Firm Growth and Regional Income Convergence: Is There a Connection?

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Abstract

In this paper we argue that microeconomic considerations and the performance of individual firms have all but vanished in the regional science literature, especially that concerning regional income convergence. Further, because income convergence is an inherently geographic process we demonstrate that the standard OLS test for convergence violates basic statistical assumptions and yields biased parameter estimates that are frequently estimated at an inappropriate geographic scale. To remedy these inadequacies, we compare non-spatial to spatially explicit models of conditional convergence incorporating both traditional, exogenous location factors while incorporating the influence of individual high-growth firms on regional income convergence in the U.S. over the 1990-2010 period. Our main findings indicate that while convergence is taking place, the pace of convergence might be slower than previously thought. Further, accounting for the performance of high-growth firms adds significant explanatory power to the convergence process lending credence to our position that microeconomic variables should be included along side more macroeconomic variables in models of regional income convergence.

1. Introduction

Healthy regions are comprised of healthy firms. What is curious about this seemingly tautological observation is that many of us who study regional economic growth tend to focus attention on locational attributes and regional conditions while neglecting the role of firms responsible for economic growth. The omission of firm-level performance is somewhat surprising in the context of regional income convergence theories since new evidence demonstrates that the bulk of all new job creation is made by a handful of firms. Kunkle (2013), for example, recently noted that 1% of firms are responsible for 72% of net employment growth between 2005 and 2010. Equally important is his finding that large firms are not as responsible for job and income growth as they once were. Instead, the evidence he presents suggest that business establishments that grow multiple times over a five year period accumulate disproportionate shares of new job creation. In this paper, we take the important step of reinserting sustained firm-level growth into regional analysis. We do this in the context of regional income convergence theory and the models used to measure it. The goal of this paper is to examine the contribution of firm-level growth in conjunction with traditional "regional" conditions on changes in per capita income and regional income convergence.

The loss of the firm in regional analysis is unfortunate. We suspect that much of this trend can be traced to the intellectual history of regional economics and the tricky business of blending macroeconomic theories, in this case derived from international economics (see for example Krugman, 1991), and the microeconomics of the firm. This conundrum stems, in part, from a paucity of firm-level data, limiting a nuanced understanding of regional growth. In other respects, the "macro-micro" tension in regional analysis makes sense. Regions, by their very nature, fall into a kind of intermediate level of analysis where both firm- and establishment-level characteristics and larger regional-level environments provide the context in which firms make decisions, and the stage on which most of these decisions are played.

The simultaneous recognition of macro- and micro-level factors has been recognized in the location analysis literature for some time (Stafford 1980; Hayter 1997). Even Isard's (1956) discipline-defining treatise acknowledges the need for regional analysis to recognize the performance of firms, their spatial attributes, and their interconnectedness in regional context. So, while much early work in regional analysis sought to solve various profit maximizing and location-allocation problems of individual firms in the space economy (e.g. Greenhut, 1956; Garrison 1959; Schmenner, 1982), more recent work attempting to explain various economic phenomena at the regional level has resorted to a long list of geographically-defined location factors (e.g. Coughlin and Segev, 2000). In terms of blending micro- and macro-economic theory, recent work in path dependence, relational economics, and evolutionary economics (Bathelt and Gluker, 2003; Schultz et al., 2006) holds promise for bringing these two seemingly disparate traditions together, though even they tend to attribute firm-level growth to regional "*milieu*." While there are exceptions, many regional analysts have questioned the attribution of regional economic performance to vague concepts that defy precise definition (e.g. Markusen 1999).

One strain of regional research that has suffered from many of the above tendencies, particularly the omission of the firm, has been the literature addressing regional income convergence. Briefly reviewed below, the theory of income convergence suggests that, over time, regional per capita income (or their growth rates) will tend to converge as production and capital investment shift in response to geographically differentiated opportunities for profit maximization (Barro and Sala-I-Martin, 1991; Baumol, 1986). Clearly then, the convergence process (a) is inherently spatial; (b) reflects regional differentials in resource endowment and (c) is the result firm-level behavior. Initially borrowed from international economics, its application to regional economies has been fraught with problems ranging from model specification and diagnostics tests, appropriate units of observation (countries, states/provinces, and small units such as counties and their equivalents) and occasionally conflicting evidence of convergence and the strength of its predictors (James and Campbell, 2012; Quah, 1993). While this literature has become increasing sophisticated, to our knowledge in no instance has the performance of individual firms, or a sub-set of them, been included in the analysis.

As discussed below, recent computational experiments associated with spatial data analysis have provided better guidance on the geographic scale at which convergence studies should take place, but none have incorporated the role of firms exhibiting high rates of sustained growth, firms we call "hi-gros."[1] If our opening premise is correct – that healthy regions are comprised of healthy firms (or at least an important subset of healthy firms) – and the neo-classical proposition of regional income convergence is taking place in the U.S., then our findings should shed new light the specification of convergence models while taking the first steps towards blending micro- and macro-

[1] In fact, our analysis of hi-gros reflects establishment-level, rather than the firm-level, growth. Throughout the paper, however, we frequently refer to "firms" for ease of readability. We should note that more than 80% of establishments are single-establishment firms, but the growth of individual establishments, particularly for multi-establishment firms, is most relevant at the local or regional level.

economic influences on the convergence process. The inclusion of firm-level growth is made possible by the National Establishments Time Series (NETS) database.[2]

The remainder of this paper is organized as follows: In section 2 we briefly review the theory of income convergence, problems associated with traditional testing due to omission of spatial effects, and discuss the rational for including firm-level information in convergence testing. In section 3, we outline our model and data while section 4 presents our results, comparing traditional OLS tests with our spatially explicit model that incorporates the influence of firms exhibiting high rates of sustained growth. In section 5 we conclude the paper and offer a few suggestions for further research.

