E. J. OURSO COLLEGE OF BUSINESS
Department of Economics

DEPARTMENT OF ECONOMICS WORKING PAPER SERIES

Productivity Growth in Goods and Services across US States: What can We Learn from Factor Prices?

Areendam Chanda
Louisiana State University

Bibhudutta Panda
Wabash College

Working Paper 2011-16
http://bus.lsu.edu/McMillin/Working_Papers/pap11_16.pdf

Department of Economics
Louisiana State University
Baton Rouge, LA 70803-6306
http://www.bus.lsu.edu/economics/

Productivity Growth in Goods and Services across US States: What can We Learn from Factor Prices?*

Areendam Chanda
Louisiana State University

Bibhudutta Panda
Wabash College

November 2011

Abstract

This paper exploits the dual accounting technique to uncover multi-factor productivity growth patterns for goods and services across US states from 1980 to 2007. Due to changes in sectoral classifications, the period is divided into two parts, 1980-1997 and 1998-2007. Over both periods, states exhibit a wide range of productivity growth rates with the goods sector showing much larger variations. The variations are larger for the second time period with some states recording productivity growth as high as almost nine percent annually while other states showing declines at more than two percent. Underlying the wide variation in productivity growth are variations in both wage growth and real user cost growth. Since 1998, the real user cost declines at almost two per cent annually. Incorporating human capital into the analysis makes wage growth and, hence, productivity growth lower in both sectors, and on average negative in the second period. Scaling up the analysis to the national level, we also find that there are large differences between the growth rates of primal based measures of marginal product of capital and our calculations of real user cost growth. This can only be partially explained by the anomalous behavior of particular industries such as mining and real estate services, and to some degree due to the declining relative price of investment goods.

JEL: E22, O41, O47, R11

Keywords: Multi-Factor Productivity Growth, Regional Economic Growth, Real User Cost, Multi Sector Models, Investment Specific Technological Change, Growth Accounting.

1 Introduction

The role of multi-factor productivity (MFP) has historically been at the center stage of research in explaining output per worker growth differences. A large literature has developed examining the role of the MFP in explaining the disparity in labor productivity across countries.[1] A considerable amount of research has also been devoted to growth accounting exercises for the US, particularly, in an effort to explain dismal performance of output per worker growth of US during 1973-95 and

*Contacts: achanda@lsu.edu (corresponding author) and pandab@wabash.edu. We are grateful to Michal Jerzmanowski, Munechika Katayama, Kala Krishna, W. Douglas McMillin and Bulent Unel for useful advice and comments. We also thank seminar participants at Federal Reserve Bank - Atlanta, Florida Atlantic University, Louisiana State University, 2011 Midwest Macroeconomic, 2010 Southern Economic Association, and Missouri Valley Economic Association Meetings for their comments. All errors are our own.

[1] See Klenow and Rodriguez-Claire (1997), Hall and Jones (1999)

the subsequent rebound.[2] Growth accounting exercises for the US have also focused on uneven performance across sectors. While manufacturing industries like computers and office equipments and electronic components experienced higher MFP growth, the service sector was the worst affected during the period of productivity slowdown (Triplett and Bosworth, 2001, Jorgenson et. al., 2005). A unifying feature of most of this literature at the national, sectoral and cross-country level, is that it uses the "primal" growth accounting technique to back out MFP growth, whereby MFP growth is the residual of output per worker growth after subtracting factor accumulation. At regional levels however, the absence of data on capital stock, or investment, makes similar exercises more challenging to undertake. The existing literature on regional studies thus follows one of the following two solutions. The first route is to apportion the industry specific Bureau of Economic Analysis (BEA) capital stock data to the states based on the income share of each state in the total income (e.g. Garofalo and Yamarik, 2002 and Turner et. al., 2011). The other solution is to simply assume a steady state where the growth in return to capital is zero or equalized across regions (Iranzo and Peri, 2009).

In this paper we employ the dual growth accounting procedure to calculate state-specific MFP growth for the goods and service producing sectors from 1980 onwards.[3] This approach is based on the idea that any growth in MFP which causes output to grow will also cause real factor prices to grow due to the increases in the marginal product of the factors. MFP growth can then be measured as the weighted average of the growth rates of the real factor prices i.e. real wages and real user cost of capital (in a two factor model). The intellectual origins of this idea extends at least as far back as to Jorgenson and Griliches (1967) and was more recently revived by Hsieh (2002) in the context of East Asian economies.[4] Hsieh (1999, 2002) expresses concern over utilizing capital stock data from the national accounts as they are prone to errors due to the computational difficulties. Instead, he advocates the use of dual growth accounting over the primal approach as data on real factor prices is directly observable. To accomplish the task in hand, we need data on both wages and user costs for both sectors across states. For wages, we rely on individual level data from IPUMS-CPS. On the other hand, for the real user cost of capital, we rely on more aggregated sources. We construct it by using national depreciation rates, price indices for investment goods, state specific sectoral GDP deflators and effective corporate income taxes and exploiting inter-state variations in the composition of sectors. Using these constructed measures of real user cost and real wage growth, we can calculate MFP growth for the two broad sectors. While our coverage extends from 1980 to 2007, because of changes in classification of various sectors, we undertake the analysis separately for two sub-periods, 1980-97 and 1998-2007.[5] Underlying our reasoning for focussing on

[2]See Gordon (2010, 2000), Steindel and Stiroh (2001) and Jorgenson et.al. (2008)

[3]We define mining, construction and manufacturing industries together as the goods producing sectors. The service sector includes all the private service providing industries.

[4]See Barro (1999) for a review of this approach. Also, see Aiyar and Daalgard (2005) for a cross country application and Ciccone and Peri (2006) and Iranzo and Peri (2009) for applications on the US States. However, Ciccone and Peri (2006), and Iranzo and Peri (2009) assume real wage growth as the measure of dual accounting MFP growth.

[5]We stop the exercise at 2007 mainly because of the unusual economic conditions since that time which might have a disproportionate effect on the overall calculations.

the broad sectors of goods and services is the rich literature on structural change which focuses on the rise of the service economy and the decline in manufacturing. A lot of this research focuses on unbalanced technological change often captured by unequal multi-factor productivity growth across sectors.[6]

The paper presents estimates for productivity growth for various sectoral definitions over various time periods and competing data sources. Therefore, before we overwhelm the reader with all these numbers, it is useful to provide an overview of the main findings here. The constant theme across sectors and different time periods is the very large range in differences in MFP growth across states. This is true for both services and goods but much more so for the latter. Both wage growth and real user cost growth vary substantially across states and across time. For example, for 1980-97, we find that the range for multi-factor productivity growth in the goods producing sector is almost seven percentage points. While the range is driven by extreme cases and, in particular by mining rich states for this time period, we also observe quite a bit of variation once the mining sector is removed. MFP growth continues to have a range of more than four percentage points annually. Moreover, both wage growth and real user cost growth contribute to this. In fact, for this time period, the goods sector shows real user cost growth that is almost equal to real wage growth. During the same period, we know that the service sector was disproportionately affected by the productivity slowdown. Our calculations show that this mostly reflects negative real user cost growth. However, variations in MFP growth across states largely reflect variations in wage growth as real user cost growth shows no systematic relationship with MFP growth. During the more recent time period of 1998-2007, we see even more variation across states. For the non-mining goods sector, the standard deviation in MFP growth is 2.11% which is approximately twice that of the mean growth of 1.05%. Both wage growth and real user cost growth again show considerable dispersion. At the same time overall MFP growth in this sector is a little lower than in the earlier period. Interestingly, in the service sector, productivity growth across states is extremely low and is in fact negative at about 1% annually. Negative real user cost growth is to blame largely for this with all states recording rates lower than -3% annually. Like the earlier period, it shows little dispersion with all states falling within a one percentage point range. Investigating this further, we found that real estate services played a disproportionate role. This is not surprising given the real estate boom that coincided with the later portion of this period. Once we dropped the real estate sector, MFP growth in services turns out to be much higher but still approximately zero. Moreover, the dispersion in real user cost growth increases which in turn results in a greater variation in MFP growth. Extending all of this analysis to incorporate Mincerian measures of human capital unambiguously lowers MFP growth across the board. This in itself is not surprising since the two key inputs into a Mincerian human capital construction- returns to schooling and years of education have increased over this time period.

Since we do not have any other estimates to compare our results, we also undertake sectoral

[6] Buera and Kaboski (2011) and Ngai and Pissarides (2007) are examples of recent contributions on the expansion of the service sector and unbalanced technological change, respectively.

estimates at the national level. This allows us to check if our trends at the state level are also replicated at the national level. Secondly, it allows us to compare the dual estimates with their primal counterparts. Paradoxically, for the 1980-1997 period, the differences are not large for the goods sector but actually becomes wider when we drop the mining sector. For services the gap is slightly smaller, but in both cases it is the dual estimate that is lower. During 1998-2007, the dual estimate for the service sector is considerably lower and reflects what we see in the inter-state analysis while the primal estimate does show evidence of a "productivity revival". However, once we drop the real estate sector, we find that the primal and dual estimates are closer to each other. Investigating these issues further we look at the various components that make up the real user cost of capital- the relative price of investment goods, real interest rate plus depreciation and depreciation deduction adjusted tax component. The main story here is that the service sector, not surprisingly shows a much higher rate of decline in the relative prices of investment goods (or what Greenwood et. al. (1997) labeled "investment specific technological change"). This is true for both periods but less so for the latter period and stronger once we drop real estate services.

The paper contributes to a rich literature that examines growth differences across states. Within the context of "new" growth theory, this can be traced back at least to Barro and Sala-i-Martin (1991) and Holtz-Eakin (1993) which dealt with questions of convergence. Caselli and Coleman (2001) and Garafalo and Yamarik (2002) have further extended this line of research while Turner et.al. (2011) undertake development accounting exercises across states. Increasingly, a number of studies have exploited the heterogeneity of states to examine growth questions. Some examples include, Ciccone and Peri (2005) on the elasticity of substitution across different types of labor, Caselli and Coleman (2002) on measurement of the US technology frontier, Kalemli-Ozcan et.al. (2010) on capital flows across states, and Andersen et.al. (2010) on technology diffusion across states, to name a few. An added contribution of our paper is that the calculations of real user cost growth combined with capital incomes shares implies one can back out measures of capital stock growth and thus compare investment rates across states for the two broad sectors.[7]

Before moving on, we would like to address two issues that confront this paper. First, we are not just examining states, but goods and service sectors at the state level. This would invite skepticism with respect to the assumption of perfect competition that any growth accounting technique, be it primal or dual, relies on. To some extent, we believe that this is mitigated by the fact that we are still considering sectors that are broad enough- it is difficult to think of a state where the entire service sector might be subject to a degree of imperfect competition that this would be truly damaging for our results. However, given the declining size of the goods sector, one might be concerned that it would be subject to a greater degree of firm concentration. Nevertheless, since states have open borders, and manufacturing goods produced in one state is unlikely to be sold only in the same state, firms are unlikely to have monopolistic power. However, at the same time, firms might exhibit monopsony power on local labor markets. To the extent that labor is mobile

[7] Chirinko and Wilson (2008) have also constructed a state-wise data set on the real user cost of capital but only for the manufacturing industry.

across states, this concern would be alleviated. Nevertheless, we do not deny that the results might be less robust for small states.

While openness can alleviate concerns regarding perfect competition, they can also raise concerns as to why MFP should differ at all across states. One can argue that since technology flows freely across states, there is no reason for MFP growth to differ. In principle workers and capital should move to states with the highest marginal products and ultimately differentials should not exist. Nevertheless, we know that this does not hold in practice.[8] One can list a number of reasons why this might be happen: a) This could simply be for the same reasons that drive productivity differences across cities. Since states are created due to political reasons whereas cities emerge due to a separate set of dynamics, it is easy to see that productive states might to a large extent be driven by the presence of productive cities. For example, Ciccone and Hall (1996) show that counties with higher population densities seem to be more productive. Higher population densities allow for lower transport costs of goods between different stages of production, can allow for externalities from close physical proximity, and higher degrees of specialization. Glaesar and Gottlieb (2009) notes that the extent to which people can move to cities with higher productivity is a function of the elasticity of housing supply. If the housing supply is elastic, then boosts to local productivity would be followed by an inflow of workers and not raise overall incomes. However if the housing supply is inelastic then it would show up in increased incomes. b) Secondly, there is a fairly large mainstream literature on the business competitiveness of states which seems to make the case that firms would be more productive in certain states compared to others.[9] c) Third, in our work, at least as far as the user cost construction is concerned, it is driven mainly by variations in sub-sectoral shares. Thus if states have sufficiently different sub-sector mix, we can expect this to show up in productivity growth differences.

The rest of the paper is structured as follows: section 2 establishes the empirical framework required to conduct the dual accounting exercise. Section 3 presents the data sources. Section 4 discusses the results from the growth accounting exercise and section 5 concludes.

