the direct measures of diversity. Figure 10 shows the time-behaviour of the relationship between city-size and diversity as measured by a simple (inverse HH) index. This graph reveals (as should be expected) the negative picture of

Figure 8. There is a constantly declining in intensity positive relationship between size and diversity, implying that larger cities are more diversified. For the last year of our sample, however, this relationship ceases to exist! The negative trend implies that city size is becoming less and less significant in the determination of diversity. Moreover, maybe this relationship has stopped to hold in the late 1990s. The same picture is of course revealed by the standardised index (notice that this index only makes a difference in the measurement of diversity, in the sense that it allows us to express diversity in percentage terms), as shown in Figure 11.

Figure 12: The effect of log population on RDI



Again, the picture changes when we look at relative diversity (Figure 12). In contrast with the patterns of simple (absolute) diversity, relative diversity seems to become more and more intensively related to city-size. Specifically, while a unit increase in log population would lead to a 0.9 point increase in relative diversity in 1970, the same population increase would lead to a 1.25 points increase in diversity in 1995. Especially in the 1970s and 1980s, the intensity of this relationship was increasing fast, while in the 1990s there seems to be a stabilisation of this trend. The difference between the pictures obtained from the relative and absolute diversity graphs shows that diversity at a national level is declining very fast. In other words, the US economy seems to get more and more specialised throughout the (sample) years. This is consistent with what we saw in the previous sub-section.

Before we end this sub-section, we want to investigate any potential determinants of the time-path of the estimated coefficients (presented in figures 8-12). One reasonable assumption would be that the intensity of the relationship between population and diversity will depend on the level of economic development. This can capture both the effects of technological progress and the effects of changes in capital accumulation and investment. Hence, we proceed to the following regressions, presented in Table 2. We need to notice, though, that this analysis is simply indicative and should not be considered as conclusive. A unit-root and co-integration analysis should be undertaken before any other step is followed, as this is the standard procedure in time-series studies. (It is interesting to note, though, that a trivial co-integration test showed each one of the indexes to be co-integrated with GDP). The results presented in Table 2 suggest that there is a linear relationship between the size of population's effect on absolute diversity and GDP, with the former being smaller for higher levels of GDP.

Table 2: The impact of output levels on specialisation and diversity

Model	GDP	t-stat	GDP^2	t-stat	R^2
ZI	0.00001	23.03	-	-	0.95
RZI	0.00063	6.18	-7.45e-8	-5.55	0.76
DI	-0.00007	-16.86	-	-	0.91
BLA	-3.22e-6	-26.35	-	-	0.96
RDI	0.00033	4.09	-2.31e-8	-2.14	0.95

Hence, as economic development progresses, population (city size) becomes less significant for the determination of production diversity, but more important for the determination of the degree of domination of the most important sector (specialisation). The results concerning the relative measures suggest the existence of a positive but concave relationship for both specialisation and diversity.

V. The time-series regressions

The next step is to try and obtain some information from the time-dimension of our dataset. Hence, we run five time series regressions for each city, each corresponding to one of the diversity and specialisation indexes. In a first instance, the regressions are again specified as univariate equations, to keep reference with the cross-city regressions which, following the standard literature, were specified as univariate equations themselves. Then, we run the same regressions adding a time-trend and its square in the right-hand side of the equations. With this, we control for the time-effects identified above (which can also include the effect of GDP, as found in the previous sub-section).

Nevertheless, for the purposes of our analysis, the univariate regressions findings are of higher importance. Table 3 presents a summary of these results.

In general, in around 85% of the cases (log) population is a significant determinant of absolute diversity/specialisation. From the first three columns (first two rows) we see that in around 60% of the cases population is positively (negatively) related to absolute specialisation (diversity). The 85% of them are statistically significant, that is, around 52% of the cases (third and fourth rows). Hence, in more than half of the cases there seems to be a negative relation between city size and diversity.