2. Background

2.1 U.S. Income Convergence

Deeply embedded in neoclassical economics, geographic differences in income and industry output are thought to converge over time (Malizia and Feser, 1999). Initially developed to explain differential growth at the international level, much of the recent literature, theoretical and empirical, can be traced to Solow (1956) and explicitly defined and tested by Baumol (1986). In short, convergence theory suggests that capital will flow to regions where its return is highest (Barro and Sala-I-Martin, 1991). Assuming diminishing returns to capital, it is theorized that as returns to capital diminish over time in capital-rich regions, investment in productive activities will progressively be made in lagging regions with capital deficits (Islam, 2003). Regions of capital deficit are, by definition, also those with labor surplus. Additions to the capital stock in lagging regions will allow capital to realize greater rates of return, increasing the marginal product of labor and thereby increasing regional income. Over time, given well-functioning markets and globally fixed capital, we should expect returns to both capital and labor will equalize and income differences between geographic areas to gradually converge, allowing income in lagging regions to "catch-up" to their more advanced counterparts. Convergence thus reflects both the marginal motivations of firms and the spatial dimension of creative destruction (Harvey, 1985; Hunt, 2002; Schumpeter, 1942).

Empirically, there is much evidence for convergence, though its exact form and measurement has been the subject of some debate (Galor, 1996; Quah, 1993). More recently, income convergence models have been applied domestically to address regional convergence *within* countries, particularly the United States (e.g. Barro and Sala-I-Martin, 1991; Connaughton and Madden, 2004; James and Campbell, 2012; Rey and Montouri, 1999). However, empirical evidence of domestic income convergence has been mixed with some analyses clearly indicating an active convergence process and others showing little to no relationship between initial income levels and subsequent income growth, sometimes even within the *same* study (James and Campbell, 2012). Still others suggest it is the *rate* of income growth, not income levels per se, that tend to converge over time (Barro and Sala-I-Martin, 1991; Drennan and Lobo, 1999). In part, such divergent results are the result of overly simplistic models (i.e. regional income growth being strictly a function of initial income levels in a prior time period), the use of

[2] Access to NETS has been generously provided by the Lowe Foundation and its Institute for Exceptional Growth companies.

inappropriate geographic units to meaningfully measure income growth, or simply the omission of variables relevant to the growth process itself (see Islam, 2003; Galor, 1996; Lucas, 1988). However, recent research in the U.S. points to the optimal geographic at which convergence tests should be conducted, though the problem of omitted variables still remains.

2.2 Geography and Convergence

To set the stage it must first be acknowledged that convergence is theorized to take one of two forms. *Unconditional convergence* implies that regional incomes will converge over time regardless of the region's initial economic structure. *Conditional convergence* suggests the underlying structure of an area's economy is an important factor in its income growth. Much of the current evidence supports the latter position (Barro and Sala-I-Martin, 1991; Connaughton and Madsen, 2004; Higgins et al., 2006; Rupasingha et al., 2002). However, if regional income convergence is a conditional process and is likely to vary from region to region, what conditions are relevant to the process and at what geographic scale should it be studied?

Most Baumol-style studies of regional income convergence rely on OLS regression analysis. In unconditional models, the common test of income convergence simply regresses initial income levels on changes in per capita income with the expectation that the estimated coefficient on initial income is negative (i.e. regions of low income experience faster growth than those with higher initial incomes). The inclusion of additional explanatory variables turns the unconditional model into a conditional model (conditioned on the initial economic structure of the regions) but the expectation of a negative coefficient on initial income remains. A major problem exists, however, with this approach. First, per capita income is known to exhibit spatial autocorrelation; that is, regions of high and low per capita income tend to be geographically clustered (Rey and Montouri, 1999). Second, because convergence is an explicitly geographic process, changes in low income regions should be similarly clustered. Both conditions violate a basic requirement of OLS analysis — the independence of observations. Such a violation results in biased coefficient estimates and skewed confidence intervals (Anselin, 1988). These are some of these issues that surround the sometimes conflicted results of convergence studies.

Problems with OLS specification then require the use of spatially explicit models. Examples of spatially explicit convergence models that account for spatial autocorrelation include state-level analyses by Rey and Montouri (1999), county-level investigations by Higgins et al. (2006), and European Union tests (e.g. Badingger, et al., 2004; Fingleton, 1999; Le Gallo and Etur, 2003). While each provides evidence of convergence, questions remain about the strength of convergence evidence largely due to the geographic units employed. States, having their generic policy, levers are too large to affect the nuances of the firm's location decision; and counties are too small to accurately reflect the process of *regional* income convergence. However, there remains yet another fundamental issue to be resolved, that of the so-called Modifiable Arial Unit Problem (MAUP). It has long been known that how data are grouped affects the results statistical analysis (Gehlke and Biehl, 1934; Fotheringham and Wong, 1999). MAUP addresses two major problems: the aggregation problem and the zoning problem. The

aggregation problem refers to the tendency for estimated R^2 values to increase as the units of observation are increasingly aggregated into larger groups (e.g. counties aggregated into states). In effect, aggregation pulls observation toward the mean thereby masking variation present at lower levels of aggregation. The zoning problem acknowledges that different groupings of data at the same level of aggregation produce different estimates of model parameters (see Openshaw and Taylor, 1978).

While there are direct tests for spatial dependence at both the global level (Moran's I statistic) and the local level (LISA statistics, see Anselin, 1995) there is no formal "solution" to the MAUP problem. However, the MAUP problem must be acknowledged because it affects the proper choice of model specification. With respect to convergence studies of the U.S. and the choice of appropriate model form, the most rigorous analysis to date clearly indicates that neither states nor counties are optimal units to observe and explain regional convergence (James, 2012). Through extensive exploratory data analysis, James and Campbell (2012) have demonstrated that BEA Economic Areas (EAs) are most likely the best geographic unit with which to study convergence because they are designed to represent "functional" economic areas — the very scale at which hi-gros and policy makers alike make their economic development decisions.