2 Empirical Framework

To understand the dual approach, we start with the standard national income equality between output generated in the economy and the sum of incomes that accrue to the factors of production, i.e., labor and capital,

$$Y = wL + rK \tag{1}$$

where Y =real GDP, L =labor, K =real capital stock, $w = W/P^Y$ =real wage and $r = R/P^Y$ =real user cost of capital and P^Y is the price index used to deflate the GDP.

[8]It is well known, that even if capital flows freely, labor is not as mobile across states as one would expect. For evidence on this, see Bernard et. al. (2011) and additional references cited therein.

[9]For example *Forbes* magazine publishes annual rankings of states by best climates for business. The rankings are based on six different categories- costs, labor supply, regulatory environment, current economic climate, growth prospects and quality of life. See Badenhausen (2011).

The idea behind dual accounting is that any growth to MFP that increases output, will also raise the return to the factors of production. In that case, MFP growth can be measured as a share weighted average of growth rates of returns to the factors of production i.e. real wage and real user cost growth rates. To see this, and, to also see the equivalence between primal and dual accounting, we can begin by time differentiating equation (1) and dividing it by Y,

$$\dot{Y} = \dot{w}L + w\dot{L} + \dot{r}K + r\dot{K} \tag{2}$$

$$\Rightarrow \frac{\dot{Y}}{Y} = \frac{\dot{w}}{w}\frac{wL}{Y} + \frac{\dot{L}}{L}\frac{wL}{Y} + \frac{\dot{r}}{r}\frac{rK}{Y} + \frac{\dot{K}}{K}\frac{rK}{Y} \tag{3}$$

$$\Rightarrow \hat{Y} = \alpha_L(\hat{w} + \hat{L}) + \alpha_K(\hat{r} + \hat{K}) \tag{4}$$

$$\Rightarrow \hat{Y} - \alpha_K\hat{K} - \alpha_L\hat{L} = \alpha_K\hat{r} + \alpha_L\hat{w} \tag{5}$$

Here α_L is the labor income share and α_K is the capital income share which is equal to $1 - \alpha_L$. The hat, $\hat{}$, on the variables denote their growth rates. In the last equation, the expression on the left represents the traditional MFP growth measures from the primal (quantity) growth accounting and the expression on the right represents the dual accounting counterpart. Thus primal growth accounting measures derived from the Bureau of Economic Analysis (BEA) should be exactly equal to the dual measures. To interpret it differently, the observed factor prices should be consistent with the "implied" factor prices from the national accounts of BEA. Any differences between them would create a wedge between the two measures. In practice, however this equality rarely holds. Both Hsieh (1999, 2002) and Aiyar and Daalgard (2005) find divergence between these two measures implying inconsistencies between the observed factor prices and implied factor prices of national accounts.

The above equality relies on the assumptions of constant returns to scale and perfect competition. Under these conditions, factors are paid their marginal product. However, one does not need any assumptions other than the equality shown in equation (1). Any departures from the assumptions of perfect competition and constant returns to scale affect both the primal and dual MFP growth calculations. Since most goods are tradable across states, the assumption of perfect competition is unlikely to be violated. However, we know that non-tradable goods do exist and this can increase the degree of concentration of industries at the state level. Therefore another reason for choosing two major sectors is to reduce the likelihood that the assumption of perfect competition is violated. Our definition of the goods sector includes the mining, construction and manufacturing industries together. The private service sector which comprises of all the service providing industries is itself large enough at the state level which implies a lower degree of concentration and hence makes the assumption of perfect competition reasonable. Furthermore since labor is mobile across states, that too reduces the extent to which imperfect competition might jeopardize our results.

To obtain the measures of MFP growth, we need to construct the measures of real wage growth, real user cost growth and labor income share for the sectors at the state level. In the following sub-sections, we outline the computational details of these measures.

2.1 Real Wage Growth Rate

Our constructed series on the real wage growth is composition-adjusted based on different kind of labor groups. Following Hsieh (2002), the labor groups are based on four educational categories (some school, high school graduate, some college and college graduates) and gender. With this, we have eight groups of labor in each sector and state. This quality adjustment ensures that the real wage growth only results from the growth of the real wage of a labor group and not due to the increase in the share of the labor group which increases the average real wage. Allowing for different groups, the weighted real wage growth rate of the sector 'i' and state 's' is

$$\triangle \ln w_{i,s,t} = \sum_{g} \bar{S}_{L,g,i,s} \triangle \ln w_{g,i,s,t} \tag{6}$$

where 'i' represents the broad sector and 's' the state. Here, $\bar{S}_{L,g,i,s} = \frac{S_{L,g,i,s,t}+S_{L,g,i,s,t-1}}{2}$ and $S_{L,g,i,s,t}$ is the share of labor income of each group in total labor income and $g = education \times gender$. Total income of each group and sector can be obtained by summing over the labor income of all the individuals. The real wage growth for sector 'i' is obtained by subtracting the growth rate of SGDP deflator from the nominal wage growth.

2.2 Real User Cost of Capital

The conceptual framework for calculating the real user cost of capital was established by Hall and Jorgenson (1967) and Coen (1968). Following these papers, a profit maximizing competitive firm invests in capital till the marginal product of capital is equal to the real user cost of capital,

$$RUC_t = \frac{P_t^I}{P_t^Y}(i_t + \delta_t - \pi_t)\frac{(1-\tau_t z_t)}{(1-\tau_t)} \tag{7}$$

Here, a decision to invest in one unit of capital depends on $\frac{P_t^I}{P_{,t}^Y}$, the relative price of the new capital goods in terms of the price of the final good, the real interest rate which is the financial cost of this investment $(i_t - \pi_t)$, depreciation rate of the capital goods (δ_t) and the tax applications in terms of the effective corporate income tax (τ_t) and the present value of depreciation deductions (z_t). $\frac{(1-\tau_t z_t)}{(1-\tau_t)}$ reflects a tax subsidy. If the government does not provide any tax benefits in terms of depreciation deductions, i.e. $z_t = 0$, the real user cost will increase by a fraction $\frac{1}{(1-\tau_t)}$.[10]

Since our study involves the aggregation of industries, we construct a share weighted average of the growth rate of the user cost in each of the industries. Thus, for the goods producing sectors, the user cost growth rate is the weighted sum of user cost growth in manufacturing, mining and

[10] Hall and Jorgenson (1967) also incorporate investment tax credits. We have omitted investment tax credit while constructing the real user cost as the federal investment tax credit was rolled back in 1986 and although some states allow for investment tax credit, most of the time it is targeted towards specific firms or industries.

construction,

$$\triangle \ln RUC_{i,s,t} = \sum_{j} \bar{S}_{K,j,i,s} \triangle \ln \left(\frac{P^{I}_{j,t}}{P^{Y}_{j,s,t}} (i_t + \delta_{j,t} - \pi_{j,t}) \frac{(1-\tau_{s,t} z_{j,t})}{(1-\tau_{s,t})} \right), \quad (8)$$

$\bar{S}_{K,j,i,s} = \frac{S_{K,j,i,s,t}+S_{K,j,i,s,t-1}}{2}$ and $S_{K,j,i,s,t}$ is the share of capital income of each industry in total capital income of the sector. i_t is the nominal interest rate. $P_{j,s,t}$ is the state specific state GDP (SGDP) deflator. $\tau_{s,t}$ is the state specific effective corporate income tax rate which is constructed following Chirinko and Wilson (2008), $z_{j,t}$ is the present value of depreciation deductions of $1 investment which is calculated using the double declining balance method by Hall and Jorgenson (1967) using sector specific depreciation rates $\delta_{j,t}$. The inflation rate $\pi_{j,t}$ is constructed as a five year moving average lagged inflation of investment prices indices $P^{I}_{j,t}$ following Gilchrist and Zakrajšek (2007). Henceforth, we refer to $\frac{P^{I}_{j,t}}{P^{Y}_{i,s,t}}$ as the relative price, $(i_{s,t}+\delta_{j,t}-\pi_{j,t})$ as the financial component, and $\frac{(1-\tau_{s,t}z_{j,t})}{(1-\tau_{s,t})}$ as the tax component of the real user cost.[11]

2.3 Labor and Capital Income Share

It is evident from equation (5) that factor income shares play an integral part in constructing the MFP growth rate. Unsurprisingly, there is also evidence that factor income shares can vary widely across sectors. For example, a recent study by Herrendorf and Valentinyi (2008) finds that the factor income shares for five major sectors of US vary significantly (Agriculture, Manufacturing Consumption, Services, Equipment Investment and Construction Investment). Secondly, industry composition varies across states. Therefore, the aggregated sectoral labor income share across states will vary because of the varying industry mix. We calculate the the industry as well as sector specific labor income shares for the states following the methodology of Gollin (2002) and Gomme and Rupert (2004),

$$\alpha_L = \frac{\frac{Compensation of Employee}{Wage and Salary Employment} \times Total Employment}{SGDP - ITS} \quad (9)$$

where α_L is the labor income share and 'ITS' is the indirect taxes less subsidies. This method of computing labor income share also addresses the allocation of the income of the self employed between labor and capital. Their labor income is imputed by assuming a value equal to the average compensation of wage and salary employed (Gollin, 2002). Capital income share is calculated as $1 - \alpha_L$

Finally, in calculating MFP growth, we use the two period averages of factor income shares, i.e.

$$MFPG_{i,s,t} = \bar{\alpha}_{K,i,s} R\hat{U}C_{i,s,t} + \bar{\alpha}_{L,i,s} \hat{w}_{i,s,t}, \quad (10)$$

[11]Gilchrist and Zakrajšek (2007) also adopt a similar nomenclature, but refer to $\frac{P^{I}_{j,t}}{P^{Y}_{i,s,t}} \frac{(1-\tau_{s,t}z_{j,t})}{(1-\tau_{s,t})}$ as the tax adjusted relative price of investment goods and $(i_{s,t} + \delta_{j,t} - \pi_{j,t})$ as the financial cost of capital.

where, $\bar{\alpha}_{L,i,s} = \frac{\alpha_{L,i,s,t}+\alpha_{L,i,s,t-1}}{2}$, $\bar{\alpha}_{K,i,s} = \frac{\alpha_{K,i,s,t}+\alpha_{K,i,s,t-1}}{2}$, and $R\hat{U}C$ and $\hat{w}$ reflect the growth rate of real user cost and real wages respectively for sector 'i' and state 's'. The dual measures at the national level is constructed analogously to the state level calculations.

3 Data Sources

This section briefly documents the data used for constructing our series. The data appendix section deals with the definitions and sources in greater detail. The data is in Standard Industrial Classification (SIC) for years 1980-1997 and in North American Industrial Classification System (NAICS) for years 1998-2007. Because of incompatibilities, we present the results separately for the two classifications. The nominal series are converted to real series using the price indices with base year 1997.

To construct a composition adjusted measure of real wage growth, we rely on the micro data set of March Current Population Survey (CPS) published at IPUMS-CPS for 1980-2008. Quality adjustment is applied based on four educational groups of labor (some school, high school graduate, some college and college graduate) and gender. Our measure of annual real wage growth is based on the weekly wages derived from this data set.[12] Our constructed wage growth and weeks worked corresponds only to full time equivalent employees. Anybody working below 35 hours a week and 40 weeks per year is dropped from the sample.[13] Correspondingly, for the state-sector specific labor productivity measure we use output per weeks worked.[14]

To construct the series on real user cost, we require data on the nominal interest rate, investment price deflators, SGDP deflators, depreciation rates and state effective corporate income tax rates.[15] The nominal interest rate is a twelve-month average of the Moody's Seasoned AAA Corporate Bond Yield available at St. Louis Federal Reserve Bank web site and is same across all the states. Industry specific investment price deflators for the US are constructed using industry-specific "Investment in Private Fixed Assets" and its "Chain-type Quantity Indices" from the BEA Standard Fixed Assets tables. Industry specific measures of the real depreciation rates for the US are constructed using the industry specific real depreciation cost and real net capital stock of private fixed assets. We use data from the BEA Standard Fixed Asset tables on "Current Cost Depreciation of Private Fixed Assets by Industry" and its "Chain-type Quantity Indices" to construct real depreciation cost and "Current Cost Net Stock of Private Fixed Assets by Industry" and it's "Chain-type Quantity Indices" to construct real net capital stock of private fixed assets. Industry specific SGDP deflators for each state are constructed using the state-industry specific data on SGDP, real SGDP and

[12]Autor et.al. (2008) cautions against using hourly wage distribution in March-CPS data set as it lacks a point-in-time measure. An estimate of total hours worked last year can be obtained by multiplying weeks worked in the last year and usual hours worked per week last year in March-CPS data. But they find this measure to be noisy.

[13]We also tried our analysis with different hour and week combinations such as: all hours and all weeks, 40 hours and 40 weeks, 35 hours and 40 weeks, 30 hours and 40 weeks. But this did not alter our results.

[14]We derive the average weeks worked data by state and sector from the IPUMS-CPS and total employment numbers from the BEA.

[15]Present value of depreciation deductions and inflation rates are calculated using the constructed series on the depreciation rates and investment price deflators respectively.

quantity indices of SGDP from the BEA Regional Economic Accounts. Effective corporate income tax rates for the states are constructed using data on federal corporate income tax rates from the Tax Foundation, data on state corporate income tax rates and federal tax deductibility from various editions of the "Book of the States" published by the Council of the State Governments.

