How Important are Human Capital, Physical Capital and Total Factor Productivity for Determining State Economic Growth in the United States, 1840-2000*

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Abstract

This paper introduces a new data set of state-level physical capital in the United States from 1840 to 2000. The new data is combined with measures of the labor force, human capital, land, and output by state to perform traditional accounting decompositions. Growth in measured inputs accounts for three-fourths of output growth, but variation in the level or growth of measured inputs accounts for only one-third of the variation in the level or growth of output. Our methodology is comparable to that used for cross-country accounting studies, and yields a quantitatively similar conclusion: most cross-state and cross-country variation in levels or growth rates is driven by variation in TFP. One interpretation is that while states have less institutional and technological heterogeneity (and consequently less TFP variation), this is matched equally by less input heterogeneity, with the relative importance of TFP and inputs remaining constant throughout the process of output per worker convergence. In this case, the relative importance of inputs and TFP may constitute a robust fact that applies across a variety of settings.

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1 Introduction

Empirical research seeking to explain cross-country output per worker differences has expanded greatly since the introduction of new data, particularly the Penn World Tables (Heston, Summers, and Aten 2009) and Barro and Lee's schooling data (Barro and Lee 2001). Recent advances have been based mostly on development and growth accounting. With some presumed knowledge of a common production function, it is possible to disaggregate countries' output per worker levels and growth experiences into the relative contributions of measured inputs and the efficiency with which those inputs are used, commonly called total factor productivity (TFP). Accounting exercises seek the answer to one or more of three questions. First, what proportion of cross-sectional output variation can be accounted for by input variation, and what proportion is left to TFP? Second, what proportion of output growth can be accounted for by input growth, and what proportion is left to TFP?? Finally, what proportion of the variation in output growth rates can be accounted for by the variation in input growth rates, and what proportion is left to TFP? The answer to the first and third question has been that most of the variation comes from TFP, and has spurred the search for the sources of TFP differences across countries.[1]

In this paper we adopt the methodology of the development and growth accounting to analyze the output and growth of states in the United States. Output differences across states were small by the end of the 20th century, with the average output per worker in the most productive state less than twice that of the least productive. However, output differences were much larger before World War II. Our state output data show that the ratio of output in the most to least productive state was a factor of 3.4 in 1840, when there were many fewer states. The output difference was as large as a factor of 19.4 in 1870, and remained a factor of 4 as late as 1930, before relative convergence after World War II. We ask the same three questions the literature has asked of cross-country output differences. Our central finding is that TFP also accounts for most of the cross-state variation in output levels and growth rates.

The accounting approach requires data on production inputs and outputs by state for a long time period. The first contribution of this paper is to construct such a series for physical capital by state. It covers twenty-eight states for the entire 1840-2000 period of study, with data for other states becoming available later (generally, around the time of statehood). It also disaggregates physical capital into three broad sectors: agriculture, manufacturing, and other. For agriculture and manufacturing we rely directly on historical

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[1] On the importance of TFP, see for example Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), or Caselli (2005). The search for a theory of TFP can be traced at least to Prescott (1998).

measures of, or proxies for, each state's capital stock, while our measures for the remaining sector requires some imputation.[2]

We combine our new data with measures of human capital, number of workers, land in agriculture, and output by state previously constructed in Turner, Tamura, Mulholland, and Baier (2007). We then have a sufficient data set to do standard accounting exercises. The first is a development accounting exercise, which asks what fraction of cross-state variation in output per worker can be accounted for by cross-state variation in weighted inputs. Caselli (2005) provides a useful overview of this literature in the cross-country context, as well as updated results; we compare our results directly to his. We find that the variation in measured inputs accounts for roughly one-third of measured output across states, as compared to 38% across countries in Caselli's sample. Cross-state figures are much more affected by outliers than are the cross-country figures.

Our second exercise is a growth accounting exercise, which asks what fraction of the growth of state output per worker can be accounted for by the growth in measured inputs. This exercise follows in the footsteps of Young (1995) or Young (2003). A long literature has performed similar but more detailed exercises for the United States; see Jorgenson (2005) for an overview. Our contribution relative to this literature is that we study cross-state growth over a longer time period than is typically studied, and that our methodology allows for direct comparison to cross-country results. We find that 58%-68% of state growth is accounted for through input growth, slightly less than in a standard cross-country sample. This figure is similar for different broad regions of the United States, but varies a good deal by time period: input accumulation mattered relatively more before World War II, and TFP matters relatively more after.

Our final exercise is a variation in growth accounting exercise, which asks what fraction of the variation in the growth of states can be accounted for by the variation in the growth of measured inputs. In essence, it aims to find the source of idiosyncratic rather than common growth across states, in the spirit of Klenow and Rodriguez-Clare (1997). This question is particularly pertinent given the output per worker convergence of states: was convergence driven by idiosyncratically high input growth or idiosyncratically high TFP growth in unproductive states? Here, we find that one-third of the variation in output growth rates comes from variation in input growth rates, almost identical to the cross-country figure. Overall, we conclude that cross-state and cross-country accounting yield similar results: input growth accounts for over half of output growth, but only about one-

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[2] The data are available on the authors' webpages, as well as a detailed appendix describing the construction and robustness of the capital stocks.

third of output growth variation or output level variation.

We have two main concerns with our finding that drive us to explore some robustness checks. First, we worry that about the potentially important historical role for land. While our results do change, the basic summary is still the same: input accumulation accounts for more than half of growth but less than half of output level or growth variation. Second, we are concerned about the reliability of our imputed capital stock for the residual sector. We conduct separate accounting exercises focusing on the manufacturing sector, where our estimates of physical capital are based on historical state-level observation. We find that focusing on the manufacturing sector makes our quantitative results stronger and more similar to cross-country results.

Overall, our results suggest that TFP variation is as important to accounting for cross-state output variation as it is to accounting for cross-country output variation. We view this finding as a significant new empirical fact. We possess data on states for a much longer time period than most data on countries. In the 19th century, states had large differences in measured TFP and output, driven by factors such as mining activity, differences in legal systems (Berkowitz and Clay 2005, Berkowitz and Clay 2006), differences in disease burden (Bleakley 2007, Bleakley forthcoming), or the legacy of slavery (Mitchener and McLean 2003). Over time, TFP and output across states have converged in a way that TFP and output across countries have not. Over a long period of time and through significant convergence, the relative importance of TFP and measured inputs has remained relatively fixed and comparable to their relative importance across countries. Hence, it seems that the common stylized fact that explaining TFP variation is the key to explaining output variation holds across a variety of settings and time periods.

The paper proceeds as follows. Section 2 describes our physical capital data series. Section 3 briefly describes the other input and output data from prior work. Section 4 performs the baseline accounting exercises, while Section 5 performs robustness checks utilizing land and looking at only manufacturing. Section 6 concludes.