2.3 Hi-Gros and the Resource Based View of the Firm

Variously called Gazelles, High Fliers, High-Impact Firms, there has been growing interest in how high-growth firms (hi-gros) create and sustain their growth, and how the rapid, sustained growth of these few firms contribute to economic development (Acs, et al., 2008; Beyers and Lindahl, 1996; Davidsson and Delmar, 2006; Delmar and Davidsson, 1998, 2003). The connection between hi-gros and regional income convergence seems clear enough: the bulk of new job creation (and by extension new capital investment and income) is created by a small cadre of firms that exhibit exceptional, sustained growth (Kunkle, 2009). In some states, hi-gros can be found in most every economic sector and most every area, urban and rural. If so, then the dynamics of hi-gros might be partially responsible for regional income convergence witnessed in the U.S. Given the plausibility of this connection, it is somewhat surprising the role of hi-gros has yet to receive its due attention in the convergence literature.

One dominant school of thought explaining the sustained growth of firms comes from Penrose (1959) and her Resource Based View (RBV) of the firm. At issue for Penrose and other RBV scholars (Oliver, 1997; Hoopes et al., 2003; Spender, 2006) is a deceptively simple question: What accounts for systematic performance differences between firms, even those in the same industry?. The answer, according to Penrose (1995) lies in the economic value created by firms from idiosyncratic combinations of resources and capabilities which are assembled and deployed by creative and entrepreneurial managers. Isolation mechanisms, which might have a geographic basis, protect unique and valuable strategic resources from being imitated by competitors which helps to sustain performance. The resources to which she refers can be tangible, intangible or organizational and are most likely to sustain competitive advantage if they are valuable, rare, and isolated from substitution or imitation (Hoopes et al., 2003). Her distinction between resources and the services that they yield opened a 'conceptual space' to introduce the concept of managerial learning (Spender, 2006).

Isolation mechanisms ensure that valuable resources remain rare by preventing duplication or substitution by competitors. Thus, the sources of superior performance and the mechanisms for their sustainability are 'inextricably intertwined' (Kor and Mahoney, 2004). These mechanisms are often complex, path dependent, unique, and involve causal ambiguity (Oliver, 1997). Kor and Mahoney (2004) argue that Penrose described five sources of isolating mechanisms: "(1) path dependencies in resource deployment; (2) firm-specific knowledge possessed by managers; (3) shared team-specific experience of managers; (4) entrepreneurial vision of managers; and (5) the firm's idiosyncratic capacity to learn and diversify" (p. 186). Thus, tacit knowledge possessed by managers and entrepreneurs play a central role by finding market niches that are not easily replicated, profitably deploying resources to exploit those niches, and isolating the sources of competitive advantages to reduce replication by other firms.

The environment to which RBV refers is both internal and external to the firm. Internally, it consists of opportunity sets for investment and growth that entrepreneurs and managers perceive, which vary between firms depending on their specific collection of human and other resources. Moreover, the environment is not fixed and immutable, but can be manipulated by the firm to serve its own purposes. Identifying and understanding these internal dynamics has been the focus of much of the RBV driven research making it a largely an aspatial body of research. However, Penrose (1995) acknowledges that there are external conditions that may induce a firm to expand, such as changes in market demand or production technologies. But she seeks to point out that internal dynamics within the firm can produce as strong a motivation for growth as external conditions. She argues that "growth will take place which cannot be satisfactorily explained with reference only to changes in the *environment* of the firm" (p.79), though the interaction between internal factors and the external environment has yet to be fully explored. Perhaps as a result of this paradigm, Penrose (1995) and RBV scholars have contributed very little to theories of regional growth. They emphasize dynamic activities within the firm rather than how the firm relates to its environment or its contribution to regional economies suggesting that "there are no such things as strong or weak locations, but only strong and weak firms" (Hoogstra and Van Dijk 2004).

Drawn together, however, convergence theory and RBV theory provide two theoretically consistent explanations for the growth of firms *and* regions. While both theories acknowledge the potential impact of the other, there has yet to be an attempt to assess the microeconomic role of individual firm performance on regional income convergence. In this paper, we address this gap by developing a spatially explicit model that tests for the impact of specific firms exhibiting sustained growth (hi-gros) on regional income growth and convergence.

3. Method

In the preceding sections, we have presented two competing theories of growth: a region-focused neo-classical understanding and a firm-focused resource based view. Though addressing growth at fundamentally different units of observation, both are connected as regions are comprised of firms, and firms locate in particular regions. As

such, firms are influenced by the amenities of their home region, and regions are influenced by the successes of the firms they house. Their growth trajectories, therefore, should be intertwined. However, neither theory has incorporated aspects of the other in to their explanation of growth, resulting in a rather substantive gap in our understanding of regional and firm-level growth. This project begins to fill that void by constructing a regional income convergence model that explicitly includes the role of firms in the United States from 1990-2010 at the level of Economic Area's (EAs) as defined by the Bureau of Economic Analysis. Specifically, we address the following questions: (1) How strongly do growing firms influence regional growth? (2) What is the relationship between firm performance and other predictor variables? (3) Do established sustained growth firms impact regional growth differently than rapidly growing startups? (4) Does the inclusion of firm-level growth variables solve some of the omitted variable problems plaguing neo-classical growth models?

Our choice of study area, level of aggregation, and time period offer several advantages. The United States has been the subject of landmark convergence analyses (such as Barro and Sala-I-Martin, 1991 and Rey and Montouri, 1999), with a preponderance of evidence supporting convergence (James and Campbell, 2012). EAs are constructed by the BEA to be functionally independent economies and should provide reasonably independent units of observation (Johnson and Kort, 2004). As a conditional convergence model, our takes the following form:

$$\Delta PCI_i = a + \beta_1 PCI_{i,1990} + \beta_2 X_{ij} + \beta_3 W\lambda + \varepsilon$$

where ΔPCI is the rate of change in per capita income in region i from 1990-2010, $PCI_{i,1990}$ is base year per capita income in region i, X_{ij} is a vector of location-specific explanatory variables including those related to hi-gros, $W\lambda$ is a spatial weight matrix defining the spatial lag, ε an error term, while β are the estimated coefficients. If the individual coefficient on the hi-gro variable is significant then our modeling framework will indicate the extent to which firms exhibiting exceptional growth and performance contribute to regional income convergence and their contribution to convergence relative to other explanatory variables related to firm location (access to transportation, labor, markets, etc.) in a spatially explicit model constructed at the proper geographic scale. Additional regional predictors include traditional measures theorized to be drivers of regional growth including urbanization economies and labor specialization in both skilled and unskilled sectors.