To construct the factor income share series at the state level, we use the data on State Gross Domestic Product (SGDP), Compensation of Employees, Indirect Taxes Less Subsidies, Wage and Salary Employment and Total Employment published by the BEA Regional Accounts Section.

4 Growth Accounting Analysis

We discuss the state level MFP growth measures from the dual growth accounting exercise below beginning with the goods sector and then moving on to the service sector. We discuss both the 1980-97 period covered by the SIC measures and the 1998-2007 NAICS measures concurrently. After presenting the main results, we extend the analysis by incorporating Mincerian measures of human capital that have become popular since their introduction into the growth accounting literature by Klenow and Rodriguez-Clare (1997). To resolve some of the questions posed by the results obtained at this juncture, we then turn to some sectoral estimates at the national level. We compare our dual results to primal estimates, and investigate further the patterns of wage growth and real user cost at the national level.

4.1 State Multi-Factor Productivity Growth

4.1.1 MFP Growth in the Goods Producing Sector

Figure 1(a) displays the average annual labor productivity growth against the MFP growth for the goods producing sector for 1980-97.[16] The corresponding summary statistics are presented in the first four columns of table 1(a). The unweighted means for state level labor productivity and MFP growth are 2.87% and 2.24% respectively. This implies, on average, a 78% contribution of MFP growth to labor productivity growth. Mining rich states like Wyoming, New Mexico, Louisiana, North Dakota, Oklahoma and Texas have the highest MFP growth rates. Table 1(a) also summarizes the data on real wage growth and real user cost growth. While we find the mean for annual real wage growth to be 1.69%, the mean for real user cost growth stands higher at 2.90%. This high average for real user cost growth stems from the aforementioned mining rich states which experience an annual real user cost growth rate of 6% or more. Figure 3(a) is scatterplot of the real user cost growth against the labor productivity growth. These mining rich states clearly stand out. Their unusually high growth can be attributed to initial high oil price of the early 1980's which leads to an initial high value of the SGDP deflator for the mining industry, hence a very low initial real user cost. The subsequent decline in oil prices implies a rising relative price of investment goods and hence high growth in real user cost. This is further accentuated by high growth in the

[16] To recap, the goods producing sector comprises of manufacturing, construction and mining industries.

financial component resulting from subsiding inflation in the investment price deflator of the mining industry.

Given the unusual behavior of oil prices during this period, we recalculated the various growth rates after excluding the mining sector for all states. The updated summary statistics are presented in the last four columns of table 1(a). The average for real user cost growth is now considerably lower at 1.26% compared to the earlier value of 2.90%. Real wage growth also declines marginally from 1.69% to 1.37%. This results in a mean MFP growth rate of 1.34% which is approximately 48% of the mean labor productivity growth of 2.78%. Table 1(b) lists the correlations between various growth rates. The correlation between labor productivity and MFP growth increases from 0.29 to 0.70. This improvement in correlation originates from the real user cost growth. The correlation between labor productivity growth and real user cost growth shows a visible increase from 0.07 to 0.76.[17] The stronger role of MFP growth in driving the labor productivity growth is in the line with the existing literature at national level for the goods producing sector (Triplett and Bosworth, 2001, Jorgenson et al., 2005). Figure 1(b) depicts the relationship between labor productivity growth and MFP growth while figures 2(b) and 3(b) depict the relationships between labor productivity growth and real wage growth and real user cost growth respectively. New Hampshire, Massachusetts, Vermont, New Mexico and Oklahoma are the states with the highest MFP growth rates. It is noteworthy to mention that New Hampshire, Massachusetts, Vermont, and Oklahoma also record the highest values of real wage growth and real user cost growth which explains their higher MFP growth. However, the higher MFP growth of New Mexico is mainly due to a high real user cost growth rate of 3.77% while its wage growth is only average.[18] Nevada, Washington, Montana, Maryland and Virginia have the lowest values of MFP growth.[19] It is needless to say that lower MFP growth results from both lower real wage and real user cost growth for these states. In fact, Montana, Nevada, Maryland and Washington experience negative real wage growth. Finally, it is important to draw attention to the variability among the measures across states. The coefficient of variation (CV) for real wage growth is 67% while for real user cost growth it is 61%. Together, this implies a CV of 62% for MFP growth across states. The non-zero real user cost growth for states along with a variability which is comparable to that of real wage growth underscores the fact that the marginal product of capital cannot be assumed to be constant over the medium run.

In table 2(a), we list the summary statistics for 1998-2007. Admittedly, this is a much shorter period of time and is subject to a variety of fluctuations. The average for labor productivity growth for the goods sector (table 2(a), column 1) averages to 2.40%. At first glance, it seems odd that this is lower than the previous period which coincided with the productivity slowdown. Moreover, MFP growth averages to -0.20% which also contradicts the productivity revival literature. This stems from very low averages for factor price growth rates for the states. The average for real wage

[17]The correlation coefficient for real wage growth and labor productivity growth experiences a marginal decline from 0.60 to 0.56 though the correlation between wage growth and MFP growth is much higher now at 0.96.

[18]New Mexico experiences remarkable growth in labor productivity at 8.68% annually in the goods producing sector. This results from exceptional real SGDP growth in the manufacturing industry of 15.33% annually.

[19]It can also be seen from figure 1(b) that Montana and Washington experience near zero labor productivity growth.

growth is 0.85% which is about half of the previous period. More importantly, the real user cost growth averages to -1.72%. A quick look at the figure 1(c) and 3(c) which display the scatterplots of MFP growth and real user cost growth against the labor productivity growth respectively reveals the source of this problem. States like Wyoming, Louisiana, Oklahoma, Texas, Montana, Nevada and West Virginia with relatively larger shares in the mining industry drive down the average real user cost growth, and consequently, MFP growth. It is important to mention here that the SGDP and investment deflators for the mining industry experience considerable growth originating from the oil price increases during this period. This causes the relative price and the financial component to decline and thus resulting in negative real user cost growth for the mining industry and for the goods sector for these mining rich states.[20]

Given the behavior of the prices in the mining sector, like before, we revisit all our calculations for 1998-2007 after dropping this sector. The average for labor productivity growth (table 2(a), column 5) increases to 2.86% which is marginally higher than the previous time period. The averages for factor price growth rates also increase with the average for real user cost growth significantly improving to 0.33% and real wage growth improving to 1.35%. The average growth rate of MFP increases substantially to 1.05%. Figure 1(d) portrays the relationship between MFP growth and labor productivity growth for the states after dropping the mining industry. The correlation coefficients between labor productivity growth and MFP growth (and its constituents) however do not undergo large changes as can be seen from table 2(b), columns 5-8. The primary effect of dropping the mining sector is the larger role of MFP in explaining labor productivity growth. New Mexico, Oregon, Idaho, New Hampshire and South Dakota record the highest MFP growth rates. Though New Mexico experiences an annual labor productivity growth of 3.97%, its annual MFP growth is much higher at 8.55% which implies negative factor input growth. It is important to mention that New Mexico's SGDP deflator for the manufacturing industry drops sharply between 1998-2007. This causes the relative price of investment goods and, hence, the real user cost growth for manufacturing to be very high. Since the sectoral growth for the real user cost is a capital income share weighted growth rate of industrial real user cost growth, the goods sector for New Mexico experiences high real user cost growth at the rate of 9.92% which causes the MFP growth to be inflated. Oregon deserves a special mention with its labor productivity displaying an annual growth rate of 11.14%. This results from the remarkable growth performance of the Oregon manufacturing industry where the real SGDP grew at a rate of 14.7%. Similarly, Oregon also displays an annual MFP growth rate of 7.04% reflecting high factor price growth rates. Idaho and New Hampshire also experience very high MFP growth rates resulting from very high real wage and real user cost growth rates.[21] Nevada, Louisiana, Wyoming, Montana, Maryland and Florida are the bottom most states in MFP growth. Except Louisiana all of the mentioned states experienced

[20]The mining industry GDP deflator rises faster than the investment deflator which causes the relative price to fall. Further, the rapidly increasing inflation rate in the investment deflator causes the financial component to experience a rapid decline. The inflation in the SGDP deflator also adversely affects the constructed labor productivity growth and real wage growth measures for these states.

[21]New Hampshire, like New Mexico, displays a lower labor productivity growth than MFP growth implying negative factor input growth.

negative growth rates in both wages and real user cost which explains their lower and negative MFP growth rates. Louisiana experienced a positive real wage growth rate, but had the lowest real user cost growth (-4.44%) among the 48 contiguous states. Figures 2(d) and 3(d) provide a visual representation of the real wage growth and real user cost. It is important to make a brief note on the cross state variations in MFP growth rate. MFP growth across states displays considerable variability with the CV amounting to 201%. This results from an extremely wide variation in real user cost growth with a CV of 827%.[22]

Finally, it is important note that the statewide average for MFP growth is lower than the previous time period despite dropping the mining industry. This warrants further explanation. Average MFP growth contributes only 37% this period to average labor productivity growth as opposed to 48% of the previous period which seems to fly in the face of all that we know about the productivity revival post 1995. Since any increase in MFP reflects increases in real factor price growth, our constructed real factor price growth should reflect higher growth. However, we do not find high enough real wage growth and real user cost growth to support the existing literature. Under the standard assumptions, growth in MFP increases the marginal product of capital and labor. A higher marginal product of capital leads to rapid accumulation of capital and causes the marginal product of capital to fall over time. Thus it is possible that over the long run, the direction of real user cost growth is ambiguous. However, capital accumulation should also lead to an increase in the marginal product of labor (real wage) and therefore, a dual growth accounting approach ought to still capture MFP growth despite a fall in the marginal product of capital.[23] Given this line of reasoning, it is not surprising that real user cost growth averages only 0.33%. Nevertheless, we do not see a substantial gain to real wage growth either. Thus, we do not see evidence of a productivity revival in our state level data. There are, however, a couple of caveats. First, so far we have restricted our analysis to the goods producing sectors and at least for the manufacturing industry we know that the productivity slowdown was shortlived and the turnaround had begun much earlier. Triplett and Bosworth (2001) find that though both mining and manufacturing industries slowed down during 1973-1997 in comparison to 1960-1973, the rebound to the previous period growth was evident during 1987-1997.[24] A second possibility is that data from the CPS does not incorporate all the information on labor income since it only reports wages. Baker (2007), for example, finds a sharp increase in the non-wage share of compensation during 2001-2006. The growth rates calculated from IPUMS-CPS would then be an underestimate. This concern is addressed in a later section when we briefly examine the national numbers at the sectoral level.

[22]The CV for real wage increases to 133% and the CV for real user cost growth increases to 827% in comparison to 67% and 61% respectively for the previous period.

[23]For more on this, see Fernald and Ramnath (2004).

[24]According to Triplett and Bosworth (2001), while the growth rates for MFP during 1963-73 are 1.4% and 2.5% respectively for the mining and manufacturing industries, the growth rates show visible improvements to 4% and 2.4% respectively during 1987-1997. The authors' calculations also suggest that the construction industry never experienced a productivity slowdown.

4.1.2 The Service Sector

Table 3(a) displays the summary statistics for the service sector for 1980-1997. The presence of productivity slowdown is evident in the annual labor productivity growth and MFP growth rates which average to 0.74% and -0.01% (Table 3(a), column 1) respectively. Our results are consistent with the existing literature which provides evidence that the service sector was the worst affected during the productivity slowdown (Triplett and Bosworth, 2001, Jorgenson et.al., 2005). The near zero MFP growth results from very low real factor price growth rates. While real wage growth averages to 0.49%, real user cost declines at -0.82% annually. Figure 4(a) which displays the relationship between labor productivity growth and MFP growth, provides further insight. Labor productivity growth and MFP growth are positively correlated with a correlation coefficient of 0.40 (Table 3(b), column 1). North Carolina, Virginia, Connecticut, Kansas, Rhode Island and Tennessee emerge as the MFP leaders in the service sector. Except for North Carolina and Virginia, the contribution of MFP growth is less than 20% for the ten states with the highest labor productivity growth. Montana, Delaware, Wisconsin, North Dakota, Nevada are the bottom most states in MFP growth. Figures 5(a) and 6(a) plot the real wages growth and real user cost growth respectively against labor productivity growth. Labor productivity growth is positively correlated with wage growth with a correlation of 0.66 (Table 3(b), column 1). Real user cost growth on the other hand is negatively correlated with a coefficient of -0.54 (Table 3(b), column 1). Since labor income has a higher share compared to capital income, overall MFP growth is positively correlated with labor productivity growth. Looking further at real user cost, the states with highest labor productivity growth such as Connecticut, Delaware, New Hampshire and Massachusetts are the ones that experience the largest declines. In fact, a close look at the plot reveals that all states barring Wyoming experienced negative real user cost growth rates. Delving further into details, we find that the negative real user cost growth for the states stems from the rapid fall in the relative price of investment goods. This feature coined as "Investment Specific Technological Change" (henceforth, ISTC) by Greenwood et.al. (1997) implies rapid accumulation of capital goods. Another interesting observation that the decline in the relative price of investment goods takes place in the service sector but not in the goods producing sectors. The standard deviations (Table 3(a), column 2) suggest that though the MFP growth across states displays some variation, it is not as strong as it is in the goods sector. The variation in the real wage growth is approximately twice as large as the variation in the real user cost growth across states.