2 Physical Capital

The first contribution of this paper is to provide original estimates of physical capital for each state, dating back as far as 1840 for twenty-eight states, with coverage for the last "state" (Washington, D.C.) beginning in 1929. Our estimates of total physical capital are decomposed into estimates for agriculture, manufacturing, and the total of the remaining eight broad SIC industries, hereafter called the NMNA (non-manufacturing, non-agriculture) sector.[3] We distinguish between the three series because our estimates for Agriculture and Manufacturing are based on historical state-level observations on capital or proxies for capital, while our estimates for the NMNA sector involve more imputation. We briefly introduce our sources, imputation procedures, and the resulting series here. A longer online appendix provides further detail. When robustness checks are suggested here, the details are available in that appendix.

2.1 Agriculture and Manufacturing Physical Capital

The Census of Agriculture first collected capital stock data for some states in 1850, and continues doing so today. In five Censuses spanning 1900-1930, a detailed breakdown of capital was collected, allowing us to construct our preferred measure of physical capital in agriculture: buildings, livestock, machinery, and equipment. We account for acres of farmland separately; see Section 3.3. For other years, a detailed breakdown was not given. Instead, there is a consistent and related measure, the value of land and buildings, which spans the entire time period. We fit the relationship between our preferred measure of capital stock and the value of land and buildings in the 1900-1930 Censuses and use this relationship to impute the agricultural capital stock for the entire 1850-2000 time period.[4]

We estimate the national physical capital stock growth from 1840 to 1850 by assuming that the capital-output ratio remains constant between these years and using agricultural output data from Turner, Tamura, Mulholland, and Baier (2007), discussed below. We project each state's capital stock back from 1850 to 1840 by assuming it shared the common national growth rate. Finally, we make some imputations for Alaska, Hawaii, and Washington, D.C., which have less data available. We aggregate our results and compare them with the BEA estimates of the national physical capital stock in agriculture from 1947 onward; we underestimate the capital stock somewhat for 1947-1965, but our estimates agree closely with theirs after 1965.

The Census of Manufactures also collected information on the capital stock or proxies for the capital stock starting in 1850. In two Censuses (1890 and 1900) they collect a detailed breakdown of capital that allows us to construct our preferred measure of physical capital in manufacturing: buildings, plus machinery and equipment. For the other Censuses from 1850-1919 they collected an aggregated measure including both fixed and working capital;

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[3] The BEA data uses the following industry classifications: Agriculture, Forestry and Fishing; Mining; Construction; Manufacturing; Transportation and Public Utilities; Wholesale Trade; Retail Trade; FIRE; Services; and Government.

[4] Our baseline regression relates the log of agricultural capital to the log of land and building value with state fixed effects and time trends that vary by region; we try several other specifications.

the former is what is now simply called capital, while the other is a measure of cash on hand, bills receivable, and so on. Again we use the overlap between our preferred measure of capital and this Census-available measure to impute the value of the manufacturing capital stock for 1850-1919.[5]

The Census began asking about each state's available horsepower in 1904; between 1925 and 1954 they asked only various measures of horsepower. Their many measures of horsepower are highly correlated (greater than 0.99), so we rescale them into a single horsepower series. We estimate the relationship between physical capital and horsepower using the overlap between the series from 1904-1919.[6] We use this relationship to project manufacturing physical capital to 1954. From 1954 onward the Censuses asked two measures of capital expenditures by state. We combine the measures and project forward using perpetual inventory from 1954 to 2000, with a standard six percent depreciation rate. Again, we project capital back from 1850 to 1840 using the estimated national growth rate and make some corrections for the lesser data availability in Alaska, Hawaii, and Washington, D.C. We check our results against the BEA estimates of national physical capital in manufacturing from 1947 onward and find that they agree closely throughout the time period.

2.2 Physical Capital for Other Industries

Censuses for the other industries began later and lack measurement of capital stocks suitable for our purposes.[7] Given the lesser capital data availability, we are forced to impute data for the capital stock in these industries. Our basic approach is to use the approximation:

$$K_{it} = \sum_j \frac{K_{ijt}}{Y_{ijt}} Y_{ijt} \approx \sum_j \frac{K_{jt}}{Y_{jt}} Y_{ijt}. \tag{1}$$

where K is capital, Y is output, and i, j, and t subscripts denote states, industries, and years. Hence, we use aggregate data on the capital-output by industry and the state composition of output by industry to impute each state's capital stock for the NMNA sector.[8] Doing so requires ignoring any state-level variation in capital-intensity within an

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[5] Our baseline regression is log-log without any controls, but we try several other specifications.

[6] Our baseline regression is again log-log, this time with state fixed effects. We find no role for time interactions of any sort.

[7] For example, the Census of Mining first collected a proxy for capital - aggregate horsepower - in 1902, while the Census of Finance, Insurance, and Real Estate was not separated from the Census of Construction until 1992.

[8] Since we are focusing on the 1840 - 2000 period, we did not use the seminal work of Jorgenson, Gollop, and Fraumeni (1987), which produces sectoral capital measures from 1948 to 1979, inclusive.

SIC industry, an assumption previously made by Garofalo and Yamarik (2002) in their work on regional convergence from 1977 to 1996; of course, we have reason to suspect that capital-output ratios may be more similar across states at the end of the 20th century than they were in the 19th. Given the lack of outside data it is difficult for us to circumvent or test this assumption.

We construct the aggregate capital-output ratio using NIPA data, available from 1947-1997. Outside this range we are forced to impute the data, but most industries show no trend. Indeed, Gallman (1986) reports values for several industries from 1840-1900 that closely agree with those observed from 1947-1997 (his Table 4.8). For these industries we use the average K_{it}/Y_{it} observed. For wholesale trade and the government there is a significant trend; we assign the 1947 value to all years before 1947, and the 1997 value to 1998-2000. Our results are robust to allowing for time trends.

From 1963 through 1997, the BEA provides measures of gross state product in each industry for each state. While the BEA does not provide estimates of GSP from 1929-1962 or from 1998-2000, they do provide measures of wages and salary disbursements in each industry at the state level.[9] We find that gross state product and wages are highly correlated. We fit a relationship between GSP and wages and use this to project GSP by industry for 1929-1946 and 1998-2000.[10] With the exception of agriculture, the fit is quite good. We use actual or imputed GSP by industry and aggregate capital-output ratios by industry to construct the state NMNA capital stock using equation (1) for 1929-2000.

Before 1929, our only data source is GSP for agriculture, manufacturing, and NMNA. We proceed by projecting the value-added share of each of the eight industries in the NMNA sector back from 1929 to 1840.[11] We then construct capital stocks as:

$$K_{it} = \sum_j \frac{K_{ijt}}{Y_{ijt}} \frac{Y_{ijt}}{Y_{it}} Y_{it} \approx \sum_j \widehat{\frac{K_{jt}}{Y_{jt}}} \widehat{\frac{Y_{ijt}}{Y_{it}}} Y_{it}. \tag{2}$$

where $\widehat{\frac{Y_{ijt}}{Y_{it}}}$ denotes a projection of industry i's share of state j's NMNA production at time t.