Urbanization benefits refer to those benefits a firm receives simply by locating in a large urban area such as the availability of existing physical and business infrastructures or the innovative ideas that can come from a diverse labor force (Stafford, 1980). In terms of growth models, urbanization amenities offer a way of capturing public capital provision. Traditional production needs (such as electric power and transportation access) provided by the public sector lower overall costs to the firm thereby making the region more attractive to firms and positively impacting growth (O' hUaullachain and Satterwaite, 1992; Stafford, 1980). Here, urbanization benefits are captured by the 1993 weighted Beale Code. These ordinal codes rank counties with a score from 0-9 and are released by the USDA to measure urbanity for counties through population and

proximity to an urban core. Counties with a score of 0 are most urban, and those with a score of 9 are least. To create a measure for EAs, we first reversed the order and calculated a population weighted average for the component counties in an EA.

Localization benefits are the external advantages that firms receive, such as a trained labor force or specialized business services, by locating near firms engaged in a similar activity (Stafford 1980). The impact of these benefits, however, has been less than clear cut in their ability to influence growth (O'hUallachain and Satterwaitte, 1992). A potential reason for this discord might come from the respective positive and negative effects that skilled service and unskilled manufacturing/primary activity can exert on a region. For example, a concentration of skilled workers was one factor helping Silicon Valley grow (Saxenain, 1994), while a concentration of employment in one, semiskilled sector presented a problem for Detroit when the production system and spatial margins of profitability for automobiles changed (Rubenstein, 1992). These types of specializations are typically included in conditional models as controls for economic structure (Rupisngha et al., 2002; Le Gallo et al., 2011).

In our model, we account both types of localization impacts. Low skill employment is measured by location quotients in Agriculture, Farm Employment, Mining, and Construction and high skill employment specializations are measured by location quotients for Finance, Insurance, and Real Estate (FIRE). The Farm, Agriculture, and Mining specializations are control variables for economic structure representing regional specialization in primary sector activity (Le Gallo et al., 2011).[3] Regions with low wages typically associated with primary sector activity should be attractive to relocating investment. However, regions with exclusive specialization in primary activities might not have sufficient infrastructure *in situ* to suit manufacturing needs. Construction, though low skill, is a measure of the relative health of the economy, as growing economies will have a need for new facilities, housing and infrastructure. FIRE, on the other hand, represents a high skill specialization. These sectors drove much of the growth associated with the 1990-2010 time period and an early advantage in these sectors might have given regions of competitive advantage through the study period.

In addition to the traditional regional growth variables mentioned above, two establishment-level variables specifically related to hi-gro firms were included. As presented in Kunkle (2009), we define hi-gros as firms that experience two or more hiring events without any employment reductions in a given time period, in this case 1990-1995. Using that definition, the first hi-gro measure we include is hi-gro age (*HGA*). *HGA* is the percentage of hi-gro firms that survived through the first five years of the time period (that is, in business in 1990 *and* 1995). *HGA* reflects the nature of the high growth firm: is it a reliable, sustained "old" growth firm, or a rapidly growing start up? This is an important distinction, as it can capture the internal dynamics of the firm. Newer firm growth may be driven by one innovative product that has yet to mature, while survivor firms will have shown the internally adaptive framework noted by Penrose (1959). Thus, a large concentration of these sustained growth firms suggests

[3] While wages in mining activities are usually higher than regional averages, the skill requirements of this activity typically are not.

these firms have an innovative advantage in the region which should help drive regional growth.

The other hi-gro measure included is a hi-gro survivor location quotient (*LQHG*). Here, we examine the proportion of surviving hi-gro firms in the region, 1990-1995, divided by the same proportion for the nation. That is, LQHG measures of the concentration of sustained growth firms in the region relative to the nation. If the value is large, there should be a critical mass of firm expansion helping to drive regional growth.

Our establishment-level data draw from the National Establishment Time Series database (NETS) which contains information on all known establishments between 1990 and 2010. NETS is compiled using Dun and Bradstreet's (D&B's) DMI records on an annual basis. Dun's Market Identifier (DMI) files contain information on more than 100 variables related to establishment demographics (e.g. age, location, industry, ownership), operations (e.g. corporate structure, secondary and tertiary SICs, relocations), as well as performance (e.g. sales and employment). Walls & Associates, under contract with D&B, obtains annual updates for all DMI files. It then uses the DUNS to create a time-series for each company by linking these annual files based on the DUNS numbers. Walls & Associates then applies a proprietary screening system to eliminate duplicates and identify reporting anomalies in the records. One of the primary advantages of DMI files over federally-generated statistics is that government data releases are limited by legal requirements that ensure confidentiality of each business entity. Further, NETS also allows researchers to fully decompose the source of employment change into its components: births, deaths, expansions, contractions, and relocations into and out of a U.S. region. While relatively few studies have employed NETS, those that have generally indicate a high level of confidence in the data in studies of firm-level employment changes, regional employment growth and agglomeration (see Wallace and Wallas 2004). For example, Neumark et al (2005) compared the employment levels of NETS for the State of California with several federally-produced datasets including the Quarterly Census of Employment and Wages (QCEW) and the Current Employment Statistics survey (CES), and the Size of Business data (SOB). They found a correlation of 0.994 in the total level of employment between NETS and QCEW; a 0.948 correlation between NETS and CES; and a 0.817 correlation between NETS and SOB. In fact, NETS reports 184% more employment in establishments in the 1-4 employee size range than SOB, and 29% more in the 5-9 employee size range. They also report NETS had total employment of 17-22% higher than QCEW for various size ranges. Although there is no "gold standard" for establishment-level data, the NETS dataset is the only available source of information that will allow the establishment-level analysis needed to adequately address the research questions posed by this inquiry.[4]

Table 1 shows the explanatory variables, their definitions and their expected signs.

To demonstrate the importance of accounting for spatial effects in convergence we start by running a conditional model with no spatial parameters. After assessing model

[4] For more information regarding the use of NETS for employment and regional analyze and comparisons with federal sourced data, see Kunkle (2011).

diagnostics, we then re-run the same model but account spatial effects via a spatial lag model. The contrasting model results not only reveal the importance of including spatial effects in the study of regional income convergence generally, but provide unbiased estimates of the impact hi-gro performance on the convergence process.