Moving on to the more recent time period of 1998-2007, we find that while labor productivity growth increases compared to the earlier period, MFP growth does not follow suit. Though the average for labor productivity growth shows a significant improvement to 1.73% (Table 4(a), column 1) in comparison to 0.74% in the previous period (Table 3(a), column 1), MFP growth clearly shows the opposite behavior with an average of -0.99%. This contradicts the existing literature which finds a surge in productivity growth for the service sector post 1995. In a study on the service sector industries, Triplett and Bosworth (2006) find that after 1995 service sector industries experience accelerated MFP growth. While our period of study starts a little later than 1995 and goes well beyond the years covered by these papers, nevertheless one would have expected to see some semblance of MFP revival. To the contrary, it is evident from figure 4(b) that barring Arkansas, Utah, Massachusetts and Mississippi, all states experience negative MFP growth. This negative MFP growth obviously originates from very low real factor price growth rates for the states. While the average for real wage growth amounts to 0.65%, the average for real user cost growth is extremely low at -3.50%. In fact, it can be gleaned, from figure 6(b) that all the states experience negative (at least -3%) real user cost growth rates. While the wage growth is higher than in the previous period, obviously it is not anywhere near as high to compensate the steep decline in real user cost growth. Earlier we noted that wage growth might be underestimated in the IPUMS-CPS data set. Nevertheless, it should be obvious to the reader that even small adjustments to the wage growth cannot rescue the productivity revival story here. The decline in real user cost growth itself is the source of the problem.

Pursuing the problem further, we looked at the various sub-sectors that comprise the service sector. We found that real estate industry could partially explain the huge decline in real user costs. The years 1998 to 2007 coincided with the real estate boom. This produced high inflation rate in the investment price deflator for the real estate industry specially after 2001. As a result, the financial component declined rapidly, which was reflected in the negative growth rate of the real user cost. Moreover, the real estate sector accounts for the largest share of capital income in the service sector.[25] Recall that the sectoral real user cost growth is a capital income share weighted growth rate of industrial real user cost growth rates. With a larger share in capital income and rapid decline in the real user cost, the real estate sector produces a rapid fall in the real user cost for the entire service sector. So as an additional exercise, we dropped the real estate industry from the service sector. The summary statistics are presented in table 4(a) columns 5-8. Clearly the fall in real user cost growth is now relatively lower and so is the decline in MFP. Nevertheless MFP growth is still lower than what was observed in the earlier period and real user cost growth continues to show a 2% annual decline. Therefore, it cannot explain all of the story. Moreover, one can debate the usefulness of removing a sector that accounts for such a large share of the capital income within services.

So far we have discussed sectoral patterns in MFP growth across different time periods. A natural extension is to look at correlations across sectors within the same time period and also over time within sectors. In the interest of brevity, we summarize the main results and do not display an entire table. The correlation between goods and services for both time periods is quite weak. The largest magnitude is -0.15 between overall goods and services for 1980-1997. Interestingly, once the mining sector is dropped this correlation flips signs and is at 0.12. For 1998-2007, the inter-sectoral correlations are negligible with the highest value for the non-mining goods sector and non-real estate services standing at 0.08. When considering the same sector over the two time periods, we see some more interesting numbers. For the overall goods sector, the correlation is -0.55. However once the mining sector is dropped in both time periods, the correlation flips signs

[25]The mean for the capital income share of the real estate industry in the entire services is 42%.

again and is now positive at 0.52. Therefore, anomalies in the mining sector aside, there is some continuity in the performance of the goods sector. The service sector presents an entirely different story with the correlation between the two time periods standing at -0.06, i.e. again virtually at zero. Thus clearly over time the service sector records very different patterns. Interestingly, if we focus only on 1998-2007, we also find that the correlation between the overall service sector and the non-real estate service sector is 0.98. Thus dropping the real estate sector increases the level of MFP growth uniformly across states.

4.2 Incorporating Human Capital

The measurement of human capital as a factor of production has been one of the key innovations in the cross country productivity literature. Klenow and Rodriguez-Clare (1997), and Hall and Jones (1999) were the first to construct human capital stocks by incorporating the Mincerian notion of returns to years of schooling. The strategy is to redefine the labor input as a human capital augmented input. In the simplest terms, if L is the labor input measure, then hL is the augmented version where, h is the human capital per unit of labor. The logarithm of h is a product of the returns to schooling and years of schooling. Note that all else equal, augmenting the labor input by an average measure of human capital per worker would necessarily lower the level of MFP in a standard production function. Moreover, in a standard primal growth accounting exercise, as long as the rate of growth of h is positive, this will also reduce the growth rate of MFP. Given the ex-ante equality between dual and primal growth rates, it will also reduce the growth rate of any dual growth accounting based MFP estimates. To see this define $\tilde{w}$ as the wage per unit of human capital augmented labor (i.e. hL). Since the wage bill observed in any data source is still the same, it must be that

$$wL = \tilde{w}hL \tag{11}$$

$$\Rightarrow \hat{w} = \hat{\tilde{w}} + \hat{h}, \tag{12}$$

where, $\hat{}$, continues to denote the growth rate. Equation (5) would now need to be modified to,

$$\Rightarrow \hat{Y} - \alpha_K\hat{K} - \alpha_L\hat{h} - \alpha_L\hat{L} = \alpha_K\hat{r} + \alpha_L\hat{\tilde{w}}. \tag{13}$$

To calculate the growth in wages per unit of human capital, we can use equation (12) in conjunction with the common construction of human capital per worker,h,

$$h = \exp(\phi \times E) \tag{14}$$

where ϕ represents the returns to an additional year of schooling and E is the years of schooling. Substituting the growth rate of this expression for the growth rate of $\hat{h}$ in equation (12) and rearranging gives us,

$$\hat{\tilde{w}} = \hat{w} - \frac{\partial \ln(\exp \phi E)}{\partial t} \tag{15}$$

$$\hat{\hat{w}} = \hat{w} - \frac{\partial(\phi E)}{\partial t} \tag{16}$$

$$\Rightarrow \hat{\hat{w}} = \hat{w} - E\frac{\partial \phi}{\partial t} - \phi\frac{\partial E}{\partial t} \tag{17}$$

To back out growth in the wage rate of human capital augmented labor we need to know changes in returns to education as well as changes in the years of schooling. The information on state and sector specific average years of education for each labor group is calculated using the IPUMS-CPS data set. However, we are unaware of any research that has calculated changes in returns to education at the state-sector level further divided by gender and level of education. Returns to education is usually available by level of education, race, gender, etc., and neither by sector of employment even at the national level and nor at the state level. After surveying the body of research on returns to education, a paper by Henderson, Polachek and Wang (2011) yielded the estimates that best match our requirements. They estimate returns for different levels of education for various years at the national level using non-parametric kernel regressions. Their estimates are for the census years and 2005 (based on the American community survey data). Our real wage growth is derived separately for 1980-1997 and 1998-2007. We have used their estimates of returns to education for 1980 and 2000 for the first year (1980) and the last year (1997) of the SIC data and returns to education for 2000 and 2005 for the first year (1998) and the last year (2007) of the NAICS data.[26] While the absence of state and sector level data on returns to education clearly marks a compromise, nevertheless, we feel the exercise is instructive. Incorporating the Mincerian concept implies that the actual share weighted calculation in equation (6) is now,[27]

$$\triangle \ln w_{i,s,t} = \sum_{g} \bar{S}_{L,g,i,s}[\triangle \ln w_{g,i,s,t} - \triangle(\phi_{g,t} * E_{g,i,s,t})] \tag{18}$$

Figures 7(a)-(d) and 8(a)-(d) display the scatterplots of the human capital adjusted real wage growth against the wage rates calculated earlier. Figure 7 captures the patterns for the goods sector and figure 8 for the service sector. The overall regularity seems to be that the growth rates are now considerably lower than the earlier numbers without compromising much on the overall ranking of states. Over the past thirty odd years, both, the returns to education and the years of schooling have increased. In other words, h has increased over time. Thus, by construction the growth rate in the newly constructed wages must be lower than the non-Mincerian version. In Table 5, we compare the unweighted means of the earlier average real wage growth rates and MFP growth rates with their new values. The first half of the table lists values for 1980-1997 and the second half for 1998-2007. In the goods sector we see rather dramatic declines. The wage growth falls from 1.69% to -1.41% during 1980-1997. This, in turn, reduces the mean for MFP growth from 2.24% to 0.74%. Dropping the mining sector does not make a difference. We again see a dramatic

[26]The estimates of returns to education by four analogous educational groups are reported in Table 4, Panel B.1 of their paper.

[27]Since we have data on returns only for the end-points of the time intervals, $\triangle(\phi_{g,t} * E_{g,i,s,t})$ reflects only the difference between the initial and the final year divided by the length of the period.

drop from 1.37% to -1.72% with MFP growth dropping from 1.34% to barely over zero. Moving on to 1998-2007, the average for real wage growth rate falls to -1.83% from 0.85% for the goods sector which results in an average MFP growth rate of -1.26%. After dropping the mining industry, real wage growth increases to -1.32% which in turn increases the average MFP growth to -0.35%. However the magnitude of the increases after dropping the mining sector are approximately similar when we did not incorporate human capital.

In the service sector, it is evident from figure 8(a) that during 1980-1997 all states experienced negative real wage growth once we apply the Mincerian adjustments. This causes the statewide average for real wage growth to decline by almost three percentage point to -2.21% which in turn results in an even lower MFP growth average of -1.57%. With both negative real wage and real user cost growth rates, all states experiences negative MFP growth rate. The ranking of the states changes marginally where New Jersey, Connecticut, Rhode Island, Virginia, Delaware and New York emerge as the states with the highest growth rates. It can be clearly seen from both figure 8(b) and (c) that for 1998-2007, real wage growth derived from IPUMS-CPS moves to negative territory for all the states for both service sector and non-real estate service sector respectively once we apply the adjustments. For the entire service sector, the already low real user cost growth rate is now matched by an almost equally low growth in real wage. Further, dropping the real estate has almost no effect on the low real wage growth. The MFP growth rates with and without the real estate sector are lower at -3.23% and -2.73% respectively. The ranking of states for MFP growth rates goes through some marginal changes where Arkansas, South Dakota, Utah, New Mexico and Montana emerge as the states with highest MFP growth rates. Wrapping the discussion on the Mincerian adjustment, we draw attention to a few interesting patterns. First off, in the goods sector the reduction in wage growth compared to our traditional measure is higher for the 1980-97 period relative to 1998-2007. In the former case, the difference is about 3% while in the latter case it is a little lower at 2.7%. For the service sector, we find the opposite. For the earlier period, the adjustment is lower at about 2.7% while for the later period it is far higher at about 4%. It is difficult to provide a unifying reason for these patterns. One explanation for the larger decline in services may lie in the fact that it constitutes of the higher skilled industries - finance, legal, insurance, scientific, technical, health, etc. Since the return to education has increased dramatically for the skilled combined with the increase in the years of schooling, the service sector might have experienced a larger effect.[28]

4.3 Sectoral Patterns at the National Level

Our measures of MFP growth so far clearly highlight a wide range of values across states for both broad sectors of the economy. Furthermore, it is evident that at least over the medium run, there is no evidence that the real user cost growth is zero. At the same time, the fact that we cannot compare our estimates at the state level with any established numbers combined with the finding

[28] According to Henderson et. al. (2011), the return for those with a college degree went up by 5 percentage points from 2000 to 2005 while that of high school or less went down by a point.

that MFP growth does not show signs of a revival would lead one to question the reliability of these findings. Since no other estimates exist at the state level, in this section we briefly look at some of the results in the national level. In particular, using the same dual approach, we construct national level MFP growth for both goods and services. The motivation here is to check whether the unusually low numbers, particularly, post 1998, are specific to the state level analysis or is replicated too at the national level. We also calculate the primal counterparts at the national level and compare the dual vs the primal.[29] To preview our main result- the lower numbers for the dual approach continue to carry over at the national level. Thus not only do we observe lower MFP growth at the national level post 1998, but our calculations based on the dual approach yields much lower numbers than the primal approach. To investigate this further, we delve deeper to see what causes our wage and real user cost of capital growth measures to be low. For wage growth, we examine the role that our choice of using IPUMS-CPS data plays. We examine what happens when this is replaced by BEA based compensation data given our earlier observations on the limitation of CPS. We also compare our dual estimates of real user cost growth with two measures of marginal product of capital derived from the BEA and the Bureau of Labor Statistics (BLS) data respectively.

