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Regional and Industrial Inversion in U.S. Patent Activity**

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Abstract

While it is clear that there has been a “regional inversion” in American patent activity over the past 25 years (i.e. relative rise of the Northwest and Southwest at the expense of the traditional invention hotbeds of the Northeast and Midwest), the reason is still open to speculation. Intuition suggests that it can be explained by some combination of changing demographics and industrial composition. We introduce constant market share analysis (CMSA), typically used only in international trade theory, offering a new extension to this tool, and conclude that industrial shifts have accounted for almost half of the regional inversion. Regression results show how the West capitalized upon the shift using demographics and policy variables, whose importance vary with the planning horizon.

Keywords:

invention, geography, clustering, regional inversion, constant market share analysis

JEL Codes: L0, O30, O38, R11, R12, R15

I. Introduction

It is clear that there has been a “regional inversion” in American patent activity over the past 25 years --- the Northwest and Southwest have risen in importance at the expense of the traditional invention hotbeds in the Northeast and Midwest. In fact, while the Northeast and Midwest accounted for seventy-three percent of all American patenting in 1963, that share has fallen continuously, to fifty-one percent by 1999. Intuition suggests that the change can be explained by a combination of changing demographics and industrial composition, and to test that intuition, this paper applies several new tools. Pioneering the use of constant market share analysis (CMSA) outside of international trade theory, we offer an extension to this tool, explaining the component parts using a system of simultaneous equations. We conclude that industrial shifts account for almost half of the regional inversion, and that the western regions of the United States capitalized on these shifts with a combination of demographics and policy variables which vary in strength by the planning horizon.

While recent literature has investigated the geography of invention, most has been in the form of industry-based case studies, particularly in computer-related and biotechnology sectors. Studies which span industries have typically been based upon cross-sectional data from one year or a brief set of years (e.g. national innovation systems literature). Yet from the point of view of technological change, it is important to analyze the interactions of geography and economics over time, in order to discover which policy tools or geographical attributes have promoted the ability to keep up with sector-based trends or to switch to growing sectors.

Section II places our work within the recent literatures of innovation geography and constant market share analysis. Section III outlines the methodology, along with summary statistics, while Section IV presents the estimation results.

II. Literature review

The two major problems faced by the literature on innovation geography have been choosing a measure of innovation, and explaining that measure in a manner more universal than a case study format. While patents are an accepted measure of invention (see Griliches, 1990, for discussion and Acs et al., 2002, for recent empirical evidence), they have obvious shortcomings. Not all innovations are patented, with some instead kept as trade secrets. There has been a changing propensity for inventors to patent their inventions over time (Sullivan, 1989) and most critically, all sectors do not rely on patent protection to a similar degree, even at the same point in time. Therefore, patent counts over-represent the inventiveness of sectors which protect many small inventions, and under-represent sectors filing for fewer (but possibly equally important) patents. In short, patents do not reflect the research effort involved in new technologies, nor do they reflect the marketable value of the underlying inventions.

However, patents have the benefit of offering a nationally accepted standard, where all pass an inspection for novelty and usefulness by examiners trained in the field. Records are then publicly accessible, including details to place the invention in geographic and economic space (i.e. sectors of origin and use). While distinguishing an invention's "importance" is critical in some contexts, this paper concentrates on the geographical dispersion of sheer inventiveness at or above the standardized level provided by patenting, regardless of effort or degree of importance to the firm

or society. Since constant market share analysis relies on comparison with national trends, it is the perfect tool to control for changes in the propensity to patent across industries or over time.

Inventions which are not patented are the most serious source of potential bias in this dataset, but little can be done to remedy it. The obvious alternative measures of inventive activity are lists compiled by industrial experts (e.g. Audretsch and Feldman, 1994; Feldman and Florida, 1994; Bania et al., 1992; Oakey et al., 1980), or direct surveys of firms (e.g. Kleinknecht and Poot, 1992; Davelaar and Nijkamp, 1989; Felsenstein and Shachar, 1988; Howells, 1984). However, since our goal is historical coverage across a range of industries and locations, such an exercise is infeasible. At any rate, information about unpatented innovations may be held secret during surveys as well.