Table 3: Summary results from the univariate time-series regressions

	ZI	DI	BLA	RZI	RDI
negative	134 (40.2%)	201 (60.4%)	200 (60.1%)	183 (55%)	126 (37.8%)
positive	199 (59.8%)	132 (39.6%)	133 (39.9%)	150 (45%)	207 (62.2%)
signif (-)	118 (35.4%)	171 (51.4%)	170 (51.1%)	142 (42.6%)	96 (28.8%)
signif (+)	176 (52.9%)	118 (35.4%)	118 (35.4%)	118 (35.4%)	179 (53.8%)
insig (-)	16 (4.8%)	30 (9%)	30 (9%)	41 (12.3%)	30 (9%)
insig (+)	23 (6.9%)	14 (4.2%)	15 (4.5%)	32 (9.6%)	28 (8.4%)
signif	294 (88.3%)	289 (86.8%)	288 (86.5%)	260 (78.1%)	275 (82.6%)
insig	39 (11.7%)	44 (13.2%)	45 (13.5%)	73 (21.9%)	58 (17.4%)

Concerning relative diversity and specialisation (which, of course, is a more appropriate measure for the time-series analysis), it is around 80% of the cases that are statistically significant (columns four and five, rows five and six). The difference with the absolute-measures regressions is rather small in this respect. Nevertheless, looking at the percentages of positive and negative effects (first two rows) reveals quite an opposite relationship than before. In around 60% of the cases population is found to increase diversity relative to the US figure. The 80% of them are statistically significant, on average, 48% of the total number of cases. To conclude, although there is some evidence for a trend of increasing absolute specialisation but also of increasing relative diversity, this evidence is rather weak. Only 60% of the cases seem to follow this pattern and only 50% seem to follow it consistently. Hence, the observation which is of more importance here, is that -as was the case in the sub-section where we looked at the time-trends of the indexes- the experiences of diversity/specialisation and of its relation to city size are very different among cities. If we can identify a trend -from results not shown here- is that the positive relationship between specialisation and city-size is more consistent the bigger is the city. In other words, bigger cities become more specialised as they grow, while smaller cities retain a greater degree of diversity. This conclusion, though, is based on very preliminary results that need further analysis.

Tables 4 and 5, below, present the results obtained from the same regressions as the ones presented in Table 3, with the only difference being the inclusion of (i)a time-trend and its square (Table 4) and (ii)the national diversity/specialisation figure (Table 5) in the estimated equations. As it can be seen, the results change substantially and, in some cases, they reverse. We need only notice two things. First, looking at the last two rows of Table 4, we can see that the domination of the cases where (log) population is a significant explanatory variable for diversity/specialisation (that we saw in Table 3) ceases to exist. This is despite the fact that the R-squared obtained from the second set of regressions is always higher than in the previous case (R-squares not shown here). We interpret this as mixed evidence. On the one hand, the "empirical regularity" that our analysis is focused on is not after all so strong in the time-dimension. On the other hand, it is not so weak, either, despite the fact that we control for time (or technology progress). In the last two rows of Table 5 we can see that this "empirical regularity" is stronger when we control for the national figure of diversity/specialisation (corresponding to the dependent variable) rather than for time-effects.

The second thing to notice is the reversal in the shares shown in the first two rows of Tables 4 and 5. If we were to interpret the findings shown in these two rows, in the same way that we did for Table 3, we would have to conclude that absolute diversity increases as cities grow (net of time effects which can proxy for the level of development or for technological progress), while relative diversity declines as cities grow. In other words, as cities grow and the economy develops, cities tend to follow more closely the national patterns of diversity and specialisation. This is the opposite effect than the one we found in Table 3 (and the difference is attributable merely to the inclusion of the time-dummies in the second set of regressions and of the national figures in the third set of regressions).

Table 4: Summary results from the trended time-series regressions

	ZI	DI	BLA	RZI	RDI
negative	174 (52%)	121 (36.3%)	116 (34.8%)	171 (51.4%)	207 (62.1%)
positive	159 (47.7%)	212 (63.7%)	217 (65.2%)	162 (48.6%)	126 (37.8%)
signif (-)	109 (32.7%)	50 (15%)	47 (14.1%)	81 (24.3%)	109 (32.7%)
signif (+)	84 (25.2%)	119 (35.7%)	121 (36.3%)	69 (20.7%)	57 (17.1%)
insig (-)	65 (19.5%)	71 (21.3%)	69 (20.7%)	90 (27%)	98 (29.4%)
insig (+)	75 (22.5%)	93 (27.9%)	96 (28.8%)	93 (27.9%)	69 (20.7%)
Signif	193 (58%)	169 (50.8%)	168 (50.5%)	150 (45%)	166 (49.8%)
Insig	140 (42%)	164 (49.2%)	165 (49.5%)	183 (55%)	167 (50.2%)