4.3.1 Revisiting Wage Growth

Table (6) summarizes all our calculations. The first column presents the average labor productivity growth rates for the relevant years and sectors.[30] Like before, the overall patterns include higher growth in goods producing sectors in both time periods, and services showing an acceleration post 1998 but still lower than the growth in the goods sector. Within the goods sector, once mining has been dropped, like before, we see much higher growth rates post 1998. Within the service sector, dropping real estate services, has no major impact on the overall growth rate- confirming what we saw in Table (4) as well. Column (2) lists the dual based MFP growth rates. These numbers are again in line with what we have already seen. MFP growth is higher in the goods producing sectors during both time periods and both sectors show a decline in post 1998 period. Thus, so far, we see the national numbers only reinforce what we find at the state level. Therefore, it is difficult to dismiss the state level results as being the consequence of some unknown incorrect disaggregation. The national level calculations reinforce the puzzle of lower MFP growth rates in an era that the existing research indicates as a period of productivity revival. Pursuing this issue further, we first consider an alternative measure of real wage growth. So far we have relied on the IPUMS-CPS data which as pointed out earlier is top-coded and also does not reflect non-wage benefits. We substituted this with data on compensation from the BEA.[31] This data does not have

[29] In theory, one can also conduct a primal exercise at the state level by assuming that capital output ratios for each sub-sector is equalized across states. This would allow us to construct capital stocks by state as has been done by Garofalo and Yamarik (2002). While it might be interesting to compare, it does not provide a test of reliability since such a construction is itself based on imputed values and assumptions.

[30] To clarify further, what we list here are the direct national calculations. We also double checked and calculated state weighted means for all our earlier estimates. Not surprisingly only differences occur at the second decimal place and are therefore minor errors of approximation.

[31] Baker (2007) finds a sharp increase in the non-wage share of compensation during 2001 -2006.

these limitations. The downside is that the data is not refined by education and gender level and thus cannot be used to create a composition adjusted growth rate. Another factor to keep in mind while using compensation based data is that, in effect, we are imputing a marginal product of labor. This is easily understood by recalling that the same compensation data was used to calculate labor shares. In other words the data has been used as a measure of wL. The growth in compensation per worker then is nothing but the marginal product of worker growth.[32] At first glance, this may seem problematic in that we are using a variable for primal growth (growth in labor input) to infer something about dual MFP growth. Despite these issues, it is useful to see to what extent this substitution affects wage growth and in the process, MFP growth.[33] Column (3) lists the results. For the period 1980-1997, we find that this does not have a large effect on MFP growth. Overall, it leads to an increase of around 0.2 to 0.4 percentage points depending on the sector of interest. For 1998-2007, there is a much larger effect on MFP growth. For the goods sector the MFP growth is now higher by almost 0.8 percentage points both with and without mining. Further once mining is excluded, MFP growth is now similar in both time periods.[34] Underlying these increases are more than a doubling of the wage growth rate. For the service sector, the increases are more varied. For the 1980-97 period, the increase in MFP growth is 0.21 percentage points while during 1998-2007 it is 0.63 percentage points. Nevertheless MFP growth is still in negative territory and lower than the pre 1998 period. Thus, wage growth adjustments using compensation data cannot account for the anemic productivity performance of the service sector. When we exclude real estate services, the move to compensation data leads to an upward revision of MFP growth by 0.74 percentage points- enough to bring it into positive territory. To summarize, moving from IPUMS-CPS goes some way in solving the earlier apparent conundrums. Clearly the non-mining goods sectors now have MFP growth that is comparable in both periods. Within the non-real estate portion of the service sector, MFP growth is positive though still low.

4.3.2 Primal vs Dual MFP Growth

As a next step, we compare the dual measures of MFP growth with primal measures.[35] The objective here is to examine the gap between the primal and the dual estimates and see if we can look at other factors. Columns (4) and (5) reflect two alternative primal estimates of MFP. Column (4) uses factor input and output data from the BEA while column (5) substitutes capital input measures from the Bureau of Labor Statistics (BLS).[36] For 1980-1997, we find that the broad goods sector

[32]This obviously reflects the underlying assumption that wages is equal to the marginal product of labor.

[33]A more liberal viewpoint would be that substituting this measure can be viewed as a first step to bridging the dual vs primal gap that we discuss next.

[34]Even though 1980-97 was a period that was mostly marked by the well documented productivity slowdown, the goods sector experienced higher productivity growth and in fact, the rebound had begun much earlier. This can be attributed to the fact that, even during the slowdown, some manufacturing industries like computers and office equipments and electronic components experienced stronger growth (Jorgenson et.al., 2005). Triplett and Bosworth (2001) also provide similar evidence.

[35]For all subsequent comparisons we use the dual estimates based on compensation data, i.e. column (3) in Table (6).

[36]The primal measures are obtained by subtracting the share weighted factor input (labor and capital) growth from the output growth where the assigned weights are two period average of factor income share in total output.

has MFP growth from primal and dual approaches that are very close to each other. However, this similarity disappears as soon as we drop the mining sector. We now find that the primal measure continues to produce a growth rate of 2.5% which is much higher than the dual based growth rate of 1.72%. We already discussed in section 4.1.1 why the latter happened - removing the mining sector leads to a slower decline in the GDP deflator and thus a slower increase in the relative price of investment goods. For the service sector, we find that the primal MFP growth is much higher at 0.74% compared to 0.19%. The primal measure suggests that MFP growth was responsible for 80% of labor productivity growth while our dual measure suggests a contribution of only 20%. Clearly the results are diametrically opposite.

Moving on to the 1998-2007 period, the primal measure of MFP growth for the goods sector is now at 2.13% using the BEA data. This is substantially higher than our dual based measure of 0.33%. However, within the primal measure, we do not see the well known productivity revival. Only when we exclude the mining sector, we see that the MFP growth according the primal numbers is at 2.66%, slightly higher than the earlier period. Moreover the gap between the dual and primal is now much less mainly because the dual based measure is higher. For 1998-2007, we can also compare the dual measure with the primal measure that we constructed using the BLS composition adjusted capital input data. Switching data sources does not lead to large changes in MFP growth measures with the rate slightly lower at 2.47%. Thus, after dropping the mining sector, there still remains a difference ranging from 0.76 (BLS) to 0.95 (BEA) between the dual and primal measures. With respect to the service sector, the BEA based primal measures of MFP growth is 1.14%. This is clearly much higher than the dual measure of -0.43%. Moreover, it clearly captures the productivity revival which the dual measure fails to do. However, the news is not unambiguous for the primal measure. The BLS based primal measure stands sharply lower at 0.58%. Of course this is still much higher than the negative value that our dual approach produces. Once we drop the real estate sector, the differences are much smaller. While the dual approach still produces the lowest figure of 0.62%, it is close to the BLS value of 0.94% though much lower than the BEA value of 1.36%. Thus, while we have earlier questioned the validity of removing the real estate sector in our analysis, at the same time it clearly reflects some anomalous behavior.

4.3.3 Revisiting Real User Cost Growth

The comparisons between the primal and dual measures indicate that there remains an unresolved gap between the two. Moreover, for the broad service sector, MFP growth in the second period remains negative despite the substitution of BEA compensation data. If wages based on compensation data cannot drive away the differences between the dual and the primal calculations, then the residual difference has to be due to differences in the return to capital. In this section, we look at our

The BLS measure of capital input is different from the BEA in that it is composition adjusted and based on five asset types, namely, equipment, structures, rental residential capital, inventories and land. This data is only available from 1987 onwards and hence can be used in this paper only for the second time period of 1998-2007. See appendix A.4 for more details regarding the construction of primal MFP growth. For more on composition adjusted capital growth, see Gordon (2010), Jorgenson et.al. (2008, 2005), Triplett and Bosworth (2001).

measure of real user cost of capital and a derived measure of the marginal product of capital. The marginal product of capital can be easily backed out from three pieces of data - the share of capital income in total output which we have already calculated (see discussion surrounding equation (9)), real output, and capital input measures from the BEA (or the BLS). Henceforth, we will refer to these as the MPK_{BEA} and the MPK_{BLS}. In addition to these three measures of returns to capital, in table (7), we also list the growth in the three "components" of the real user cost measure - the relative price of investment goods, the financial component, and the tax component. These three components while conveying distinct information are not necessarily orthogonal to each other. For example, the inflation rate in the financial component captures inflation in the investment price deflator, the level of which appears in the numerator of the first component.

Beginning our analysis with the 1980-1997 period, the first observation is that the real user cost growth and growth rate of the MPK_{BEA} are very similar for the goods producing sector. This is not surprising given the similarity of the MFP growth in this period between primal and dual measures. Almost any difference that existed was already removed once we substituted the BEA compensation data for the CPS measure of wages. However, we have already seen that removing the mining sector caused differences in MFP growth to emerge. Not surprisingly, this is reflected in the returns to capital. In fact, once the mining sector is dropped, the growth of MPK_{BEA} increases while the real user cost of capital growth decreases. For the MPK_{BEA}, which is a derived value, this is obviously reflects a deceleration in the BEA measures of capital accumulation in the manufacturing and construction industries during this period. On the other hand the fact that our real user cost growth measure actually declines outside the mining sector indicates that these two sectors experience faster capital accumulation during this period. Clearly the results are inconsistent.

While we cannot explain BEA numbers, columns 4-6 provide some insight as to why the real user cost growth is lower once mining is excluded. Our initial year is 1980 by when oil prices had reached their peak. The subsequent decline meant that the relative price of investment goods for that sector, P_I/P_Y, experienced higher growth rates. Once the mining sector is removed, the growth rate of investment price ratio falls to -0.13% from 0.63%. This decline, while not as drastic as that documented by Greenwood et.al (1997), can be traced to their notion of investment specific technological change. One reason the decline is more muted is the fact that the goods sector produces part of the "equipment and softwares" and invests in them as well. Thus the final good in the goods producing sector is itself the investment good, and hence the relative price of investment goods obviously does not show a rapid fall. As a part of this exercise we had to calculate relative price of both construction and manufacturing industries. We found that indeed this argument holds up. The relative price for the construction industry declines at 1.34% annually while the manufacturing industry, the major producer of "equipments and softwares", recorded near zero growth. Secondly, notice that the growth in the financial component of the entire US goods sector, at 3.31% annually, was almost exactly equal to the growth in MPK_{BEA}. However, once the mining sector is removed this fell to 1.89% . This too can be tracked to the oil price shock of the 1970's.

Given the higher oil prices of 1970's, the investment deflator of the mining industry experienced rapid inflation during this period. It can be recalled that our constructed inflation rate is a five years moving average of lagged inflation rate of investment price deflator. This caused the inflation rate for the starting year 1980 to be extremely high (at 14%) which subsided drastically as we moved ahead in time (to 1% in 1997). Since this enters with a negative sign, this caused the growth rate of the financial component to be very high. With the removal of the mining industry, the growth rate in the financial component reduces to 1.89%.[37]

When we look at the service sector for the period 1980-1997, we see that the real user cost growth is about 1.4 percentage points lower than the MPK_{BEA}. Looking again at the components of the real user cost growth, we see clear differences compared to the goods sector. There is a steep decline in the relative price of investment goods and also a steep increase in the financial component. Clearly, we see evidence of investment specific technological change in the service sector. An industry-wise break up reveals that all the service providing industries experience falling relative prices of investment goods during this period. The tax component, which falls at the rate of 0.99% annually, also contributes to the negative growth rate of the real user cost. While the reduction in the federal corporate tax rate is obviously uniform across sectors, an increasing depreciation rate in the service providing industries increased the present value of depreciation deductions.[38]

We have already seen that during 1998-2007, the gap between dual and primal measures for MFP growth was substantial (Table 6). Given that share of capital income is usually about a third, the gap between our real user cost growth and the MPK measures would increase three-fold relative to the MFP gaps. Indeed, this is what we see in Table (7). As the table also suggests there is no obvious explanation based on the three components of user cost growth. The real user cost growth even when mining is dropped, remains only slightly higher than zero and far lower than growth in BEA_{MPK}. Interestingly, unlike the earlier time period, we now see a slight increase in the relative price. If we look at the service sector, again, we find extremely large differences. Interestingly, the MPK measure imputed from the BLS shows negative growth, though the absolute value of real user cost growth is higher by an order of magnitude. However, once the real estate sector is dropped, we see that there is jump in the growth rate of the real user cost, though it still remains in distinctly negative territory. Looking at the various components, we see that removing the real estate sector leads to a decline in the relative price for investment goods though the pace is not as rapid as in 1980-97.[39] Ceteris paribus this would have reduced the real user cost growth even further. Nevertheless, the financial component shows a significant increase which more than compensates for the decline in in the relative price of investment goods. When the real estate sector

[37] The negative growth rate in the tax component can be attributed to the one time fall in the corporate income tax rate to 34% post 1987.

[38] Schaller (2006) argues that the surge in investment in information technology equipment, which have lower life spans, contributes to higher depreciation rates.