The second problem, explaining the trends in invention across industries, can now be overcome in a novel fashion due to two tools: the Yale Technology Concordance (YTC) and constant market share analysis (CMSA). The challenge historically has been that patents are recorded with legal classifications which do not readily match potential explanatory variables, but the YTC, described in the next section, overcomes that problem, giving counts of patents in an input-output matrix format. Thus, each region and time period can be described with a matrix showing patents manufactured in, and bound for subsequent use in, the spectrum of economic sectors.

This format is perfect for CMSA, obviating the need for case studies (for good reviews, see Suarez-Villa and Walrod, 1997; Malecki, 1986) and adding the benefit of econometric precision to the wonderful work of Sokoloff (1988) and Suarez-Villa (1993). CMSA has been used exclusively in international trade circles, to investigate whether changes in trade patterns are associated with variations specific to the economic sector of production or geographic destination

(Laursen, 2000; Boltho, 1996; Balassa, 1979; Leamer and Stern, 1970; Renten and Duffy, 1970).

The tool decomposes a region's change in trade (or patents) into parts associated with the overall national trend, trends in the sector of export (or origin), trends in the sector of import (or use), and residuals to capture shifts into growing sectors and out of stagnating sectors. However, it is almost always used as an endpoint of analysis, whereas we extend it another step, asking how demographic and policy variables affect the relative size of each component.

III. Methodology

Upon application, patents are assigned a product code which helps examiners and lawyers in grant and litigation decisions. While the patent class system is useful for legal purposes, it is of little use to researchers who wish to combine patent data with other datasets, since the product definitions correspond with no other classification system¹. Fortunately, between 1972 and 1995 the Canadian Intellectual Property Office simultaneously assigned product codes along with an industry of manufacture (IOM) and sector of use (SOU) code to each of over 300,000 granted patents. The Yale Technology Concordance² utilizes that information to determine the probability that any patent with a specific product code has a particular IOM-SOU combination. Since the U.S. uses the same product code system for American patents³, we can infer the probable IOM-SOU details of each patent. Although the concordance is based on Canadian data,

¹ For example, the International Patent Class B05 includes all goods or processes involved in “spraying or atomizing in general; applying liquids or other fluent materials to surfaces, in general”, and so will include products and processes from a variety of different industries, from cosmetics atomizers to agricultural pesticide sprayers.

² Software and sample data are available at www.wellesley.edu/Economics/johnson/jeps.html

³ Technically, the U.S. has only used the same definitions since the international standard was established in 1975. For data prior to that, we formed a concordance between the U.S. system and the international system, to infer what the international class would have been for U.S. patents granted prior to 1975. See the original working paper version (Johnson, 1999) for details on the historical concordance.

the industrial structure of Canadian inventions is not imposed on American patent data, since the concordance indicates a relationship between a product/process definition and an industry definition, but permits enormous flexibility for the data to display the industrial composition of patenting in the United States. Statistical tests of its accuracy compared to hand-tabulation are uniformly strong, even across time periods and nations (most notably Johnson, 2002; also Kortum and Putnam, 1997; Johnson and Evenson, 1997). The concordance thus presents an alternative to the time-consuming efforts of previous historical scholars (e.g. Sullivan, 1990) who either individually assigned patents to industries or had to rely on rough guidelines about the relation between product classes and industries.

Constant market share analysis (CMSA) is based on the following mathematical identity, attributing to each component a portion of the total change in patenting between the origin and terminal year:

$$\begin{aligned}
 V'-V &= rV + \sum_i (r_i - r)V_i + \sum_i \sum_j (r_{ij} - r_i)V_{ij} + \sum_i \sum_j (V'_{ij} - V_{ij} - r_{ij}V_{ij} + \frac{|r_{ij}V_{ij}|}{2}) - \sum_i \sum_j \left| \frac{r_{ij}V_{ij}}{2} \right| \\
 &= (a) + (b) + (c) + (d) + (e)
 \end{aligned} \tag{1}$$

where V' is the number of patents in the state in the terminal year

V is the number of patents in the state in origin year

V_i is the number of patents in the state in the origin year from the i th IOM

V_{ij} is the number of patents in the state in the origin year from the i th IOM and j th SOU