As a check on our data, we also project the agriculture and manufacturing output share of each state back in time. As we will discuss below, we have outside evidence on output for these industries at the state level for 1840 to 1920. Hence, we can use this data as a

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[9] Wage and salary disbursements by place of work are reported in BEA series SA07.

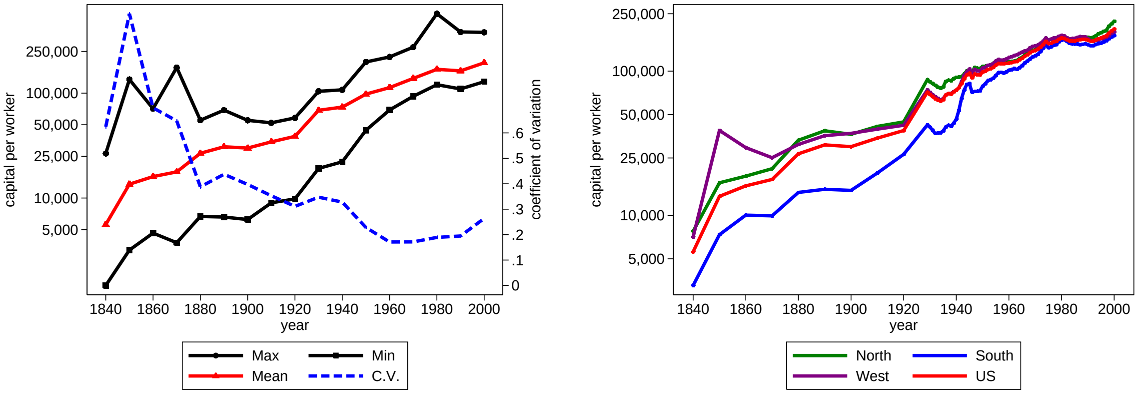
[10] The baseline regression is log-log and controls for time trends.

[11] Our projection is $\log(gsp_{ijt}) = \beta_0 + \beta_1 * \log(gsp_{it}) + \beta_2 * \log(pop_{ijt}) + \sum_i \alpha_i D_i + \sum_i \gamma_i D_i t$ where pop represents population, the D_i are state dummy variables, and $D_i t$ are state-time interactions.

check on the validity of our projections. We find that our projections deliver a good fit in manufacturing ($R^2 = 0.64$), but not as good a fit in agriculture ($R^2 = 0.25$), driven by a poor fit in Western states. We then construct capital for 1840-1928 using equation (2). We try several alternative ways of projecting back NMNA and find that most reasonable alternative specifications yield capital stock measures with similar properties, as measured by the correlation across alternative capital stocks and the average growth rate. Further, we will also compile results for only manufacturing where our capital stock estimates are based on direct observation.

2.3 Physical Capital Estimates

We sum our measure of physical capital in the three sectors to arrive at a state-level total physical capital stock. Figure 1a displays the labor force-weighted average physical capital per worker for the United States, as well as the coefficient of variation and figures for the state with the least and most capital per worker. The general process of convergence is immediately apparent.



(a) Aggregate Statistics

(b) By Region

Figure 1: Physical Capital

Figure 1b breaks down the capital stock for three broad regions: the North, the West, and the South. See Appendix A2 for our allocation of states to regions. The West was particularly capital-intensive at the start of the period, driven largely by the high mining share. The other dominant fact of the figure is the tremendous extent to which the South lagged the rest of the country in capital per worker until after World War II.

3 Output, Human Capital, and Land

Our other data were previously collected and presented in Turner, Tamura, Mulholland, and Baier (2007). We overview the main features of those data here.

3.1 Real Output per Worker

Annual data on income by state is available beginning in 1929 from the Bureau of Economic Analysis. We use Richard Easterlin's estimates of output by state for 1840, 1880, 1900, and 1920 (Easterlin 1960b, Easterlin 1960a). Turner, Tamura, Mulholland, and Baier (2007) developed measures of state output for 1850, 1860, 1870, 1890, and 1910. These estimates are based primarily on agricultural and manufacturing output as recorded in the Censuses; separately enumerated mining output for minerals-intensive regions; and imputation of Easterlin's figures for other industries.

We need information on the size of the labor force and prices to transform nominal output into real output per worker. State labor force measurements in Turner, Tamura, Mulholland, and Baier (2007) draw on *Historical Statistics of the United States*, various census issues, and work done by Weiss (1999) to correct the 19th century census estimates for rural undercounts. Nominal values were converted to real values using information on both annual national price level variation and less frequent observations of interregional price variation.[12]

Figure 2a gives the average output per worker for the United States, as well as the coefficient of variation and the output per worker for the richest and poorest state in each year. As with capital, the general trend has been towards convergence over time. Figure 2b shows the breakdown by region, which mirrors the trends for physical capital. The West had high output in the mid-19th century, driven mostly by mining, but rapidly converged. The South experienced large output per worker gaps as late as 1930. Output per worker converged more slowly than did physical capital per worker for the South.

3.2 Human Capital per Worker

Turner, Tamura, Mulholland, and Baier (2007) use information on school enrollment rates by state to develop estimates of the average education of the state population by year,

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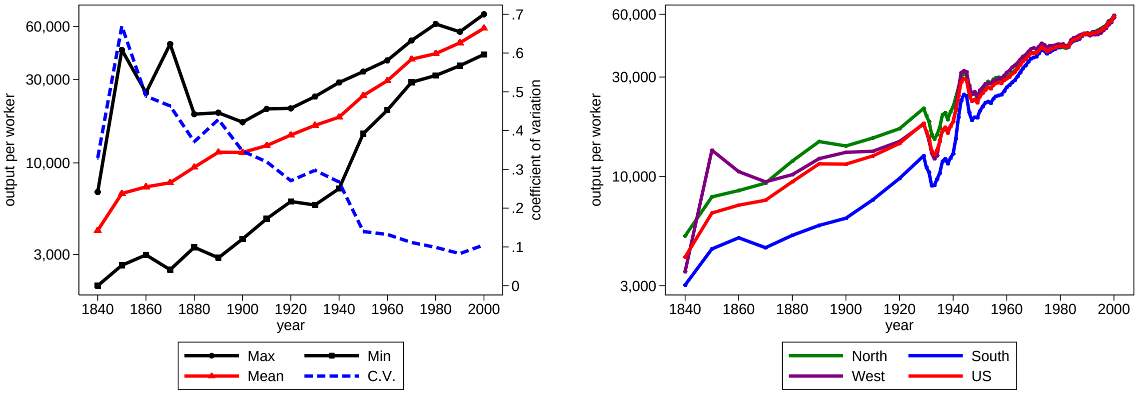
[12] Data on national price level comes from Gordon (1999) for 1875 – 2000, while data prior to 1875 is from *Historical Statistics of the United States*. Regional prices combine information from Mitchener and McLean (1999), Williamson and Linder (1980), and Berry, Fording, and Hanson (2000), which obtains complete coverage except that the Pacific and Mountain regions only have price data beginning in 1880; earlier observations are normalized using national price levels.