Table 1: Explanatory Variables		
Variable Name	Description	Expect Sign
PCI_{1990}	Per Capita Personal Income, 1990	(-)
URB	Weighted average of Beal Codes, 1993	(+)
LQF	Location quotient of Farm employment, 1990	(-)
LQAg	Location quotient of Agriculture employment, 1990	(-)
LQM	Location quotient of Mining employment, 1990	(+)
LQC	Location quotient of Construction employment, 1990	(+)
LQFIRE	Location quotient of Finance, Insurance and Real Estate employment, 1990	(+)
HGA	"Age" of hi-gro firms	(+)
LQHG	Location quotient of surviving Hi-Gro Firms,1990-95 relative to all surviving firms, 1990-95	(+)
$W\lambda$	Spatial weight matrix	(+)

4. Analysis

4.1 The Standard Conditional Model

Given the above, we begin with a traditional OLS analysis in order to provide baselines and model calibration for the spatial analysis that follows. OLS results are sensitive to changes following the inclusion of spatial effects, but still can provide insight in to broad processes. Additionally, they especially provide insight in terms of model fit and outliers. Results are displayed in Table 2.

In general, the OLS model provides a reasonable explanation of growth, explaining roughly one-third of the variation in growth rates with an adjusted R^2 of 0.327, and an F-statistic indicating overall model significance. For baselines to compare to the spatial model (an MLE), the log-likelihood value is -636.325 and an AIC of 1292.72. Non-spatial residual diagnostics, however, indicate specification problems, as the Jarque-Bera and Bruesch-Pagan indicate non-normal and heteroskedastic residuals, respectively. The normality check is not particularly disturbing, as a larger number of observations can increase the likelihood of non-normal distributions. The heteroskedastic residuals are more problematic because they can influence the standard errors of the estimate,

invalidating p-values, as well as suggesting omitted variables. Accordingly, results from the OLS are subject to confirmation via the spatial model.

Table 2: OLS Results

Adjusted R-squared	0.327	F-statistic	10.51
Log-likelihood	-636.325	Jarque-Bera	35.52 (0.01)
AIC	1292.72	Breusch-Pagan	17.47 (0.042)
Schwartz	1324.48	Koenker-Bassett	10.38 (0.321)
Constant	343.255 (0.00)	LQC	1.116 (0.77)
1990 PCPI	-39.086 (0.00)	LQFIRE	11.977 (0.006)
LQAg	-3.625 (0.05)	URB	-0.392 (0.896)
LQFarm	-0.747 (0.599)	LQHG	-19.423 (0.00)
LQM	1.196 (0.03)	HGA	196.75 (0.003)

In the OLS model, the relationships between individual predictors and income change generally follow suggested theory. For example, the negative and significant coefficient on 1990 per capita income indicates the presence of beta convergence—higher initial income levels are associated with slower rates of income growth. Other significant predictors included *LQAg*, *LQM*, *LQFIRE* and both hi-gro variables. As expected, specialization in farm and other agriculture had a negative impact on per capita income growth. Though primary sector activities (such as agriculture) produce low per capita wages, and a large concentration of agricultural employment should associated with lower prevailing wages, a concentration in agricultural employment might also indicate an infrastructure deficit and lack of a critical population mass that is key to industrial location decisions (Stafford, 1980). Mining, however, had an opposite effect on regional income growth. As a primary sector activity, this might seem counterintuitive, however, during this time period there was rapid growth in the energy sector, especially that in the Dakotas and upper plains that might possibly explain this result. If true, these regions should appear as residual outliers in the LISA cluster maps. *LQFIRE* was highly significant and positive, which is expected given its growth up to 2007 and the on-set of the Great Recession. By virtue of the high skill and wages associated with *LQFIRE*, it operates differently from those sectors driving investment associated with convergence. However, with the wealth that can be generated by a skilled worker in this sector, firms are generally willing to pay the premium for them, similar to the willingness to pay for skilled labor in early phases of the product cycle. In early phases of product cycles, productivity advantages associated skilled labor in a high value product market can offset their added costs. As such, locations with a concentration of these workers (e.g. New York City), will exhibit lower rates of firm mobility reflecting the embeddedness of their labor market.

Finally, of central interest to this study, the hi-gro variables were both significant predictors of growth. However, their relationship to growth is not the same. For instance, *HGA* was significant and positive. This result fits well with theory—a large number "old" hi-gro firms that demonstrated a sustained ability to innovate and adapt

more strongly influenced regional growth than the startups whose hi-gro status might still be a result of their initial idea. However, the other hi-gro variable, *LQHG*, had a smaller though significant and negative impact on growth. On the surface, this is a surprising result, as a cluster of hi-gro firms should be responsible for associated levels of employment and wage growth. However, *LQHG* might be reflecting a different process than theorized. It is possible that the mere presence of hi-gros in smaller EAs might exert a proportionately larger influence on per capita income growth than a higher concentration of them in larger, more urban areas. Perhaps they are, to coin a phrase, like big fish in small ponds.

In general, however, urban areas tended to have larger concentrations of hi-gro firms during the time period under study, though the variable reflecting urbanization (*URB*) was not significant. *LQHG* was highest in the industrialized Midwest, stretching southward along the I-65 - I-75 corridor. Urbanized areas of the industrialized upper-Midwest were at the center of deindustrialization that began in the mid-1970s but even by the 1990s, an initial concentration of hi-gros was apparently not sufficient to sustain per capita income growth. Thus, hi-gro firms in the upper-Midwest are rather special; they managed to grow despite regional decline in other sectors though their growth could not off-set broader sectoral declines. It appears, then, that the upper-Midwest experienced top-down convergence. The concentration of urban hi-gros in the Southern portion of the I-65-I-75 corridor was centered in places like Atlanta, Knoxville, and Louisville. Though otherwise conducive to interregional shifts in investment and branch plant location (Erickson, 1976), it is possible that rapid population growth in these areas off-set per capita income gains that might otherwise might have been associated with an initial concentration of urban hi-gros.