V'_{ij} is the number of patents in the state in terminal year from the i th IOM and j th SOU

r is the national percentage increase in the number of patents between the origin and terminal years

r_i is the national percentage increase in the number of patents in the i th IOM between the origin and terminal years

r_{ij} is the national percentage increase in the number of patents in the i th IOM and j th SOU between the origin and terminal years

The first three terms measure how effectively a state keeps up with the national trend. That is, they project the impact of national trends if the state maintains a constant “market share”, or relative level of patenting activity consistent with its initial endowment, in each sector. Term (a) reflects the potential rise in patenting if the state follows the aggregate national trend, regardless of industrial composition. Term (b) considers the national growth rate in each industry of manufacture (IOM), projecting growth for states with initial endowments in IOMs which grow rapidly on the national level. In parallel, term (c) is positive for any state whose SOUs grow rapidly on the national stage.

The final two terms, or residuals, reflect the agility of a state, or its ability to shift out of an original endowment of sectors, into more inventive industries. Term (d) is a residual which measures the ability of a state to shift market share into IOMs or SOUs with high growth rates. Term (e) is similarly associated with changing market share, but measures the ability of a state to shift out of IOMs or SOUs with stagnating growth rates. Thus, (d) and (e) are zero for states which maintained their exact original industrial endowments relative to the national average, and are positive for states which outperformed their initial endowments, as defined by economic sector.

Notice that to obtain a positive value of (d) or (e), it is not sufficient for a state to shift into sectors with a higher *propensity* to patent their inventions, since all components are measured

relative to the national average. However, it is still important to interpret positive values as more patenting, and not necessarily more invention.

Armed with only these tools, we can offer an answer to an open question in the economic geography literature: how much of the regional inversion from East to West in the U.S. over the last quarter-century was due to industrial inversion? That is, what share was due to a change in which sectors create patents, and what share was instead due to new regions carving a niche out of the traditional sectors of the Northeast and Midwest? As Table 1 shows, over the 1975-99 period, states in the Northeast and Midwest had the national trend to their great advantage (component *a*), and the Northeast at least was poised in sectors with good growth potential (components *b* and *c*). However, those regions were not adept at switching into expanding sectors and out of stagnating sectors (components *d* and *e*). Looking at all components in absolute value, we suggest that 43 percent of the regional inversion is associated with encroachment on the Northeast's traditional industrial strongholds, and the remainder is associated with new opportunities in new sectors.

[insert Table 1 approximately here]

As an obvious robustness test, we investigate a range of different lag lengths, for every combination within the 1963-1999 period (e.g. for the five-year lag analysis, we use 1963-68, 1964-69, etc.). Summary statistics are presented in Table 2. Note that by construction, (*a*) always averages the total national increase in patenting per state, (*b*) and (*c*) always average zero and the national average of components (*d*) and (*e*) exactly offset each other. However, there is wide variation within each component. For lags less than ten years, national trend (*a*) accounts for an average of one-quarter of the total variation (dropping to fifteen percent for the twenty year

lag). On average, sector-based trends (*b*) and (*c*) account for only three and one percent respectively, while movement between sectors (*d*) and (*e*) make up the bulk of all variability, ranging between seventy to eighty percent. The moral --- that to remain inventive, regions must agile, open to sectoral shifts --- is surprising only in magnitude, not in the underlying message.

[insert Table 2 approximately here]

It is critical to recognize two inherent limitations of the CMSA process. First, it is sensitive to the level of aggregation, so we chose a relatively disaggregated set of economic sectors (42 industries, in a list available from the authors) and a geographic level consistent with state-level policy choices. We also test whether the results generalize to different geographic aggregations (by region) or are sensitive to time period.

Second, since the decomposition is purely mathematical, it offers no causal interpretations. While other CMSA studies usually terminate at this point, we use the results as a starting point for the Seemingly Unrelated Regression (SUR) analysis which follows in Section IV. Postulating a set of five reduced-form linear equations, we test whether the effects of demographic and economic policy variables are similar across components.