(a) Aggregate Statistics

(b) By Region

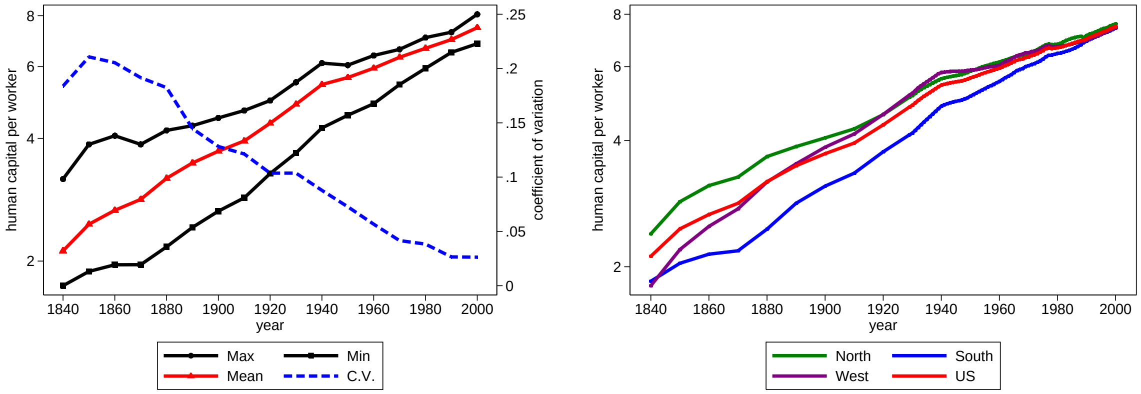
Figure 2: Output Per Worker

similar to the approach in Barro and Lee (1993) and Baier, Dwyer, and Tamura (2006). Information on school attainment is transformed into human capital using the log-linear approach pioneered in Bils and Klenow (2000). Log-human capital is assumed to be linear in school:

$$\log(h_{it}) = \phi_P P_{it} + \phi_I I_{it} + \phi_S S_{it} \tag{3}$$

where P_{it} represents years of primary schooling, I_{it} years of intermediate schooling, S_{it} years of secondary schooling. Following Hall and Jones (1999) we allow the rate of return to vary by the level of education, so we impose $\phi_P = 0.134$, $\phi_I = 0.101$, and $\phi_S = 0.068$. These values are an attempt to represent a diminishing marginal returns to higher levels of schooling sometimes seen in the data; more importantly, they are standard in the literature we take as our benchmark, particularly Caselli (2005).

We use equation (3) to measure human capital for each state for each year. Figure 3a gives the national results, and Figure 3b decomposes the effect into the regions. The primary difference between human capital and the previous series is in the West; while the West in early years was a leader in physical capital and output per worker, it lags in human capital. The South lags behind for the entire period; given the slow-moving nature of average human capital, the South has converged in human capital only recently.



(a) Aggregate Statistics (b) By Region

Figure 3: Human Capital Per Worker

3.3 Land per Worker

Some of our specifications evaluate the role of farmland per worker as a separate input to the production process. Our value for land is the acreage in farms from the Historical Statistics of the United States.[13] Figure 4 gives the evolution of land per worker by state: as expected, the data show a divergence rather than a convergence across states. Land quantities change over time as new land is cleared, or as land is removed from the agricultural sector into other sectors of the economy.

4 Baseline Development and Growth Accounting Results

The last ingredient for an accounting exercise is a production function governing the relationship between inputs and outputs. Our goal is to compare our results to the cross-country development and growth accounting studies, particularly those found in Caselli (2005). Hence we adopt as our baseline specification:

$$y_{it} = A_{it} k_{it}^{\alpha} h_{it}^{1-\alpha} \tag{4}$$

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[13] HSUS Series K 17-81. A plausible alternative is to use the value of land. We lack a historical series that spans the entire time period. Further, as noted in Tostlebe (1954), changes in the value of land can be due to improvements and investments, or to changes in agricultural productivity; conceptually we would like to include only the former.

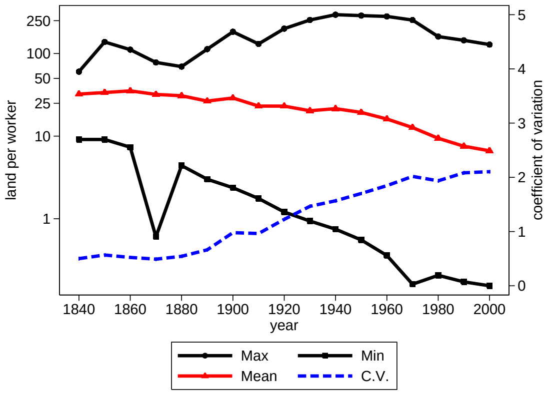
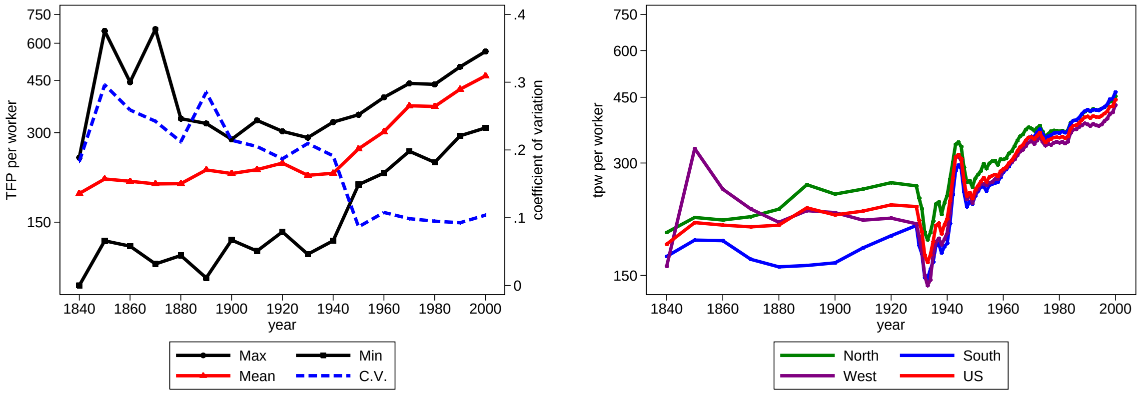


Figure 4: Land Per Worker

where y, k, and h denote output, capital, and human capital per worker. We take the same $\alpha = 1/3$ as Caselli. Given measured inputs and outputs, A_{it} is constructed as a residual term. It represents the effect of institutions, laws, technology, and other factors that improve the efficiency with which measured inputs can create output.