[39] Jorgenson et.al. (2008) find a greater role for IT capital accumulation and productivity growth in IT producing industries for the productivity surge during the period 1995-2000 and emphasizes the importance of non-IT sector for the post 2000 growth.

was included, the financial component showed a rapid decline mainly because the investment price deflator for the real estate sector was accelerating.[40]

To conclude there is no silver bullet to explain why the dual and the primal numbers do not coincide for MFP growth. This is more true for the post 1998 period than for the earlier period. While the idiosyncratic behavior of mining and real estate services can explain part of the anomaly, it is not enough. At the same time it is not clear one should be swayed too much by this inequality. It is possible that this is a period that is not long enough to average out some of the major fluctuations in the economy. This might have prevented the equalization of the marginal product of capital and the real user cost. From the literature on primal vs dual accounting we also know that in general the two measures do not coincide and thus it is not surprising that is the case here. Furthermore, it is possible that adjustment costs drive a wedge between the marginal product of capital and real user cost.[41] It is also important to remember that this entire section was carried out without undertaking the Mincerian adjustment. We have seen that the Mincerian adjustment reduced real wage growth and therefore the dual-based MFP growth. Since the adjustment would also imply defining labor stock as labor input multiplied by human capital per unit of labor, this would also reduce the primal MFP growth as well.

5 Concluding Remarks

In this paper we have presented a wide range of results on productivity growth in goods and services across states that covers a period of twenty seven years. Clearly, the main conclusion is that even within these broadly defined categories, states exhibit remarkably divergent behavior. Nevertheless, this is only an important first step. There is no gainsaying that some of this variation reflects the underlying sub-sector variation. Clearly to what extent the sub-sectors play a role in explaining the differences across states is an important next step. Another extension is the role of skill content of various sectors that might explain both variations in wage growth. An important extension of this work would be, subject to data availability, to undertake an intermediate goods based productivity analysis which can provide more precise estimates at the state-sectoral level. This would require data on the gross product at the state level which is not available but might be addressed by focussing on firm level data instead. While these are important issues for future work, highlights some significant issues. In particular, the finding that the real user cost growth seems to be consistently lower than the marginal product of capital as implied by the BEA and BLS data clearly indicates that capital accumulation might have been faster than thought otherwise. The flip side is that productivity growth is lower. This is particularly true of the period beginning from 1998 and is further accentuated when human capital is incorporated. Finally, we should highlight two important byproducts of this research - by constructing real user cost growth by state implies

[40] This is also true of the mining sector during this period.

[41] Textbook treatments derive the real user cost in terms of the shadow value of capital and not the market price. The difference between the market price and the shadow value is usually the first derivative of an adjustment cost function. Therefore as long as investment is not zero in the steady state, the first derivative is not zero either.

that we can back out capital stock growth which can be extremely useful in analyzing the pace of investment and other issues related to capital accumulation at the state level. In similar vein, our calculations of sectoral productivity growth at the state level can be potentially useful for regional business cycle research that has become more popular over recent years.[42]

References

[1] Aiyar, S. and Dalgaard,C-J. (2005) "Total Factor Productivity Revisited: A Dual Approach to Development Accounting," *IMF Staff Papers*, Vol. 52(1), 82-102.

[2] Andersen, T.B., Bentzen, J., Dalgaard, C-J. and Selaya, P. (2010) "Lightning, IT Diffusion and Economic Growth across US States," forthcoming *Review of Economics and Statistics.*

[3] Autor, D.H., Katz, L.F. and Kearney, M.S. (2008) "Trends in U.S. Wage In equality: Re-Assessing the Revisionists," *Review of Economics and Statistics*, Vol. 90(2), 300-323.

[4] Badenhausen, K. (2011) "The Best States for Business," *Forbes*, November 22.

[5] Baker, D. (2007) "Behind the Gap between Productivity and Wage Growth," *Center for Economic and Policy Research Issue Brief, February.*

[6] Barro, R.J. (1999) "Notes of Growth Accounting," *Journal of Economic Growth*, Vol. 4(2), 119-137.

[7] Barro, R. J., and Sala-i-Martin, X. (1991) "Convergence across States and Regions," *Brookings Papers on Economic Activity*, Vol. 22(1), 107-182.

[8] , Bernard, A.B., Redding, S.J., and Schott, P.K. (2011) "Testing for Factor Price Equality with Unobserved Differences in Factor Quality or Productivity," mimeo, *Princeton University.*

[9] Buera, F.J., and Kaboski, J.P. (2011) "The Rise of the Service Economy," forthcoming *American Economic Review.*

[10] Caselli, F. and Coleman II, W.J. (2001) "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation," *Journal of Political Economy*, Vol. 109(3), 584-616.

[11] Caselli, F. and Coleman II, W.J. (2002) "The U.S. Technology Frontier," *American Economic Review*, Vol. 92(2), 148-152.

[12] Chirinko, R.S. and Wilson, D.J. (2008) "State Investment Tax Incentives: A Zero-Sum Game?," *Journal of Public Economics*, Vol. 92(12), 2362-2384.

[13] Ciccone, A. and Hall, R.E. (1996) "Productivity and the Density of Economic Activity," *American Economic Review*, Vol. 86(1), 54-70.

[14] Ciccone, A. and Peri, G. (2005) "Long-Run Substitutability between More and Less Educated Workers: Evidence from U.S. States 1950-1990," *Review of Economics and Statistics*, Vol. 87(4), 652-663.

[42] See Hamilton and Owyang (2010) and references therein for recent contributions to the regional business cycle literature. While we have presented long run averages, it is important to remember that our calculations are based on annual data and hence can be used for more short term studies.

[15] Ciccone, A. and Peri, G. (2006) "Identifying Human-Capital Externalities: Theory with Applications," *Review of Economic Studies*, Vol. 73(2), 381-412.

[16] Coen, R. M. (1968) "Effects of Tax Policy on Investment in Manufacturing," *American Economic Review*, Vol. 58(2), 200-211.

[17] Fernald, J.G. and Ramnath, S. (2004) "The Acceleration in U.S. Total Factor Productivity after 1995: The Role of Information Technology," *Federal Reserve Bank Chicago Economic Perspectives*, Vol. 28(Q1), 52-67.

[18] Garofalo, G.A. and Yamarik, S. (2002) "Regional Convergence: Evidence from A New State-By-State Capital Stock Series," *Review of Economics and Statistics*, Vol. 84(2), 316-323.

[19] Gilchrist, S. and Zakrajšek, E. (2007) "Investment and the Cost of Capital: New Evidence from the Corporate Bond Market," *National Bureau of Economic Research Working Paper No. 13174*.

[20] Glaeser, E.L. and Gottlieb, J.D. (2009) "The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States," *Journal of Economic Literature*, Vol. 47(4), 983-1028.

[21] Gollin, D. (2002) "Getting Income Shares Right," *Journal of Political Economy*, Vol. 110(2), 458-474.

[22] Gomme, P. and Rupert, P. (2004) "Measuring Labor's Share of Income," *Policy Discussion Paper No. 7*, Federal Reserve Bank of Cleveland.

[23] Gordon, R.J. (2000) "Interpreting the 'One Big wave' in U.S. Long Term Productivity Growth," in Ark, B.V., Duipers, S. and Kuper, G. (eds.), *Productivity, Technology and economic Growth*, Kluwer Publishers, 19-65.

[24] Gordon, R.J. (2010) "Revisiting U. S. Productivity Growth Over the Past Century with a View of the Future," *National Bureau of Economics Research Working Paper No. 15834*.

[25] Greenwood, J., Hercowitz, Z., and Krusell, P. (1997) "Long-Run Implications of Investment-Specific Technological Change," *American Economic Review*, Vol. 87(3), 342-362.

[26] Hall, R.E. and Jones, C.I. (1999) "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," *Quarterly Journal Of Economics*, Vol. 114(1), 83-116.

[27] Hall, R.E. and Jorgenson, D.W. (1967) "Tax Policy and Investment Behavior," *American Economic Review*, Vol. 57(3), 391-414.

[28] Hamilton, J. D., and Owyang, M.T. (2010) "The Propagation of Regional Business Cycles," forthcoming *Review of Economics and Statistics.*

[29] Henderson, D.J., Polachek S.W. and Wang, L (2011) "Heterogeneity in Schooling Rates of Return," *Economics of Education Review*, Vol. 30(6), 1202-1214.

[30] Herrendorf, B. and Valentinyi, Á. (2008) "Measuring Factor Income Shares at the Sector Level-A Primer," *Review of Economic Dynamics* Vol. 11(4), 820-835.

[31] Holtz-Eakin, D. (1993) "Solow and the States: Capital Accumulation, Productivity and Economic Growth," *National Tax Journal*, Vol. 46(4), 425-439.

[32] Hsieh, C-T. (1999) "Factor Prices and Productivity Growth in East Asia," *American Economic Review*, Vol. 89(2), 133-138.

[33] Hsieh, C-T. (2002) "What Explains the Industrial Revolution in East Asia? Evidence from the Factor Markets," *American Economic Review*, Vol. 92(3), 502-526.

[34] Iranzo, S. and Peri, G. (2009) "Schooling Externalities, Technology and Productivity: Theory and Evidence from US States," *Review of Economics and Statistics*, Vol. 91(2), 420-431.

[35] Jorgenson, D.W. and Griliches, Z. (1967) "The Explanation of Productivity Change," *Review of Economic Studies*, Vol. 34(3), 249-283.

[36] Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2005) "Growth of US Industries and Investments in Information Technology and Higher Education," in Corrado, C., Hulten, C. and Sichel, D. (eds.), *Measuring Capital in a New Economy* , Chicago, University of Chicago Press, 403-472.

[37] Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2008) "A Retrospective Look at the US Productivity Growth Resurgence," *Journal of Economic Perspectives*, Vol. 22(1), 3-24.

[38] Kalemli-Ozcan, S., Reshef, A., Sorensen, B. and Yosha, O. (2010) "Why Does Capital Flow to Rich States?," *Review of Economics and Statistics*, Vol. 92(4), 769-783.

[39] King, M., Ruggles, S., Alexander, J.T., Flood, S., Genadek, K., Schroeder, M.B, Trampe, B. and Vick, R. (2010) "Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. [Machine-readable database]," Minneapolis, *Minneapolis: University of Minnesota.*

[40] Klenow, P.J. and Rodriguez-Clare, A. (1997) "The Neoclassical Revival in Growth Economics: Has It Gone Too Far?," in Bernanke, B. and Rotemberg, J. (eds.), *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press., 73-103.

[41] Ngai, L. R., and Pissarides, C.J. (2007) "Structural Change in a Multisector Model of Growth," *American Economic Review*, Vol. 97(1), 429-443.

[42] Park, J.H. (1994) "Estimation of Sheepskin Effects and Returns to Schooling using the OLD and the New CPS Measures of Educational Attainment," *Princeton University, Industrial Relations Section,* Working Paper # 338.

[43] Schaller, H. (2006) "Estimating the Long Run User Cost Elasticity," *Journal of Monetary Economics*, Vol. 53(4), 725-736.

[44] Steindel, C. and Stiroh, K. (2001) "Productivity: What Is It, and Why Do We Care about It?," *Business Economics*, Vol. 36(4), 13-31.

[45] The Council of State Governments. "The Book of the States", *The Council of State Governments: Lexington, Kentucky*, (Various Issues).

[46] Triplett, J.E. and Bosworth, B.P. (2001) "Productivity in the Services Sector," in Robert Stern (editor), *Services in the International Economy*, Ann Arbor: The University of Michigan Press.

[47] Triplett, J.E. and Bosworth, B.P. (2006) "Baumol's Disease" Has Been Cured: IT and Multifactor Productivity in U.S. Services Industries," In Jansen D.W., (ed.) *The New Economy and Beyond: Past, Present and Future*, Edward Elgar.

[48] Turner, C., Tamura, R. and Mulholland, S.E. (2011) "How Important Are Human Capital, Physical Capital and Total Factor Productivity for Determining State Economic Growth in the United States, 1840-2000?," *Munich Personal RePEc Archive Paper No. 32846*.

Table 1: **Productivity Growth in the Goods Producing Sector (1980-1997)**

(a) Summary Statistics

	Goods				Goods (No Mining)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean	SD	Min	Max	Mean	SD	Min	Max
ALPG	2.87	1.10	0.25	5.82	2.78	1.39	-0.34	8.68
			(MT)	(NM)			(MT)	(NM)
MFPG	2.24	1.47	-0.13	6.65	1.34	0.83	-0.38	3.63
			(WA)	(WY)			(NV)	(NH)
RWG	1.69	0.86	-0.32	3.98	1.37	0.92	-0.70	3.99
			(MD)	(NH)			(MT)	(NH)
RUCG	2.90	2.36	0.06	9.38	1.26	0.77	-0.40	3.77
			(WA)	(NM)			(VA)	(NM)

(b) Correlation Matrix

	Goods				Goods (No Mining)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ALPG	MFPG	RWG	RUCG	ALPG	MFPG	RWG	RUCG
ALPG	1.00				1.00			
MFPG	0.29	1.00			0.70	1.00		
RWG	0.60	0.59	1.00		0.56	0.96	1.00	
RUCG	0.07	0.90	0.26	1.00	0.76	0.73	0.55	1.00

Note: The number of states included is 48. The growth rates refer to average annual growth rates in percentage. ALPG=Average labor productivity growth rate, MFPG=Multi-factor productivity growth rate, RWG=Real wage growth rate, RUCG=Real user cost growth rate.