IV. Regression results and interpretation

Our goal in regression analysis is to determine significant relationships between patent activity and demographic or economic variables, particularly those under policy control. More precisely, via the CMSA decomposition, we can investigate whether a variable aided existing sectors to follow national trends, or gave agility to switch into more actively patenting sectors. This adds

depth, which is missed by simpler regressions of raw patent counts on the demographic and policy variables directly (e.g. Furman et al., 2002).

Maintaining the state as the unit of observation, we follow the literature in choosing explanatory variables (United States Patent and Trademark Office, 1997; Bureau of Economic Analysis, 2002; National Science Foundation, 2002; Bureau of the Census, 1961-66; Hammond, 1991) to include⁴

- population and population growth (in millions)
- income per capita (in thousands of 1996 dollars)
- land area (in hundreds of thousands of square miles)
- federal grants per research institution, current and cumulative since 1963 (in tens of millions of 1996 dollars)
- institutions of higher education per capita and changes in that number, and
- scientists and engineers per capita and changes in that figure.

Intuition and previous literature predicts positive effects of all variables except land area, especially on (a), (d) and (e).

Our results, shown in Table 3, are surprising on several fronts. First, there is less significance to our explanatory variables than expected, with R^2 values averaging only 0.35. Second, there are strong differences in estimated coefficients both between components and between different lags for the same component.

[insert Table 3 approximately here]

Unexpectedly, we have only minimal success explaining how states maintain shares in their initial sectors, with R-squared statistics of roughly 0.05 for short-term lags to 0.2 for long-term

lags of (a), (b) and (c). Apparently, a state's ability to follow national trends is explained more by historical factors which we have not captured.

Equally surprising is our unequivocal success at explaining the variability in how states shift between sectors via (d) and (e), where R^2 values range between 0.5 and 0.7 across all lag lengths. This is particularly surprising for short lags, where inertia might have been expected to play a larger role.

It is no surprise that states which are initially more populous subsequently patent more, as they are more able to follow (and set) the national trend. However, while states with large initial populations show some ability to enter growth sectors (d), it is slightly overmatched by a propensity to stay in stagnating sectors (e). On the other hand, growth in population unambiguously creates more patent activity, through virtually every conduit.

In the short-term, real income per capita enhances the ability of a state to keep up with the overall national trend, regardless of initial endowment (i.e. it helps (a) but neither (b) nor (c)). It also slows a state from exiting stagnating sectors, perhaps because they are still effective income-generating sectors despite their fall in invention-creation status. Over the long-term, real income per capita has a strong positive impact on all components except (e), where it shows that wealthier states are slowest to leave invention-stagnating sectors.

States with large land area have no short-term advantage or disadvantage, but in the long-run they are less likely to maintain the national trend, and are more likely to switch out of lagging sectors. Land area was included to capture the effects of large distances between population centers, but in reality reflects changes in California, Texas and Alaska which are not captured by

⁴ Variables have been carefully constructed to avoid collinearity, which explains our use of unusual ratios such as scientists and engineers per capita.

other variables. However, robustness tests omitting this variable, or omitting those three states, show very similar results.

States with more federal research funding in the initial period have no advantage over their peers in the short-term, and actually have more trouble matching the national trend in their endowed sectors. Perhaps more initial funding fosters lock-in to those initial sectors, and a sluggishness to grow with the national trend in those sectors once funding is secured. However, the good news is that the cumulative total of federal research funding over the lag period has a strong positive effect on both maintenance of trend and agility to switch sectors wisely.

More research institutions per capita add to almost every component in both the short and long term horizons, and states with a large initial allotment fare better than others. However, states with more scientists per capita seem less able to maintain the overall national trend, and increases in their ranks worsen the problem for all lags. While states initially endowed with scientists and engineers are not very agile, increases in the ranks of scientists are beneficial, with net gains in *(d)* and *(e)* combined. In short, successful states have been those with a relatively small existing stock of scientists who might be tied to research agendas in dying sectors, but have lots of new scientists who are agile enough to move the state out of stagnating sectors.