(a) Aggregate Statistics

(b) By Region

Figure 5: Total Factor Productivity

Figures 5a and 5b give the results for TFP. The variation generally decreases from 1840-1940, then experiences a particularly large decline between 1930 and 1940. There has been no evidence of TFP convergence since 1950. When looking across regions, it is clear that the West enjoyed high TFP early in the period, similar to the high measured TFP of oil-producing nations. Since 1900, the West has been similar to the national average. The rest of the convergence process for TFP was driven by the closing of the large gap between the high TFP in the North and the low TFP in the South.

Given our measures of inputs, outputs, and TFP, we now turn to development and growth accounting exercises that parallel those of the cross-country literature.

4.1 Development Accounting

In any particular cross-section, some states enjoy higher output per capita than others. Since World War II these differences have generally been small; the most productive state has had output per capita less than twice that of the least productive state. However, before World War II these differences were generally larger than a factor of 4, and reached as high as a factor of 19 in 1870. Development accounting asks: what proportion of cross-sectional output variation variation can be accounted for by input variation, and what proportion is left to TFP?

Following Caselli (2005), we consider three different metrics to address this question. We denote by x the predicted output generated by inputs, $x_{it} = k_{it}^{\alpha} h_{it}^{1-\alpha}$. Then the log-variance of output can be decomposed as:

$$\mathrm{var}[\log(y)] = \mathrm{var}[\log(a)] + \mathrm{var}[\log(x)] + 2 * \mathrm{covar}[\log(a), \log(x)] \tag{5}$$

The first two measures of the relative role of input variation are both based on this equation. The first is simply the relative variance of measured inputs to measured output:

$$\text{Contribution of Inputs} = \frac{\mathrm{var}[\log(x)]}{\mathrm{var}[\log(y)]}.$$

The second is drawn from Klenow and Rodriguez-Clare (1997), who note that there is a positive covariance between inputs and TFP.[14] Since it is not clear (without a theory) whether inputs cause TFP or TFP causes inputs, it is unclear how to "assign" the covariance terms. They propose assigning one-half of the covariance term to inputs and one-half to TFP; Baier, Dwyer, and Tamura (2006) explore a range of alternative options. We follow their baseline procedure, yielding our second measure of the role of inputs:

$$\text{Contribution of Inputs} = \frac{\mathrm{var}[\log(x)] + \mathrm{covar}[\log(x), \log(a)]}{\mathrm{var}[\log(y)]}.$$

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[14] As Caselli (2005) notes, accounting for the covariance produces a measure designed to address a different question. In his words, foregoing the variance answers the question "what would the dispersion of incomes be if all countries had the same A?" while including it answers the question "when we see 1% higher y, how much higher is our conditional expectation of [x]" (see p. ??).

Table 1: Development Accounting Across States and Countries

	States					Countries
Year	1840	1880	1920	1960	2000	1996
Relative Variance						
var[log(y)]	0.112	0.184	0.075	0.027	0.026	1.31
var[log(x)]	0.074	0.065	0.027	0.008	0.008	0.50
Contribution of Inputs	66%	35%	36%	31%	31%	38%
Relative Variance, Accounting for Covariance						
var[log(y)]	0.112	0.184	0.075	0.027	0.026	1.31
var[log(x)]+covar(log(x), log(a))	0.067	0.102	0.042	0.011	0.011	0.779
Contribution of Inputs	60%	56%	55%	41%	41%	60%
Comparison of 90/10 Ratios						
y_{90}/y_{10}	2.56	3.02	2.13	1.50	1.49	21
x_{90}/x_{10}	2.17	1.96	1.53	1.28	1.27	7
Contribution of Inputs	85%	65%	72%	85%	85%	34%
Obs	28	44	48	50	50	94

Note: y denotes output per worker, $x = k^{\alpha}h^{1-\alpha}$ denotes weighted inputs per worker, and a denotes TFP. Country data are from Caselli (2005).

Some of the output variation across states is due to outliers, particularly in the earlier years, where discovery of gold makes a state an outlier rapidly. To address this problem, our third measure of the role of input variation uses 90-10 ratios:

$$\text{Contribution of Inputs} = \frac{x_{90}/x_{10}}{y_{90}/y_{10}}$$

where y_{90} is our notation for the output per worker of the state at the 90th centile of the distribution and so on.

Table 1 gives our results for five cross-sections of states: 1840, 1880, 1920, 1960, and 2000. In addition, it gives results for countries in 1996, taken from Caselli (2005). Comparing across rows, it is first clear that there is much less output variation across states than across countries, even at the start of the period. The outputs of states have also converged over time, resulting in a decline of nearly an order of magnitude in the variance of log-outputs.

The small and declining variation in output across states can be accounted for in part by less variation in inputs per worker and in part by less variation in TFP. What we want to know is the relative contribution of inputs, as measured by the three metrics above. The variance of inputs is 31-66% of the variance of output across states, as compared to 38% across countries. The relative variance is particularly high in 1840, when there are fewer states in our sample. If we confine our attention to the four cross-sections from 1880 onward, our estimate of the relative variance is consistently around one-third, in line with the cross-country figure.

When using the Klenow and Rodriguez-Clare (1997) metric, we find that input variance accounts for 41-60% of cross-state output variation, as opposed to 60% of cross-country output variation. Note that the the 1840 contribution of inputs is smaller by this metric than by the relative variance metric, revealing that $\text{covar}[\log(x), \log(a)]$ was negative in 1840. Otherwise, the cross-state and cross-country results are in line with one another.

However, when comparing the 90-10 ratios we find that state results are quite different from cross-country results. In particular, the 90-10 ratio of inputs accounts for 72%-85% of the 90-10 ratio of output across states, but only 34% of output across countries. This result reveals that the richest and poorest 4-5 states have more influence on our metrics and results than on the cross-country output and results.

4.2 Growth Accounting

From 1840-2000, states experienced average output per worker growth of 1.58% per year. Growth rates tended to be faster in the South and slower in the West than in the North, reflecting convergence of output across states. Our second exercise is a growth accounting exercise, which asks: what proportion of output growth can be accounted for by input growth, and what proportion is left to TFP?