Table 5: Summary results from the bivariate time-series regressions

	ZI	DI	BLA	RZI	RDI
negative	211 (63.4%)	118 (35.4%)	117 (35.1%)	180 (54.1%)	152 (45.6%)
positive	122 (36.6%)	215 (64.6%)	216 (64.9%)	153 (45.9%)	181 (54.4%)
signif (-)	159 (47.7%)	78 (23.4%)	82 (24.6%)	115 (34.5%)	89 (26.7%)
signif (+)	62 (18.6%)	164 (49.2%)	164 (49.2%)	89 (26.7%)	127 (38.1%)
insig (-)	52 (15.6%)	40 (12%)	35 (10.5%)	65 (19.5%)	63 (18.9%)
insig (+)	60 (18%)	51 (15.3%)	52 (15.6%)	64 (19.2%)	54 (16.2%)
Signif	221 (66.4%)	242 (72.7%)	246 (73.9%)	204 (61.3%)	216 (64.9%)
Insig	112 (33.6%)	91 (27.3%)	87 (26.1%)	129 (38.7%)	117 (35.1%)

VI. The pooled regressions

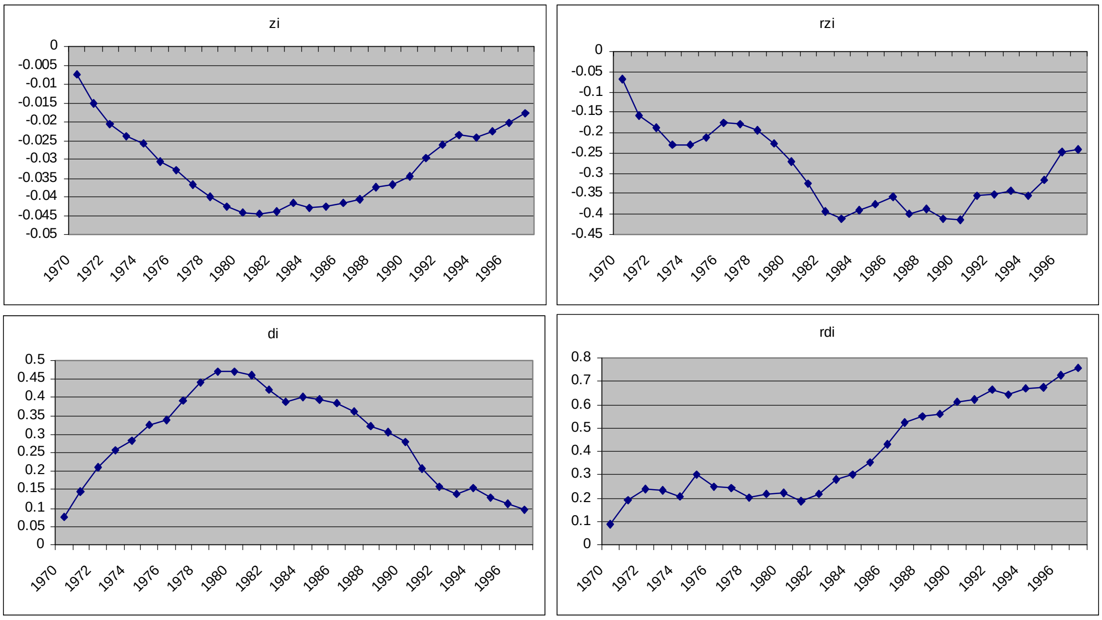
The analysis conducted so far revealed the importance of city-fixed factors, as well as of time-specific factors affecting the (sign and intensity of the) relationship between city size and production diversity. Hence, in undertaking a pooled regression analysis, we would originally expect a two-way error component model to be the best specification. We specified a big number of alternative model formulations and performed an equally big number of specification tests. Our analysis incorporated the inclusion -additionally to city size- of the square of city size, the national figure corresponding to the (city-specific) dependent variable(s), a time trend and its square, and the US GDP and its square. The last five variables (national index, time, time squared, GDP and GDP squared) only captured the impact of the time-specific effects, but in none of the cases did they contribute to the explanatory validity of the regressions more than the latter (time dummies). The square of city size was statistically significant and the quadratic specifications performed better than the linear ones, but worse than the semi-log specifications (where log-population entered as the main explanatory variable). Hence, we concluded that a univariate two-way error component semi-log model was the best specification to use. The time-specific effects are related to technological progress (otherwise captured by the time trend), economic development (otherwise captured by the GDP) and the national patterns of specialisation (otherwise captured by the national indexes), but they are depending on more things that simply the three latter variables.