V. Conclusions and policy implications

Insofar as states are interested in encouraging patent-creating activity, the results of this work generate several important conclusions. Regional inversion of patenting in the U.S. has a decidedly economic reason, with movement to new and expanding sectors accounting for just under half of the perceived inversion. We find that while initial endowments of population, income, land, funded research institutions and educated citizens are important, some actually

contributed to a sluggishness or lock-in to stagnating sectors. However, changes in demographic and economic endowments over time have a profound effect as well. In particular, we find the intuitively appealing results that cumulative research funding, increases in institutions of higher education and new scientists and engineers aid a state in choosing key growth sectors and avoiding stagnating fields. While their impacts take a longer time to appear, those variables are highly successful at explaining why the Northwest and Southwest states have inverted the traditional patent pattern of the United States.

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Table 2: Importance of CMSA factors by time horizon (1963-99)

| Variable | Mean | St Dev | Min | Max |
|---------------------------------------|-------------|---------------|------------|------------|
| lag=1, 1836 observations, all states | | | | |
| Aggregate trend (a) | 21.32 | 180.66 | -1446.77 | 2706.70 |
| IOM trend (b) | 0.00 | 14.88 | -161.83 | 206.55 |
| SOU trend (c) | 0.00 | 4.22 | -32.57 | 32.57 |
| Shifts to growth (d) | 97.97 | 192.48 | -148.60 | 3516.12 |
| Shifts to stagnate (e) | -97.97 | 180.03 | -2944.80 | -0.41 |
| lag=5, 1632 observations, all states | | | | |
| Aggregate trend (a) | 52.92 | 332.02 | -2611.52 | 3578.39 |
| IOM trend (b) | 0.00 | 34.11 | -209.50 | 580.79 |
| SOU trend (c) | 0.00 | 8.50 | -73.09 | 112.51 |
| Shifts to growth (d) | 189.93 | 363.82 | -218.82 | 6225.85 |
| Shifts to stagnate (e) | -189.93 | 325.49 | -4080.93 | -1.08 |
| lag=10, 1377 observations, all states | | | | |
| Aggregate trend (a) | 65.00 | 520.77 | -2539.20 | 4984.22 |
| IOM trend (b) | 0.00 | 45.16 | -256.52 | 561.90 |
| SOU trend (c) | 0.00 | 11.61 | -121.35 | 122.03 |
| Shifts to growth (d) | 291.81 | 525.02 | -314.99 | 7857.81 |
| Shifts to stagnate (e) | -291.81 | 483.49 | -5648.58 | -1.99 |
| lag=20, 867 observations, all states | | | | |
| Aggregate trend (a) | 73.38 | 544.63 | -2078.68 | 6437.58 |
| IOM trend (b) | -0.02 | 69.01 | -405.19 | 658.69 |
| SOU trend (c) | -0.01 | 13.15 | -89.69 | 104.53 |
| Shifts to growth (d) | 318.65 | 675.35 | -477.34 | 10482.44 |
| Shifts to stagnate (e) | -318.65 | 593.13 | -7173.17 | -1.92 |

Table 3: Regression results (SUR for all states, 1963-99)