To measure the relative contributions, we use the standard growth accounting equation:

$$\Delta \log(y) = \Delta \log(a) + \alpha \Delta \log(k) + (1 - \alpha) \Delta \log(h) = \Delta \log(a) + \Delta \log(x) \tag{6}$$

where Δ denotes the growth in the corresponding variable. Our measure of the contribution of inputs is simply the fraction of output per worker growth that comes from input growth:

$$\text{Contribution of Inputs} = \frac{\Delta \log(x)}{\Delta \log(y)}$$

Table 2 gives the results for states, expressed as average annual growth rates. The first column gives the results for the entire 1840-2000 time period. Not all states are available

Table 2: Growth Accounting Across States and Countries

	All States, Various Years		Countries, 1960-1996	
	1840-2000	1880-2000	All	Restricted
$\Delta\log(y)$	1.58%	1.74%	1.89%	1.78%
$\Delta\log(k)$	1.69%	1.63%	3.47%	2.63%
$\Delta\log(h)$	0.73%	0.72%	0.79%	0.72%
$\Delta\log(x)$	1.05%	1.02%	1.68%	1.36%
$\Delta\log(a)$	0.51%	0.73%	0.21%	0.42%
Contribution of Inputs	68%	58%	89%	76%
Obs	50	50	83	48

Note: y denotes output per worker, $x = k^{\alpha}h^{1-\alpha}$ denotes weighted inputs per worker, and a denotes TFP. Not all states are available from 1840 or 1880, in which case they enter the growth accounting when first available; see Appendix A2 for details. Country data are two samples constructed to be consistent with Caselli (2005). All countries includes every country with data for 1960-1996, while Restricted further limits attention to the subset of countries with investment data for 1950-1959; these countries' capital stocks will be less sensitive to the initial conditions.

in 1840; for other states, the growth accounting results are calculated from the first year for which we have a complete set of data. Since data in earlier years may be noisier and the set of states with complete records is fewer, the second column gives data for the 1880-2000 time period. While only 28 states have complete data for 1840-2000, 44 states do for 1880-2000. The results are similar for both sets of state results. Output per worker grew a little more than 1.5% per year, with 60% accounted for by input growth; input growth was about equally weighted between capital and human capital over this time period. In Appendix B we show that these results hold robustly across three broad regions, but not across subperiods; the relative importance of inputs has declined over time and the relative importance of TFP has risen.

To put these figures in context, we compare them to similar accounting numbers for countries in the last two columns. We take the data used by Caselli (2005) and construct two samples for a growth accounting exercise for the years 1960-1996. The first sample includes all countries from Caselli's sample that also have investment data in 1960 and schooling or human capital data in 1960. As is standard in the literature Caselli estimates an initial capital stock in each country using the first investment data available and the Solow model's steady state, so $K_0 = I_0/(g + \delta)$. For many countries in the sample, investment data is first available in 1960, so our estimate of the capital stock in 1960 (and subsequent capital growth) may be unduly influenced by the Solow steady state assumption. Hence, we also construct a restricted sample of countries for which investment data is first available in 1950; their capital stock is more influenced by actual data (1951-1960 investment flows) and less by assumptions about the initial stock.

We find that the average country grew somewhat faster than the average state, a little less than 2% per year. For countries, slightly more of growth was accounted for by input growth, 76-89%. Input growth was more driven by capital stock growth than human capital growth, although there is some concern that the implied capital stock growth is sensitive to the initial conditions since the restricted sample shows almost 1% slower growth of capital per worker. Overall, we take away that growth accounting across states is similar to growth accounting across countries, with inputs accounting for around three-fourths of total growth. Growth accounting for countries more closely parallels growth accounting for states pre-World War II than for states post-World War II.

4.3 Variation of Growth Accounting

Growth in inputs accounts for most of growth in outputs in states and countries. However, Klenow and Rodriguez-Clare (1997) and Easterly and Levine (2002) argue that most of the variation of growth rates across countries is accounted for by variation in TFP growth rates rather than variation in input growth rates. Here, we pursue this variation of growth accounting, which asks: what proportion of the variation in growth rates can be accounted for by the variation in input growth rates, and what proportion is left to TFP?

Our measure of the role of inputs is the fraction of the variation in growth rates accounted for by the variation in input growth rates. As above, we consider two measures. First, the ratio of the variances:

$$\text{Contribution of Inputs} = \frac{\text{var}[\Delta \log(x)]}{\text{var}[\Delta \log(y)]}$$

and second, a measure which assigns half of the covariance term to inputs:

$$\text{Contribution of Inputs} = \frac{\text{var}[\Delta \log(x)] + \text{covar}[\Delta \log(x), \Delta \log(a)]}{\text{var}[\Delta \log(y)]}.$$

We do not compute the 90-10 ratio for growth rates: the 10th centile of growth is too likely to be negative or small for countries, and it is hard to compare a negative 90-10 ratio to a positive one.

Our results are given in Table 3. As for growth accounting, we study two possible eras

Table 3: Variation of Growth Accounting Across States and Countries

	States		Countries, 1960-1996	
Year	1840-2000	1880-2000	All	Restricted
Relative Variance				
var[$\Delta \log(y)$]	0.0018%	0.0012%	0.0339%	0.0235%
var[$\Delta \log(x)$]	0.0006%	0.0004%	0.0128%	0.0045%
Contribution of Inputs	32%	31%	38%	19%
Relative Variance, Accounting for Covariance				
var[$\Delta \log(y)$]	0.0018%	0.0012%	0.0339%	0.0235%
var[$\Delta \log(x)$]+covar[$\Delta \log(x), \Delta \log(a)$]	0.00109%	0.0006%	0.0150%	0.0082%
Contribution of Inputs	47%	49%	44%	35%
Obs	50	50	83	48

Note: y denotes output per worker, $x = k^{\alpha}h^{1-\alpha}$ denotes weighted inputs per worker, and a denotes TFP. Not all states are available from 1840 or 1880, in which case they enter the growth accounting when first available; see Appendix A2 for details. Country data are two samples constructed to be consistent with Caselli (2005). All countries includes every country with data for 1960-1996, while Restricted further limits attention to the subset of countries with investment data for 1950-1959; these countries' capital stocks will be less sensitive to the initial conditions.

for states, 1840-2000 and 1880-2000. The results for states are similar across the two time periods; around one-third of the variance in output per worker growth is accounted for by the variance of input growth, with the other two-thirds reserved for variance in TFP growth. The figure is around one-half for methods that assign half of the covariance term to the inputs. We also present results for the same two samples of countries discussed in the previous section. The results are similar by the first metric (around one-third of output variation accounted for) but somewhat lower by the second metric, because of a lower covariance across countries than across states.

Although there is some nuance across sub-periods and in different samples, and states and countries are not of course identical, the results for our three accounting measures tend to be similar across different methodologies. We summarize them as follows: over half of output growth can be accounted for by input growth, but only about one-third of variation in output levels or growth rates can be accounted for by variation in input levels or growth rates. In the next section we ask whether these results are robust to alternative accounting assumptions.