Table 2: **Productivity Growth in the Goods Producing Sector (1998-2007)**

(a) Summary Statistics

	Goods				Goods (No Mining)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean	SD	Min	Max	Mean	SD	Min	Max
ALPG	2.40	2.21	-1.92	11.07	2.86	2.04	-1.03	11.15
			(WY)	(OR)			(NV)	(OR)
MFPG	-0.20	3.13	-11.77	6.97	1.05	2.11	-2.32	8.55
			(WY)	(OR)			(NV)	(NM)
RWG	0.85	2.09	-4.74	6.44	1.35	1.79	-2.00	6.45
			(WY)	(OR)			(NV)	(OR)
RUCG	-1.72	4.77	-16.95	10.81	0.33	2.73	-4.44	9.92
			(WY)	(VT)			(LA)	(NM)

(b) Correlation Matrix

	Goods				Goods (No Mining)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ALPG	MFPG	RWG	RUCG	ALPG	MFPG	RWG	RUCG
ALPG	1.00				1.00			
MFPG	0.76	1.00			0.67	1.00		
RWG	0.74	0.88	1.00		0.70	0.94	1.00	
RUCG	0.67	0.91	0.70	1.00	0.64	0.92	0.79	1.00

Note: Refer to table (1)

Table 3: **Productivity Growth in the Service Producing Sector (1980-1997)**

(a) Summary Statistics

	(1)	(2)	(3)	(4)
	Mean	SD	Min	Max
ALPG	0.74	0.61	-0.26	2.24
			(OK)	(CT)
MFPG	-0.01	0.27	-0.67	0.69
			(MT)	(NC)
RWG	0.49	0.47	-0.80	1.69
			(MT)	(CT)
RUCG	-0.82	0.25	-1.65	0.09
			(DE)	(WY)

(b) Correlation Matrix

	(1)	(2)	(3)	(4)
	ALPG	MFPG	RWG	RUCG
ALPG	1.00			
MFPG	0.40	1.00		
RWG	0.66	0.86	1.00	
RUCG	-0.54	0.11	-0.36	1.00

Note: Refer to table (1)

Table 4: **Productivity Growth in the Service Producing Sector (1998-2007)**

(a) Summary Statistics

	Services				Services (No Real Estate)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean	SD	Min	Max	Mean	SD	Min	Max
ALPG	1.73	0.49	0.66	2.82	1.80	0.47	0.92	2.94
			(MI)	(SD)			(MI)	(SD)
MFPG	-0.99	0.68	-2.17	0.67	-0.09	0.79	-1.57	1.68
			(SC)	(AR)			(OH)	(AR)
RWG	0.65	1.04	-1.39	2.96	0.67	1.05	-1.41	2.91
			(SC)	(AR)			(SC)	(AR)
RUCG	-3.50	0.24	-3.91	-3.02	-1.99	0.32	-3.23	-1.20
			(MD)	(KS)			(DE)	(CO)

(b) Correlation Matrix

	Services				Services (No Real Estate)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ALPG	MFPG	RWG	RUCG	ALPG	MFPG	RWG	RUCG
ALPG	1.00				1.00			
MFPG	0.06	1.00			0.07	1.00		
RWG	0.14	0.96	1.00		0.17	0.94	1.00	
RUCG	0.12	0.37	0.25	1.00	0.02	0.34	0.07	1.00

Note: Refer to table (1)

Table 5: **Productivity Growth after Adjusting for Human Capital**

	Without Human Capital		With Human Capital	
	RWG	MFPG	RWG	MFPG
	(1)	(2)	(3)	(4)
		(1980-1997)		
Goods	1.69	2.24	-1.41	0.74
Goods (No Mining)	1.37	1.34	-1.72	0.06
Services	0.49	-0.01	-2.21	-1.57
		(1998-2007)		
Goods	0.85	-0.20	-1.83	-1.26
Goods (No Mining)	1.35	1.05	-1.32	-0.35
Services	0.65	-0.99	-3.43	-3.23
Services (No Real Estate)	0.67	-0.09	-3.41	-2.73

Note: The presented numbers are the unweighted means for the average annual growth rates (in percentage). Columns (1) and (2) display values already reported in previous tables. The number of states included is 48. RWG=Real wage growth rate, MFPG=Multi-factor productivity growth rate.

Table 6: **Productivity Growth for the US: Primal vs Dual**

	ALPG	Dual (1)	Dual (2)	Primal (1)	Primal (2)
	(1)	(2)	(3)	(4)	(5)
			(1980-1997)		
Goods	2.84	2.14	2.41	2.40	
Goods (No Mining)	2.86	1.39	1.72	2.54	
Services	0.91	-0.02	0.19	0.74	
			(1998-2007)		
Goods	2.76	-0.46	0.33	2.13	1.97
Goods (No Mining)	3.22	0.90	1.71	2.66	2.47
Services	1.78	-1.06	-0.43	1.14	0.58
Services (No Real Estate)	1.85	-0.12	0.62	1.36	0.94

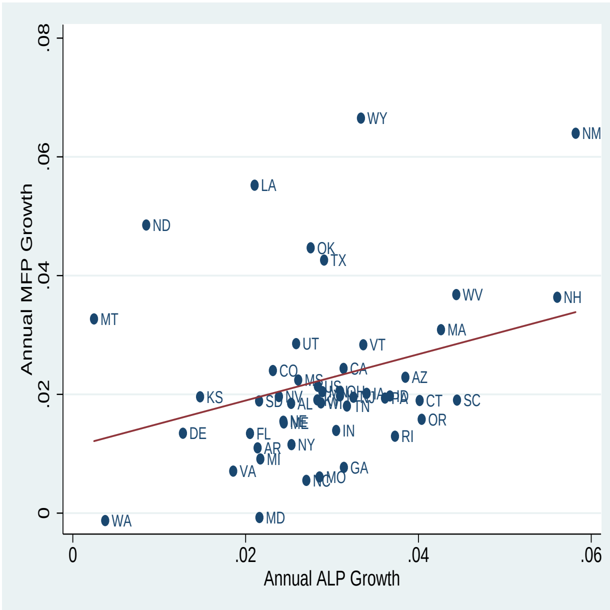
Note: The presented numbers are the average annual growth rates in percentages. ALPG represents the average labor productivity growth rate. Dual (1) presents the dual measure using the IPUMS-CPS data. Dual (2) presents the dual measures using the compensation of employees data from the BEA. Primal (1) presents the primal measures of MFP growth rate calculated using the data from the BEA. Primal (2) presents the primal measures of MFP growth rate calculated using the labor force data from the BEA, and real capital stock and capital income data from the BLS. Primal (2) undergoes quality adjustment based on the asset types: equipment, structures, rental residential capital, inventories and land.

Table 7: **Real User Cost Vs. Marginal Product of Capital**

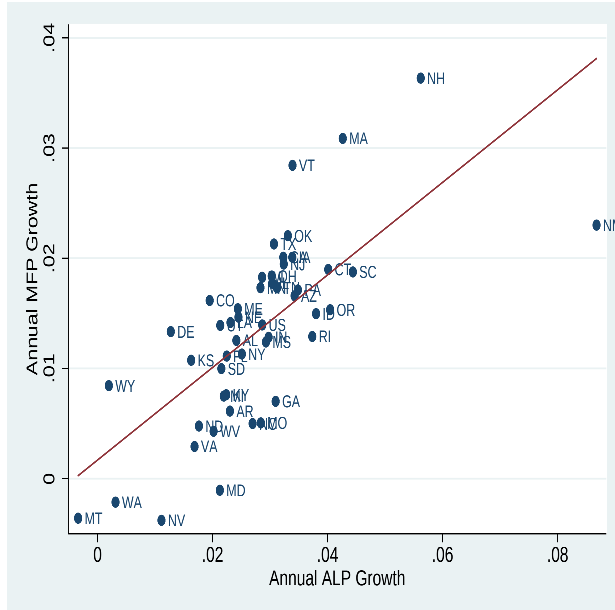
	MPK_{BEA}	MPK_{BLS}	RUC	$\frac{P^I}{P^Y}$	$i+\delta-\pi$	$\frac{1-\tau z}{1-\tau}$
	(1)	(2)	(3)	(4)	(5)	(6)
			(1980-1997)			
Goods	3.33		3.44	0.63	3.31	-0.49
Goods (No Mining)	4.53		1.21	-0.13	1.89	-0.55
Services	0.51		-0.90	-2.31	2.39	-0.99
			(1998-2007)			
Goods	2.50	2.40	-2.73	-0.25	-2.31	-0.18
Goods (No Mining)	3.35	2.90	0.31	0.59	-0.10	-0.17
Services	0.54	-0.92	-3.50	-0.46	-2.75	-0.29
Services (No Real Estate)	0.89	-0.64	-1.89	-1.60	0.04	-0.33

Note: The numbers represent the average annual growth rates in percentages. MPK_{BEA}=the BEA implied marginal product of capital. MPK_{BLS}=the BLS implied marginal product of capital. RUC=real user cost. The growth rate in real user cost is the sum of the growth rates in the relative price, financial component and tax component represented in columns 4-6. To construct MPK_{BLS}, we adopt the following procedure: we use the real capital input and capital income for three digit NAICS industries to construct industrial (two digit) growth in real capital input. The growth rate in implied industrial MPK is calculated by subtracting the growth rate in real capital input from the industrial real GDP growth and adding the growth rate in industrial capital share (α_K). The sectoral growth rate is a weighted average of industrial growth rates where the assigned weights are the capital income share of each industry in the total capital income of the sector.

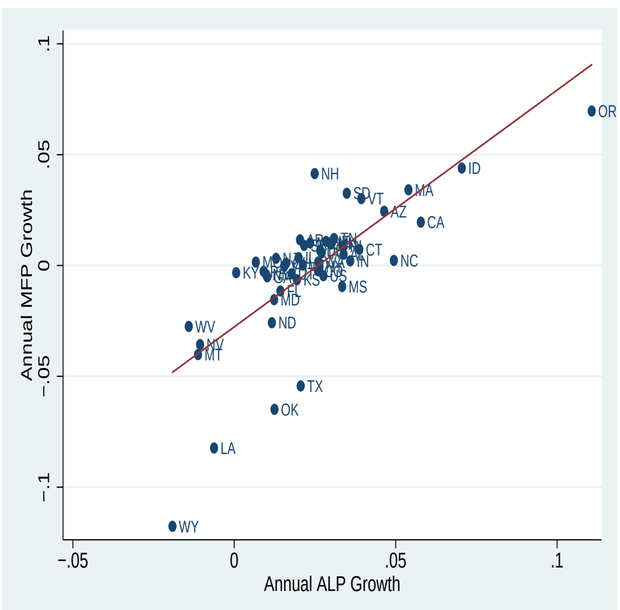
Figure 1: **Labor and Multi-Factor Productivity Growth (Goods)**



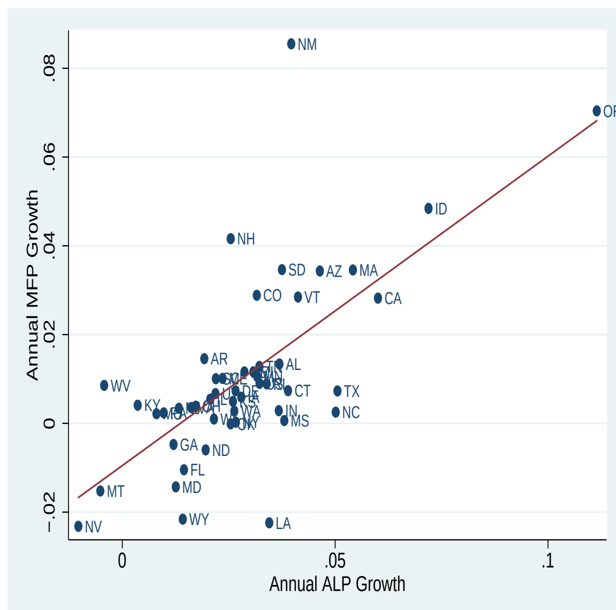
(a) Goods (1980-1997)



(b) Goods (No Mining) (1980-1997)

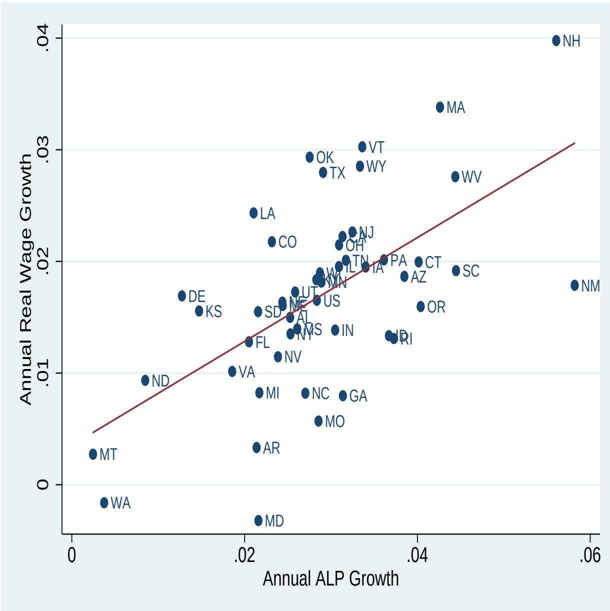


(c) Goods (1998-2007)