| Variable | Lag = 1 | | Lag = 5 | | Lag = 10 | | Lag = 20 | |
|----------------------------------|---------|---------|---------|----------|----------|----------|----------|---------|
| | Coeff. | t-stat. | Coeff. | t-stat. | Coeff. | t-stat. | Coeff. | t-stat. |
| Aggregate trend (a) | | | | | | | | |
| Population – level | 4.75 | 3.66*** | 13.35 | 5.12*** | 23.53 | 5.75*** | 52.01 | 6.48*** |
| Population – change | 108.81 | 1.57 | 112.08 | 4.06*** | 103.32 | 4.86*** | 23.21 | 1.14 |
| Income per capita | 9.35 | 6.44*** | 35.89 | 12.25*** | 64.32 | 14.11*** | 79.15 | 7.22*** |
| Land area | -6.31 | 1.11 | -34.37 | 3.10*** | -78.75 | 4.72*** | -85.21 | 2.64*** |
| Federal grants – current | -295.10 | 1.35 | -61.24 | 0.66 | -28.63 | 1.30 | -12.65 | 0.56 |
| Federal grants – cumulative | 151.46 | 1.38 | 13.14 | 0.71 | 11.21 | 1.23 | 0.39 | 0.04 |
| Institutions per capita – level | 1.20 | 1.35 | 3.99 | 2.33** | 6.91 | 2.73*** | 5.98 | 1.20 |
| Institutions per capita – change | 5.52 | 0.77 | 9.43 | 1.49 | 10.25 | 1.53 | -8.22 | 0.86 |
| S&E per capita – level | -5.08 | 1.55 | -13.11 | 1.99** | -26.66 | 2.61*** | -3.05 | 0.13 |
| S&E per capita – change | -76.48 | 2.92*** | -105.73 | 5.82*** | -94.33 | 3.91*** | -77.11 | 2.69*** |
| Constant | -188.06 | 6.83*** | -653.56 | 12.16*** | -1063.06 | 13.48*** | -1128.62 | 6.91*** |
| Observations, R ² | 1275 | 0.09 | 1173 | 0.26 | 1019 | 0.32 | 509 | 0.29 |
| IOM trend (b) | | | | | | | | |
| Population – level | 0.48 | 5.38*** | 1.46 | 5.04*** | 0.02 | 0.04 | 1.87 | 1.79* |
| Population – change | 4.96 | 1.03 | 16.07 | 5.26*** | 25.79 | 11.66*** | 18.91 | 7.14*** |
| Income per capita | -0.03 | 0.29 | 0.48 | 1.47 | 1.85 | 3.89*** | 3.29 | 2.30** |
| Land area | 0.23 | 0.58 | -0.68 | 0.56 | -6.03 | 3.48*** | -11.28 | 2.68*** |
| Federal grants – current | 5.82 | 0.38 | 8.24 | 0.80 | -11.58 | 5.03*** | -14.12 | 4.81*** |
| Federal grants – cumulative | 0.08 | 0.01 | 4.12 | 2.00** | 5.35 | 5.65*** | 6.83 | 5.88*** |
| Institutions per capita – level | 0.18 | 2.91*** | 1.03 | 5.46*** | 1.50 | 5.70*** | 3.75 | 5.75*** |
| Institutions per capita – change | 0.39 | 0.78 | 1.38 | 1.97** | 3.12 | 4.47*** | 4.58 | 3.69*** |
| S&E per capita – level | -0.09 | 0.38 | -0.90 | 1.24 | -0.47 | 0.44 | -2.26 | 0.74 |
| S&E per capita – change | -1.04 | 0.57 | -2.39 | 1.19 | -10.26 | 4.09*** | -8.54 | 2.28** |
| Constant | -6.18 | 3.23*** | -40.89 | 6.88*** | -70.09 | 8.54*** | -146.55 | 6.88*** |
| Observations, R ² | 1275 | 0.06 | 1173 | 0.15 | 1019 | 0.24 | 509 | 0.25 |
| SOU trend (c) | | | | | | | | |
| Population – level | 0.03 | 1.03 | -0.09 | 1.21 | -0.55 | 4.82*** | -0.47 | 2.31** |
| Population – change | 3.94 | 2.56*** | 5.91 | 7.57*** | 7.05 | 11.85*** | 3.42 | 6.61*** |
| Income per capita | -0.02 | 0.62 | 0.10 | 1.26 | 0.46 | 3.57*** | 0.77 | 2.76*** |
| Land area | -0.06 | 0.50 | -0.94 | 2.98*** | -2.43 | 5.20*** | -2.95 | 3.59*** |
| Federal grants – current | 1.52 | 0.31 | 2.16 | 0.82 | -2.18 | 3.53*** | -2.20 | 3.84*** |