Table 6: Pooled regression results

Model	**ZI**	**DI**	**BLA**	**RZI**	**RDI**
log(population)	0.052 (15.23)	-0.531 (-15.89)	-0.019 (-11.96)	-0.386 (-3.43)	0.614 (5.94)
R^2-bar	0.71	0.82	0.84	0.92	0.84

Table 6 presents the results from the final estimated pooled regressions (estimated using DVLS - dummy variables least squares), for the five indexes that we use here (t-statistics in parentheses). In all cases, the dependent variable is statistically significant at any level of significance. The adjusted coefficient of determination is sufficiently high. Since we have controlled for both city- and time-specific effects, we find reasonable to interpret the estimated coefficients as the true structural relationship between population and city-size. Contrary to common belief, city size seems to be inversely related to absolute diversity. Holding space and time constant, bigger cities tend to be more specialised. The estimated coefficient from the third regression (BLA) suggests that a 1-unit increase in log-population (this represents an increase of around 170% for the average city size of our sample) will tend to reduce production diversity by 2%. Nevertheless, the results from the regressions where the relative measures are used as the dependent variables show that rather the opposite is the case. This time, holding again time and space constant, bigger cities tend to be more diversified relative to the national economy as a whole. It is not clear to us whether this is because of the specific path of diversity/specialisation that the US followed over our sample period, or if this is a structural relationship (a pattern). But the point is that for the US in the three decades of our sample absolute diversity is found to decline with city size and relative diversity is found to increase with city size. This, at the end of the day, can explain why there is so much ambiguity and confusion about the patterns of specialisation and diversity and their connection to city size in the literature.

Figure 13:Plots of the estimated time-specific effects from the pooled regressions



Before we close this sub-section we want to comment on the information that is obtained from the estimated time-specific effects. All four plots presented in Figure 13, show that these time-specific effects are not random, but rather deterministic (yet, non-linear). The plots show that absolute specialisation (diversity) was decreasing (increasing) in time up until the mid-1980s, but it has been increasing (decreasing) in time since then. Relative specialisation has been decreasing in time during the 1970s, remained quite stable over the 1980s and seems to catch up after the early 1990s. On the other hand, relative diversity has been quite stable during the 1970s but has been increasing since the early 1980s. Further analysis can be undertaken in order to estimate potential determinants of the behaviour of these effects over time. In specific, these time-series can be regressed on a number of candidate variables, so as to see which are the factors that drive the patterns of diversity and specialisation (and their relationship to city size) over time. The same analysis should of course be undertaken for the estimated city-specific effects (which are not plotted here). It would be interesting to perform such analysis in the future, especially if consistent 2-digt SIC data were made available to us for a big period of time and for a sufficient cross-section of cities.[4]

VII. Conclusions

Among the extensive amount of information derived from our long dataset of nearly 10,000 observations, we believe the most important piece of information is the one obtained from the pooled regressions. This is because these regressions correspond to the best econometric specifications, but also because they provide the more general picture of the relationship and the patterns that we attempted to investigate here. Our findings suggest that over the last three decades the US was characterised by a negative relationship between diversity and city size, with a doubling of a city's size leading to a 2.25% fall in absolute diversity at the mean values. This, we have interpreted as the true (structural) relationship between (absolute) diversity and city size. Nevertheless, relative diversity is increasing in time and with city size, although this could simply be the outcome of a possibly exogenous national pattern of declining (absolute) diversity.