5 Alternative Accounting Approaches

An accounting exercise can go wrong in one of two ways: through misspecification of the production function, or through mismeasurement of the inputs or the outputs. We are particularly concerned about two possible errors. First, we have followed the literature in adopting a production function that does not allow for land, but land had a large historical role in the U.S. We augment our exercise to allow for land as a third input. Second, we may have mismeasured the physical capital stock, particularly the capital for the NMNA sector. If our imputed NMNA capital stock artificially understates cross-state variation in inputs per worker, then it will lead us to overestimate the importance of cross-state variation in TFP. To assess this possibility we perform separate accounting exercises for the manufacturing sector, where we observe state-level capital (or proxies for capital).

In the following sections we describe the alternative approaches in more detail, and then present the results.

5.1 Accounting for Land

We begin by modifying the accounting exercise to account for land. Our measure of land (acres of farmland per worker) was previously introduced in Section 3.3. We allow agriculture to enter our technology as follows:

$$y_{it} = A_{it} k_{it}^{\alpha} \mathcal{L}_{it}^{\beta} h_{it}^{1-\alpha-\beta}$$

where $\mathcal{L}_{it}$ denotes land in state i at time t. In presenting the results, we now refer to inputs as $x_{it} = k_{it}^{\alpha} \mathcal{L}_{it}^{\beta} h_{it}^{1-\alpha-\beta}$.

The primary question is how to calibrate the shares α and β for an economy where land's importance varies by state and is changing over time. Valentinyi and Herrendorf (2008) gives sectoral estimates of the land and capital shares that we use to parameterize α and β. We perform two accounting decompositions for land. In the first, we take account of variation over time and across states in land's importance to the economy by allowing α_{it} and β_{it} to vary. In particular, Valentinyi and Herrendorf show that land is much more important in agriculture than in the other sectors, and we know that agriculture's importance in the aggregate economy is declining over time. To capture this effect in our accounting model, we parameterize the shares as:

$$\alpha_{it} = 0.283$$
$$\beta_{it} = 0.05 + 0.13\frac{y_{ag,it}}{y_{it}}$$

where $y_{ag,it}/y_{it}$ is agriculture's share in state i's economy at time t. The time-varying shares capture the basic fact of their paper: land has about an 18% share in agriculture, but only about a 5% share in the remaining sectors. We call this the time-varying land share exercise.

The growth accounting results for this specification confound two changes: changes in actual inputs, and changes in the parameters used to weight the inputs. To clarify and separate the effects of these changes, we also consider an alternative accounting exercise where we keep the land shares fixed at $\alpha = 0.283$, $\beta = 0.05$. We call this the constant land share exercise. These shares are essentially the ones that prevail in the aggregate U.S. in 2000, so comparison of the time-varying and constant land shares makes it possible to disentangle the effects of incorporating land and varying the input shares over time.

5.2 Accounting in Manufacturing

Finally, we perform a separate accounting exercise for manufacturing. Our goal is to test whether our accounting exercises are unduly influenced by the estimates of the physical capital stock of the NMNA sector. As discussed previously, our physical capital stock estimates are already separated by sector. The estimates of the labor force and GSP from Turner, Tamura, Mulholland, and Baier (2007) are also decomposed into the same three sectors. We assume that the schooling and hence the human capital of the workforce is the same in all three sectors. This assumption is unlikely to hold, but the historical data (derived from schooling enrollments) provide us with no means to separate out human capital by sector.

Once again, we turn to Valentinyi and Herrendorf (2008) for the sectoral factor shares. In manufacturing they use $\alpha = 0.36$, $\beta = 0.04$ while we use $\alpha = 0.4$, $\beta = 0$. Recall that our measure of land is acreage in farms; it makes little sense to assign acreage in farms a share in manufacturing. Using superscript m to denote manufacturing, our production function is

$$y_{it}^{m} = A_{it}^{m} \left(k_{it}^{m}\right)^{0.40} \left(h_{it}^{m}\right)^{0.60}.$$

We conduct the same three accounting exercises on manufacturing and in economies with

Table 4: Contribution of Inputs: Alternative Development Accounting Exercises

	States				
Year	1840	1880	1920	1960	2000
Relative Variance					
Baseline	66%	35%	36%	31%	31%
Constant Land Share	47%	26%	32%	48%	29%
Time-Varying Land Share	28%	18%	48%	60%	34%
Manufacturing	51%	21%	21%	52%	43%
Relative Variance, Accounting for Covariance					
Baseline	60%	56%	55%	41%	41%
Constant Land Share	48%	46%	45%	30%	12%
Time-Varying Land Share	28%	32%	40%	25%	10%
Manufacturing	5%	43%	30%	42%	31%
Comparison of 90/10 Ratios					
Baseline	85%	65%	72%	85%	85%
Constant Land Share	73%	58%	72%	89%	85%
Time-Varying Land Share	59%	53%	79%	94%	85%
Manufacturing	80%	35%	56%	93%	92%
Obs	28	44	48	50	50

land as we did for the aggregate baseline case.

5.3 Development Accounting

Our first exercise is development accounting, or trying to understand the role of variation in inputs in accounting for variation in outputs in the cross-section. As before we look at five equally spaced cross-sections in U.S. history: 1840, 1880, 1920, 1960, and 2000. Table 4 gives the results. For convenience we have reported only our three measures of the contribution of inputs, eliminating the numerator and denominator that were reported in Table 1.

Our goal is to understand how including land or focusing on manufacturing might alter our understanding of the baseline results. Our first finding is that land is accounting for land generally *reduces* the ability of input variation to account for output variation. This

Table 5: Contribution of Inputs: Alternative Growth Accounting Exercises

	All States, Various Years	
	1840-2000	1880-2000
Contribution of Inputs: Growth		
Baseline	68%	58%
Constant Land Share	58%	49%
Time-Varying Land Share	50%	44%
Manufacturing	88%	69%
Obs	50	50

Note: not all states are available from 1840 or 1880, in which case they enter the growth accounting when first available; see Appendix A2 for details.

finding holds whether we use a fixed 5% land share across time and states or whether we use a time and state-varying land share. The primary reason is that land per worker is negatively correlated with capital and human capital per worker, so including land decreases the role of inputs.

The role of input variation in accounting for output variation in manufacturing is also generally smaller than in our baseline, aggregate case. However, there is some evidence (the first and third measures of contribution) that input variation was more important in manufacturing than in the entire economy in 1960 and 2000. Nevertheless, the differences are relatively small. The first basic message of the baseline results seems intact: variation in input levels accounts for most of the variation in output levels, except as measured by the 90/10 ratio.

5.4 Growth Accounting

Our second exercise is growth accounting, or trying to understand whether factor accumulation or efficiency gains account for more of economic growth. Table 5 gives the results for our alternative exercises. As for the development accounting table, we are presenting only the contribution of inputs, not the numerator or denominator of the statistic.