| | | | | | | | | |
|----------------------------------|---------|----------|---------|----------|---------|----------|---------|----------|
| Federal grants – cumulative | -0.07 | 0.03 | 0.69 | 1.31 | 1.01 | 3.98*** | 1.03 | 4.55*** |
| Institutions per capita – level | 0.04 | 2.00*** | 0.20 | 4.10*** | 0.26 | 3.66*** | 0.49 | 3.86*** |
| Institutions per capita – change | -0.05 | 0.31 | 0.32 | 1.81* | 0.72 | 3.82*** | 1.00 | 4.13*** |
| S&E per capita – level | -0.04 | 0.58 | -0.31 | 1.69* | -0.34 | 1.20 | -0.53 | 0.89 |
| S&E per capita – change | 0.24 | 0.40 | -0.30 | 0.58 | -2.02 | 2.99*** | -2.13 | 2.91*** |
| Constant | -0.81 | 1.31 | -6.34 | 4.17*** | -11.97 | 5.42*** | -20.98 | 5.04*** |
| Observations, R ² | 1275 | 0.02 | 1173 | 0.08 | 1019 | 0.16 | 509 | 0.14 |
| Shifts to growth (d) | | | | | | | | |
| Population – level | 25.58 | 24.21*** | 51.96 | 23.29*** | 55.82 | 18.23*** | 44.58 | 6.50*** |
| Population – change | -53.89 | 0.96 | 123.85 | 5.25*** | 262.58 | 16.53*** | 306.88 | 17.69*** |
| Income per capita | 0.35 | 0.30 | 4.25 | 1.69* | 22.41 | 6.58*** | 27.59 | 2.95*** |
| Land area | 4.26 | 0.92 | 9.20 | 0.97 | -18.40 | 1.48 | -27.00 | 0.98 |
| Federal grants – current | -103.38 | 0.58 | 46.68 | 0.59 | -50.18 | 3.04*** | -45.86 | 2.38** |
| Federal grants – cumulative | 79.09 | 0.89 | 23.55 | 1.48 | 25.48 | 3.75*** | 21.67 | 2.85*** |
| Institutions per capita – level | 0.88 | 1.21 | 4.54 | 3.11*** | 8.45 | 4.47*** | 16.90 | 3.96*** |
| Institutions per capita – change | 0.27 | 0.05 | -2.16 | 0.40 | 10.72 | 2.14** | 9.42 | 1.16 |
| S&E per capita – level | -0.20 | 0.08 | -6.00 | 1.07 | -5.67 | 0.74 | 18.03 | 0.90 |
| S&E per capita – change | -23.17 | 1.08 | -1.23 | 0.08 | -64.45 | 3.57*** | -85.35 | 3.48*** |
| Constant | -61.45 | 2.74*** | -254.69 | 5.54*** | -584.64 | 9.91*** | -792.28 | 5.68*** |
| Observations, R ² | 1275 | 0.46 | 1173 | 0.56 | 1019 | 0.68 | 509 | 0.65 |
| Shifts to stagnation (e) | | | | | | | | |
| Population – level | -26.48 | 29.68*** | -60.98 | 37.37*** | -85.04 | 35.96*** | -125.52 | 21.46*** |
| Population – change | 215.94 | 4.54*** | 89.43 | 5.18*** | 3.15 | 0.26 | 12.65 | 0.85 |
| Income per capita | -2.23 | 2.23** | -13.30 | 7.26*** | -35.11 | 13.34*** | -57.65 | 7.22*** |
| Land area | 1.21 | 0.31 | 14.38 | 2.07** | 52.93 | 5.49*** | 83.03 | 3.53*** |
| Federal grants – current | -34.08 | 0.23 | -139.13 | 2.39** | 22.46 | 1.76* | 14.93 | 0.91 |
| Federal grants – cumulative | -33.46 | 0.44 | 7.80 | 0.67 | -13.14 | 2.50** | -9.93 | 1.53 |
| Institutions per capita – level | 0.14 | 0.23 | -1.21 | 1.13 | -2.59 | 1.77* | -4.99 | 1.37 |
| Institutions per capita – change | 0.99 | 0.20 | 4.57 | 1.16 | -7.80 | 2.01** | -0.03 | 0.01 |
| S&E per capita – level | 0.22 | 0.10 | 6.62 | 1.61 | 5.61 | 0.95 | -16.86 | 0.99 |
| S&E per capita – change | 28.33 | 1.57 | 6.18 | 0.54 | 78.60 | 5.64*** | 93.94 | 4.49*** |
| Constant | 71.85 | 3.79*** | 309.39 | 9.20*** | 645.63 | 14.17*** | 964.69 | 8.10*** |
| Observations, R ² | 1275 | 0.54 | 1173 | 0.69 | 1019 | 0.75 | 509 | 0.66 |

Coefficients on institutions per capita are multiplied by 10^6 and those on scientists and engineers by 10^3 for readability. Significance indicated as * for 10%, ** for 5%, *** for 1% levels.