Although this paper strictly performs an empirical analysis, with little relation to theory, and despite the use of a dataset which is not the most desirable theoretically for the measurement of diversity and specialisation, we believe that the analysis is detailed enough and the empirical evidence is robust enough, so as to produce useful insights for a better understanding of the true relationship between city size and production diversity (and possibly industrial diversity, as well). Our results have produced, overall, mixed evidence. That production diversity -holding city and time effects constant- is related to smaller city size is a result offering support to the theoretical formulations of Henderson (1974) and Abdel-Rahman (1990a, 1990b, 1994). Quite on the contrary, the evidence provided for the case of relative diversity seems to suggest that in deed city size is related to more diversity, holding other exogenous factors constant, apart from the fixed effects of place and time. This reconfirms the identified "empirical regularity" and supports the approaches related to the central place theory and to the concept of urbanisation economies. Finally, it is interesting to note what our data suggest, that when one discriminates between growing and declining cities, the results are not the same. For declining cities, size is positively related to diversity, while the opposite holds for cities growing in time (which is, of course, the vast majority). Large declining cities are more diversified than smaller declining cities, while large growing cities are less diversified than smaller growing cities. This, more than showing a difference in patterns, seems to suggest that the dynamics affecting the relationship between city size and diversity are very complex and indeed dependent on a variety of factors. In this respect, the reconstruction of the central place theory in a model of constant city creation and destruction, which also allows for both large diversified cities and small specialised cities to shrink, is a valuable theoretical tool for further understanding these complex relationships, as it seems to describe sufficiently what is observed in reality.

As a piece of further evidence to that, the cross-city and time-series analyses that were performed in sections 4 and 5 revealed a big variety of patterns and evolution paths, which cannot be explained by any theory available. By and large, this seems to suggest that a significant number of factors entering the relationship between size and diversity are yet to be taken into account, not to mention them being totally acknowledged and understood. We favour an explanation which attributes a significant role for the behaviour of this relationship on the type and specificities of the sector (industry) which dominates each urban economy. This is consistent with some empirical evidence obtained elsewhere (Henderson et al., 1995; Henderson, 1997b; Black and Henderson, 1998). However, other factors, like location and proximity to a larger pool of cities (Glaeser et al., 1992; Dobkins and Ioannides, 1998) may also be playing an important role.

Similar analyses with more detailed data (possibly at the 2-digit or even 3-digit SIC level), would undoubtedly be very useful in investigating the potential significance of these factors. Moreover, they would be probably necessary to test the robustness of the results presented here, as well as the applicability of the inferences made, for the case of industrial diversity (as opposed to production diversity). Possibly, more advanced panel data econometric techniques, like the recently developed mean group and pooled mean group estimation methodologies (Pesaran and Smith, 1995; Pesaran et al., 1999), which take into account directly the sort- and long-run dynamics of the relationships investigated, are probably necessary to shed more light on the issues investigated here. For the time being, we want to summarise the results that we obtained here, in the following phrase. City size is a factor affecting positively the diversity of production.

However, this relationship is widely subject to local as well as economy-wide (national) conditions. The local industrial structure, the level of development and the growth rates of the national economy, technological progress and the patterns of international trade, are all factors that are possible candidates for that. Although an empirical regularity is definitely identified, the dynamics behind it are too complex and dramatic to be fully acknowledged and understood.

ENDNOTES

[1] For example, Crowley (1973) has found a consistent negative trend (for Canada, for the years 1951-1961) in all six different indexes of industrial diversity he tested.

[2] See the Data Appendix for data definitions and data description.

[3] It is interesting to note -as an illustrative example- that the 2-digit SIC data for New York county (not to mention the MSA), released by the Country Business Patterns for 1977-1995 contained more than two hundred disclosed or missing observations (more than 15% of the total number of observations). Bearing in mind that in order for the diversity and specialisation indexes to be calculated one has to estimate employment shares, it is clear that the specific dataset is not suitable for undertaking a panel data analysis of the type undertaken here.

[4] In a new piece of work, which is currently under progress, we actually perform such investigations for the 1-digit SIC data used here. Additionally, we re-run the regressions presented in Table 6 using, instead of DVLS, the newly developed Mean-Group and Pooled Mean-Group estimation techniques. With this, we can control for the long- and short-run dynamics and allow for co-integrating relationships. The issue of spatial co-integration is also considered.

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