Additional insight can be gained through an analysis of LISA clusters on model residuals.[5] LISA clusters represent spatial concentrations of values that are of similar (or dissimilar) magnitude to a degree that is outside of the expected clustering due to the First Law of Geography (Anselin, 1995; Tobler, 1970). When applied to regression analysis, it is useful to examine residuals for two reasons. First, spatial autocorrelation in residuals violates the OLS assumption of residual independence that can skew confidence intervals around regression coefficients and suggest the likelihood of omitted variables. Secondly, analysis of residuals can add insight to the outliers by identifying regional contexts in which the general model significantly under- or over-performed.

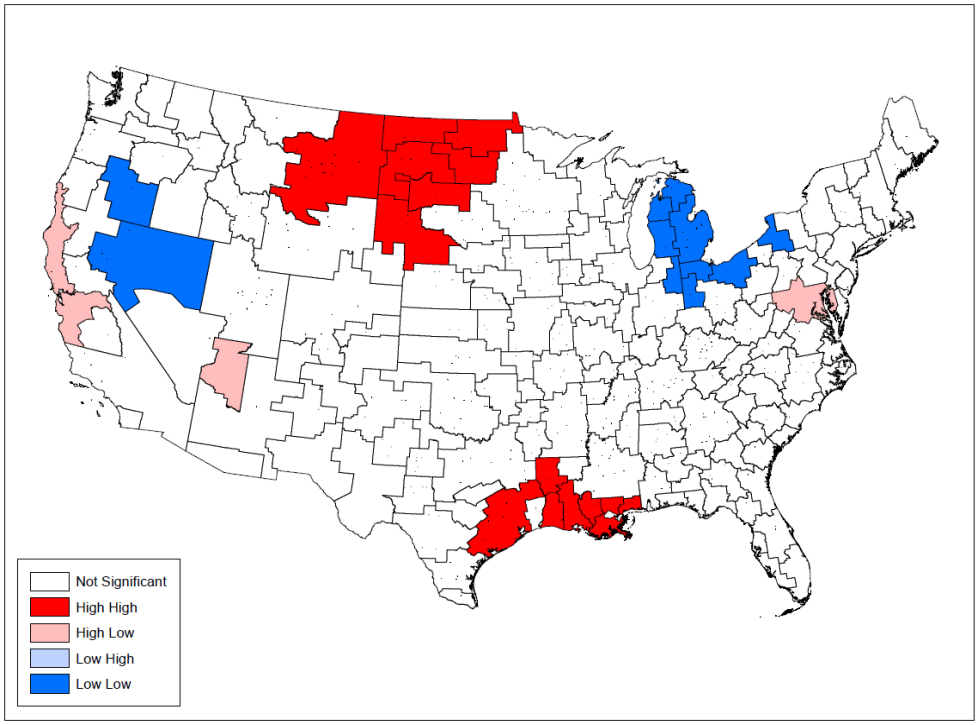
A LISA cluster map of residuals from the OLS model is displayed in Figure 1. There are significant high-high clusters in the upper Great Plains/Dakotas and Gulf Coast of

[5] LISA stands for Local Indicators of Spatial Association. LISA cluster maps show the extent to which particular observations lie outside acceptable limits predicted by the model. There are four types of LISA clusters. High-High clusters show regions that registered unusually high values surrounded by other regions that "over-performed" compared to model expectations. High-High clusters are shown in red and are frequently referred to as "hot spots". Low-Low clusters show clusters of areas that under-performed relative to model expectations. These "cold spots" and are shown in blue. High-Low clusters are areas where high performers are surrounded by low performers and are coded in pink the maps while Low-High clusters show under-performer areas surrounded by high performers. In the maps, Low-High clusters are shaded in light blue.

Texas and Louisiana. Both of these regions are home to the energy sector, a sector which experienced considerable growth during the time period under study. The growth associated with these sectors outpaced the predicted growth of the mining sector as a whole, as sectors such as oil extraction or other resources contributed to faster-than-expected income growth. Additionally, a low-low cluster located in the Detroit-Toledo-Cleveland region is strongly associated with Fordist-style heavy manufacturing, a process that was once dominant in the region through obsolete since the fourth Kondratieff (Malecki, 1997). This region represents a core of the old manufacturing region whose disinvestment has helped spur the growth in Southern regions (Hayter, 1997; James, 2010). The losses these urban areas experienced were even greater than the conditional convergence process predicted, implying a localized regional effect at work possibly due to overspecialization in particular products (automobiles in Detroit, tools in Cleveland, and glass in Toledo). So, it was not that these regions focused on manufacturing, *per se*, but rather how the locations in this particular region singularly focused their manufacturing economies.

The presence of high-low spatial outliers in the tech-orientated west coast locations is also noteworthy. These high skilled industry locations, such as Silicon Valley and Seattle, significantly outperformed the expected growth from the convergence model. Part of the reason may be the unique nature of these economies, such as the entrepreneurial spirit, knowledge base, and venture capital clustered in Silicon Valley or the concentration of aerospace and computing in Seattle that leads to unique locational factors is difficult for any model to capture. However, accounting for spatial effects may serve as a proxy to capture those clusters of unique economic activity.

Figure 2: OLS Residual LISA Clusters



4.2 Accounting for Spatial Effects and the Role of Hi-Gros

In the preceding discussion, we detected a large number of significant spatial outliers in the OLS model. Further, OLS diagnostics revealed problems of heteroskedacity. Combined with the Lagrange Multipliers from the OLS model a different model incorporating a spatial lag variable is indicated.[6] Spatial lag models are necessary when there is spatial autocorrelation among the dependent the variable in the model. In other words, while the variables themselves may not be correlated globally, variables are correlated with themselves regionally (Anselin, 1988). Results of the spatial model are displayed in Table 3.