Accounting for land reduces the role of input growth in accounting for output growth. The average state has seen a decline in the acreage devoted to farmland over time. Further, assigning land a larger role in the aggregate production function means assigning a smaller

Table 6: Contribution of Inputs: Alternative Variation of Growth Accounting Across States

	States	
Year	1840-2000	1880-2000
Relative Variance		
Baseline	32%	31%
Constant Land Share	21%	25%
Time-Varying Land Share	12%	17%
Manufacturing	14%	22%
Relative Variance, Accounting for Covariance		
Baseline	47%	49%
Constant Land Share	37%	40%
Time-Varying Land Share	25%	29%
Manufacturing	24%	40%
Obs	50	50

Note: not all states are available from 1840 or 1880, in which case they enter the growth accounting when first available; see Appendix A2 for details.

role to the (growing) physical and human capital stocks. There is little differentiation between the two land measures.

Again we use manufacturing as a test to see whether our stylized results are driven by our estimates of physical capital in the NMNA sector. As for development accounting, the manufacturing results are actually closer to the cross-country results; 69-88% of growth in manufacturing output is accounted for by growth of inputs to the manufacturing sector, as compared to 76-90% of cross-country growth.

5.5 Variation of Growth Accounting

The final exercise measures the extent to which cross-state variation in output growth is accounted for by cross-state variation in input growth. Table 6 gives the results, again expressed as the contribution of inputs with the numerator and denominator of each statistic omitted.

The results from the alternative accounting exercises are stronger than the baseline. If we focus on the relative variance metric, our baseline result was that only around one-third of variation in output growth can be accounted for by variation in input growth. When accounting for land, the figure falls to 12-25%. Focusing only on the manufacturing sector, variation in input growth again accounts for only 14-22%. A similar story holds in the metric that includes the covariance term; accounting for land or focusing on manufacturing yields lower results for the role of input growth variation.

Overall, land seems to play little role in our results. Our results also seem insensitive to potential mismeasurement of the NMNA physical capital stock; in general, the results from the manufacturing sector are stronger and more similar to the cross-country results than our baseline.

6 Conclusion

Development and growth accounting provide insight into the relative role of inputs and efficiency in accounting for cross-country income variation. However, the data on which they are based (primarily the Penn World Tables and Barro and Lee's schooling data) have a relatively short time frame. Because of this, accounting methods are somewhat limited in their ability to anticipate what will come in the future. Will input growth continue to account for most of output growth? Will variation in input levels and variation in input growth continue to account for little of the variation in output levels and the variation in output growth?

This paper provides some insight by turning to the states of the United States. Along with previous work, it collects a record of inputs and output that spans 160 years for the states. This time period includes a short window of income divergence and a long window of income convergence. Throughout this time period, we find that the relative role of TFP and inputs are relatively constant, and generally similar to their role across countries. Input growth accounts for around 60% of output growth, although the fraction is declining. Around one third of cross-country income variation and income growth variation is driven by inputs; the rest is driven by TFP variation. Our results suggest that the basic importance of TFP is a stylized fact that could hold in the future, even if cross-country income variation changes dramatically.

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A Regions and Data Availability

A.1 Regional Divisions:

Each of our broad regions (North, South, West) is composed of three Census regions (given in italics), with each Census region having between four and nine states.

North	South	West
New England	*South Atlantic*	*Mountain*
Connecticut	Delaware	Arizona
Maine	D.C.	Colorado
Massachussets	Florida	Idaho
New Hampshire	Georgia	Montana
Rhode Island	Maryland	Nevada
Vermont	North Carolina	New Mexico
	South Carolina	Utah
Middle Atlantic	Virginia	Wyoming
New Jersey	West Virginia	
New York		*Pacific*
Pennsylvania	*East South Central*	Alaska
	Alabama	California
East North Central	Kentucky	Hawaii
Illinois	Mississippi	Oregon
Indiana	Tennessee	Washington
Michigan		
Ohio	*West South Central*	*West North Central*
Wisconsin	Arkansas	Iowa
	Louisiana	Kansas
	Oklahoma	Minnesota
	Texas	Missouri
		Nebraska
		North Dakota
		South Dakota

A.2 Data Availability

Our series for inputs and output do not span the entire 1840-2000 period for each state. The year in which a complete record of inputs and outputs for each state becomes available is as follows:

1840: Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia

1850: California, New Mexico, Oregon, Texas, Utah, Wisconsin

1860: Kansas, Minnesota, Nebraska, Washington, New Mexico, Utah

1870: Colorado, Montana, Nevada, West Virginia

1880: Arizona, Idaho

1900: North Dakota, South Dakota, Wyoming

1920: Oklahoma

1930: District of Columbia

1950: Alaska, Hawaii.

Specific series (such as physical capital) may be available earlier.

B Growth and Variance of Growth for U.S. Regions and Shorter Periods

Table B1: Growth Accounting for Regions and Subperiods

	Region			Subperiod			
	North	South	West	1870-1910	1910-1950	1950-1973	1973-2000
$\Delta \log(y)$	1.59%	1.89%	1.35%	0.95%	1.94%	3.00%	1.22%
$\Delta \log(k)$	1.95%	2.23%	1.03%	1.26%	2.68%	2.07%	0.75%
$\Delta \log(h)$	0.68%	0.78%	0.73%	0.80%	0.90%	0.57%	0.56%
$\Delta \log(x)$	1.10%	1.25%	0.84%	0.95%	1.49%	1.07%	0.63%
$\Delta \log(a)$	0.49%	0.63%	0.41%	-0.01%	0.46%	1.94%	0.60%
Contribution of Inputs	69%	66%	70%	101%	76%	35%	51%
Obs	14	16	20	42	47	50	50

Note: y denotes output per worker, $x = k^{\alpha}h^{1-\alpha}$ denotes weighted inputs per worker, and a denotes TFP. For region results, not all states are available from 1840, in which case they enter the growth accounting when first available; see Appendix A2 for details.

Table B2: Variation in Growth Accounting for Subperiods

	Subperiod			
	1870-1910	1910-1950	1950-1973	1973-2000
Relative Variance				
var[$\Delta \log(y)$]	0.0103%	0.0041%	0.0061%	0.0030%
var[$\Delta \log(x)$]	0.0020%	0.0007%	0.0010%	0.0006%
Contribution of Inputs	19%	18%	16%	21%
Relative Variance, Accounting for Covariance				
var[$\Delta \log(y)$]	0.0103%	0.0041%	0.0061%	0.0030%
var[$\Delta \log(x)$]+covar[$\Delta \log(x), \Delta \log(a)$]	0.0041%	0.0014%	0.0021%	0.0011%
Contribution of Inputs	39%	36%	34%	37%
Obs	42	47	50	50

Note: y denotes output per worker, $x = k^{\alpha}h^{1-\alpha}$ denotes weighted inputs per worker, and a denotes TFP. Not all states are available from 1840 or 1880, in which case they enter the growth accounting when first available; see Appendix A2 for details.