Table 3: Spatial Lag Model Results

Pseudo R-squared	0.584	F-statistic	N/A
Log-likelihood	-606.042	Jarque-Bera	N/A
AIC	1234.08	Breusch-Pagan	17.56 (0.04)
Schwartz	1269.02	Koenker-Bassett	N/A
Constant	147.745 (0.049)	LQFIRE	5.939 (0.084)
1990 PCPI	-22.960 (0.00)	URB	-3.95 (0.093)
LQAg	-2.434 (0.098)	LQHG	-11.60 (0.003)
LQFarm	-2.462 (0.027)	HGA	154.892 (0.003)
LQM	0.563 (0.194)	LagChange	0.587 (0.00)
LQC	-0.113 (0.969)		

Model diagnostics suggest our spatial model significantly out-performed the OLS. The log-likelihood and AIC values are both closer to zero, indicating the superiority of this model versus its' OLS counterpart. The Pseudo-R-Squared suggests the model explains over half the variation in rates of income change, however as a pseudo-score, it cannot be compared directly to the "true" R-Squared provided in the OLS analysis (Anselin, 2005). The Breusch-Pagan test is brought in to compliance at the most stringent level, thus solving one of the key problems of the OLS model.

While the inclusion of spatial effects improved the explanatory power of the model, it generally reduced the impact of the individual predictor variables. This is due to spatial autocorrelation of the individual predictors; in the OLS, the individual variables accounted for the influence of spatial dependence, but in a proxy fashion, whereas as the spatial lag truly captures the spatial effect, thus improving model fit and reducing the "workload" of the individual variables. This is best reflected in the intercept term which is no longer significant at the most stringent level. Significant intercepts are a sign of omitted variables, a problem that has plagued similar studies even if spatial effects are included (James and Campbell, 2012). This is an important finding, both in terms of convergence theory and in the context of the firm. While the addition of spatial effects

[6] Lagrange Multipliers in the OLS model yields values for the spatial lag to be significant (0.00) while the spatial error is not (0.42) indicating that a spatial lag model is appropriate (Anselin, 2005).

can dramatically improve diagnostic performance in a convergence model, the omitted variable problem represented by significant constant indicates that convergence models focused solely on regional variables fall short in fully explaining the process. The ability of the spatial, firm, and regional variables to reduce the significance of the constant presents evidence that the convergence process is a function of both regional and firm level processes. Beta convergence is still present and significant at the most stringent level, though the actual coefficient is lessened. In other words, after accounting for spatial effects, regional income convergence is a slower process than that suggested by OLS studies.

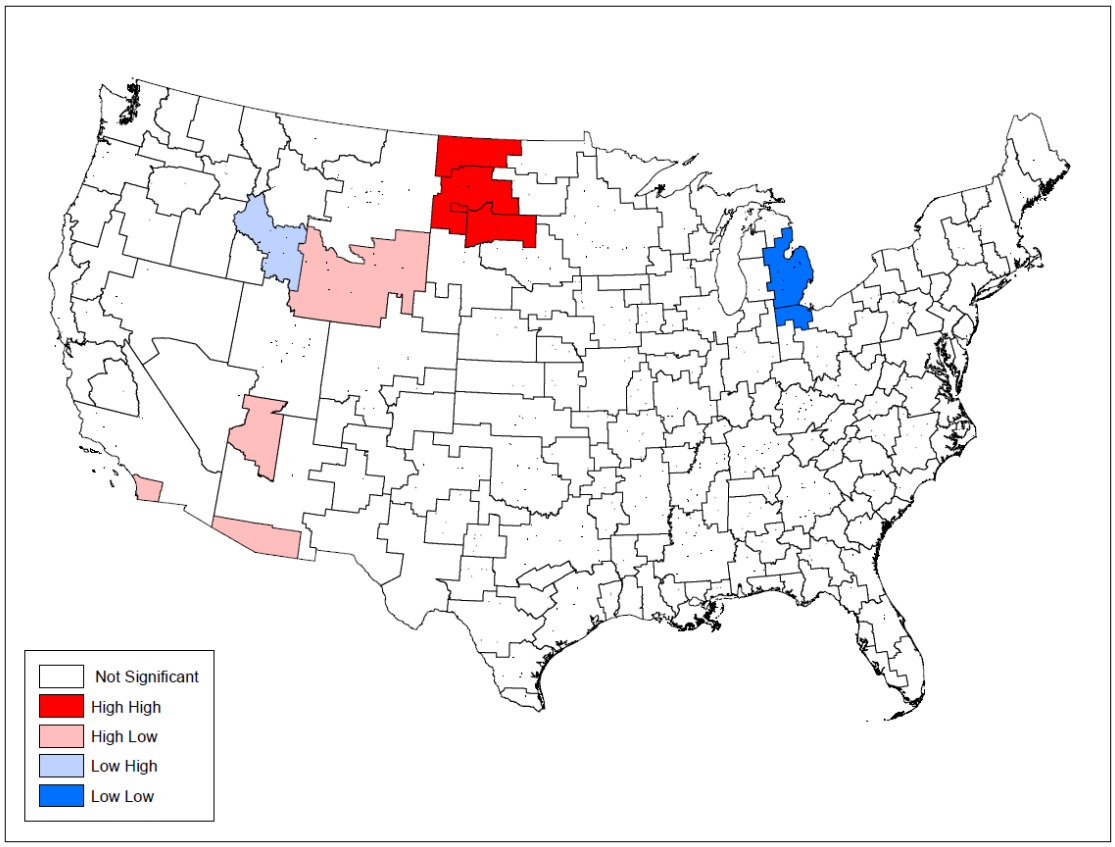
A similar story holds for *LQAg*, *LQFIRE* and both hi-gro variables. While significant predictors, their individual p-values were reduced. This implies that the spatial lag removed some of the "work" these variables needed to do, indicating an underlying spatial structure to these variables that influences growth as each of these contributed to the lag. For example, a concentration of FIRE in one EA positively impacts growth in its neighbors due to either a similar concentration of FIRE employment or the ability of a firm and workers to spread the multiplier effects. As for hi-gros, though their individual influence lessened, both are still significant. In terms of *HGA*, the presence of these long-run, sustained growth firms generated benefits not only to their home economy, but to their neighbors as well. This model stops short in identifying the nature of that regional benefit whether it be spillovers, multipliers, forward and backwards linkages, or simply a regional culture of innovation and management prowess. But it does imply that hi-gros in one region produce positive externalities among its neighbors. Similarly, the impact of hi-gro concentration, *LQHG*, was lessened. One possibility is that the density of hi-gros might be higher in more urban areas which, overall, experienced declining growth rates during the period under study. Operationally, since the spatial lag is positive, this negative effect should temper what would have been an otherwise larger beta coefficient. The implication is that hi-gro firms, both in their nature and concentration, impact the economies of their region and those surrounding them.

Worth additional note is that urbanization and *LQFarm* displayed negative impacts on growth in the spatial model, though neither at the highest level of significance. This implies a few things. First, as opposed to the OLS model, the spatial models bring diagnostics in to compliance and the p-values can be trusted. With these "true" p-values, the true factors of influence are identified. For urbanization, a concentration of population and development negatively impacted growth. For mature products this is not surprising, as the wage premium associated with urban areas has long been a deterrent to their location (Erickson, 1976). Improvements in transportation and power networks have opened-up new sites for manufacturing firms that previously might have had to locate in urban areas in order to receive those benefits. This suggests an urban-rural movement of investment, which is consistent with both theories of convergence and product life-cycles. Tempering this urban-rural movement is the negative impact of farm labor. A possible explanation here is that even though the wages in rural locations are lower, and thus attractive to relocating firms, locations that are too rural (too focused on agriculture) might not have the critical mass of infrastructure and available labor to make those locations viable for investment. So, the premium that firms historically have been willing to pay in urban areas for infrastructure and labor assurance is still relevant,

though not as strongly as before. In other words, while investment may be leaving urban areas, it is not relocating to the most rural of locations, but rather rural locations that offered a minimum of infrastructural and labor capacity.

A LISA cluster map of residuals (Figure 2) furthers the evidence of the completeness of the spatial effects and hi-gro model. Compared to Figure 1, the number of LISA clusters and scale of remaining clusters has been greatly reduced. The clusters driven by the energy boom have been greatly reduced. In fact, the Texas cluster has disappeared entirely. The remaining high-high cluster in the Dakotas is much smaller in extent, as spatial effects have accounted for the regional advantage that the energy deposits gave those regions. What remains of those clusters are truly unique economic growth characteristics that a global model might not capture. Similarly, the low-low clusters in the Rust Belt show a large reduction in scale, again offering evidence to the uniqueness of the Detroit economy. Outside of those clusters, the only noticeable clusters are spatial outliers in the western United States. These are a combination of low and high outliers, with the high outliers representing urban central places surrounded by largely rural activity. As such, they may have been the only real options offering the minimal infrastructural requirements for firms in the sparsely populated region with equally as sparse public capital.

Figure 2: Spatial Lag Residual LISA Clusters



5. Conclusions

In this paper we have attempted to blend elements of macro- and microeconomic theory to explain regional income convergence in the U.S. from 1990 to 2010. While our macroeconomic variables consisted of those location factors frequently found in the literature addressing conditional income convergence, our microeconomic variables, based on Penrose's resource based view (RBV) of the firm, reflected the presence of high-growth firms (hi-gros) and their contribution to the convergence process. Further, due to specification problems frequently overlooked in standard OLS testing of income convergence, we cast our model in a spatially explicit form using areal units that (a) reflect the scale at which firms make decisions, (b) convergence is best tested, and (c) minimize statistical problems that have plagued convergence studies. Our contribution to the literature, therefore, is threefold: We (1) incorporate the presence and dynamics of firm growth as an explanatory variable; (2) do so in a spatially explicit model involving spatial lags while (3) implementing the model at the appropriate geographic scale, that of the EA — a functional economic region.

Our results produced a parsimonious model free from statistical bias. In the process we confirmed that regional income convergence is indeed occurring in the U.S., even over relatively short periods of time. We have demonstrated that while convergence is an inherently geographic process, the pace of convergence is slower than standard models might suggest and that many of the traditional location factors found in convergence studies such as sectoral specializations and urbanization are, indeed, relevant and consistent with theories of firm location and product cycles. Hi-gro firms are of special importance, however, though their presence and impact on convergence is somewhat nuanced. On one hand, regions that contained a large proportion of hi-gro firms that survived the beginning period under study, 1990-1995, exerted a strong positive influence on subsequent regional income growth, ceteris paribus. This is an important finding as it suggests future studies of regional income growth and convergence should attempt to capture the dynamics of firms that comprise regions. On the other hand, initially high concentrations of hi-gros do not guarantee future enhancements to regional income. Like the urbanization variable, and possibly related to it, we found that high concentrations of hi-gro firms in the base period were negatively associated with convergence. While the localization and urbanization benefits of agglomeration in urbanized areas has been much-discussed (see Feser, 1998; Glaeser et al., 2001), it appears that rates of regional income growth are inversely related to urbanization and an initial concentration of hi-gro firms, a result consistent with product cycle theory.

As with many such models, ours has a large and significant constant term, indicating that important explanatory variables have been omitted. Our primary purpose was to examine the role of high-gros in a statistically valid, spatially explicit model; it was not to develop the "definitive" model of income convergence. However, the issue of omitted variables suggests directions for further research. A few such variables immediately come to mind including regional location factors that measure the presence or absence of critical infrastructure, state and regional policies that might affect firm location decisions (e.g. Right to Work legislation, use of locational incentives, etc.). At the same time, our results point to the need to more fully conceptualize and incorporate firm-level

variables that would deepen our understanding of their role in the convergence process. Examples might include firms' propensity to bundle after-sales services associated with their products, the extent to which intra-firm organization and/or their isolation mechanisms serve to protect firm-based assets and resources, the role of acquisition is stimulating firm-level growth or if the achievement of production scale produces positive externalities to their host communities and the regions that neighbor them.

However, one result is clear: The business of regional analysis must augment the traditional list of exogenous location factors and again acknowledge the performance of individual firms and firm-level considerations in the study of regional income convergence while taking into account that the convergence process is inherently geographic, thus dictating the use of spatially explicit models in conjunction with new data such as the National Establishment Times Series (NETS) database.

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