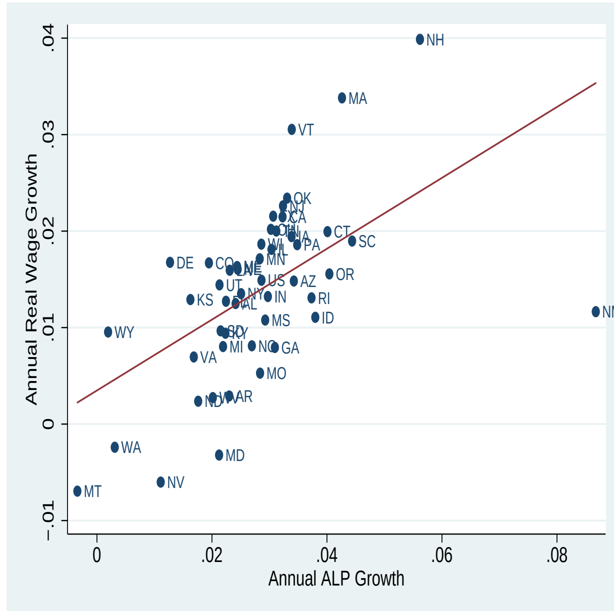


(d) Goods (No Mining) (1998-2007)

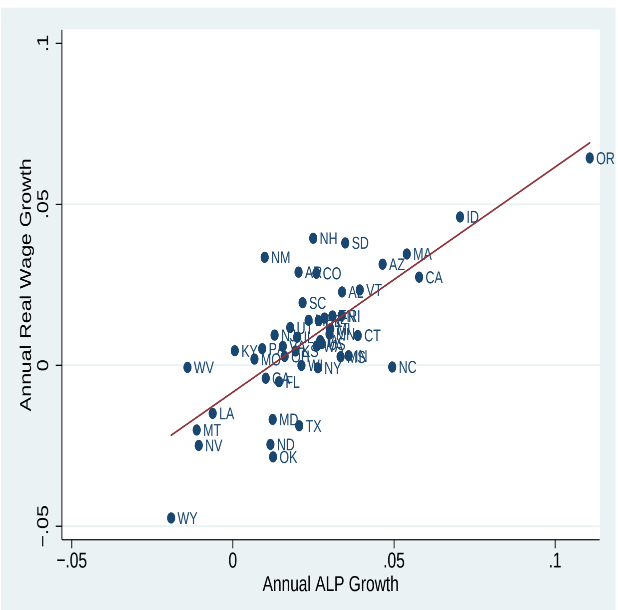
Figure 2: **Labor Productivity and Real Wage Growth (Goods)**



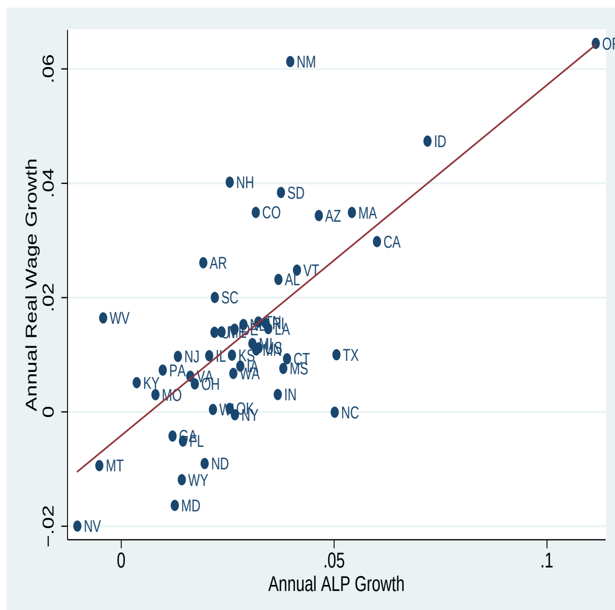
(a) Goods (1980-1997)



(b) Goods (No Mining) (1980-1997)

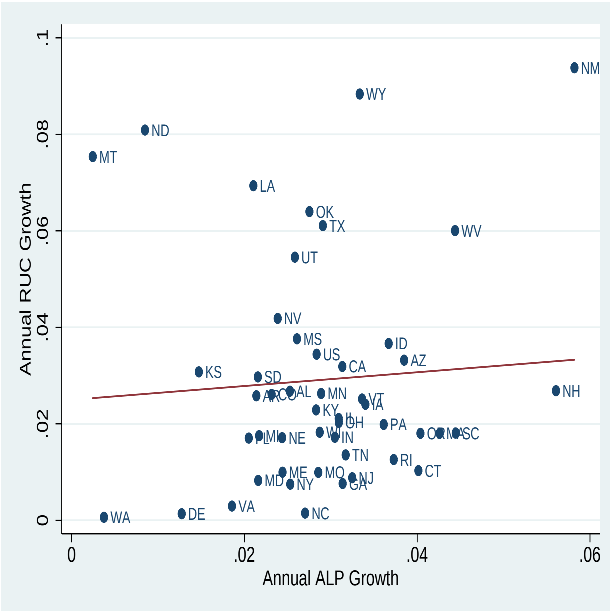


(c) Goods (1998-2007)

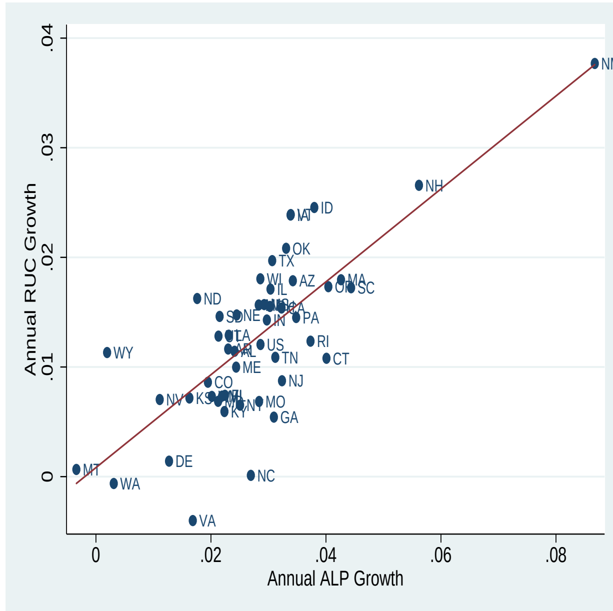


(d) Goods (No Mining) (1998-2007)

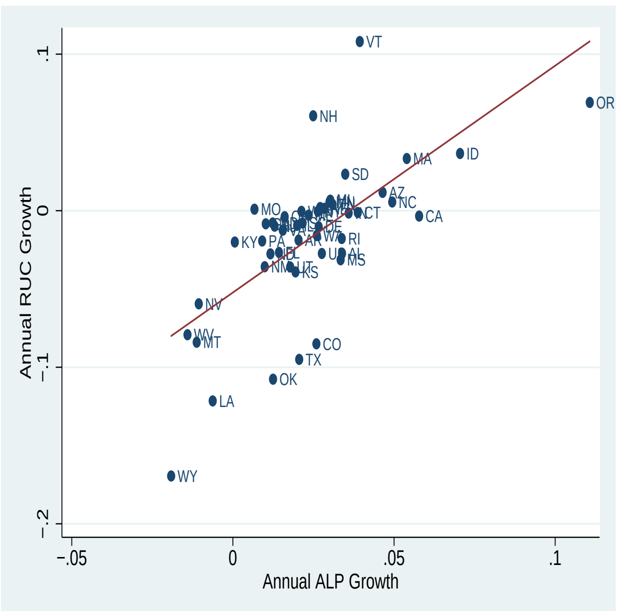
Figure 3: **Labor Productivity and Real User Cost Growth (Goods)**



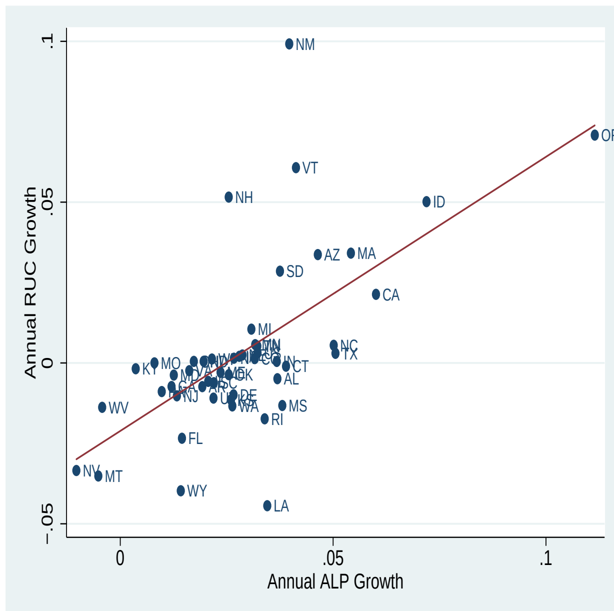
(a) Goods (1980-1997)



(b) Goods (No Mining) (1980-1997)

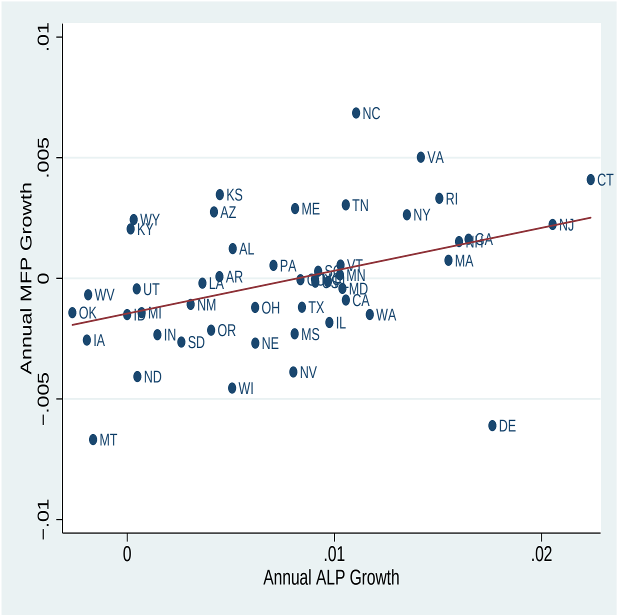


(c) Goods (1998-2007)

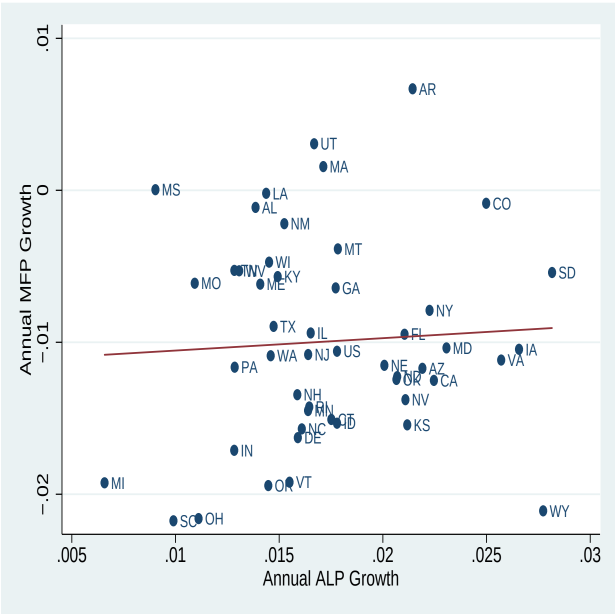


(d) Goods (No Mining) (1998-2007)

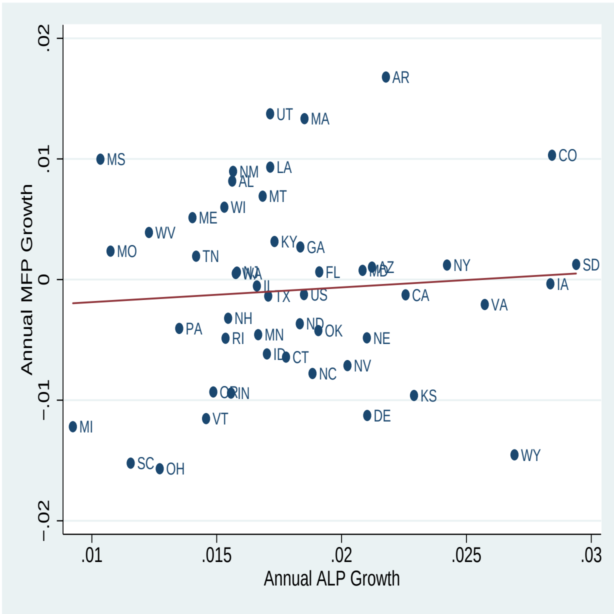
Figure 4: **Labor and Multi-Factor Productivity Growth (Services)**



(a) Services (1980-1997)

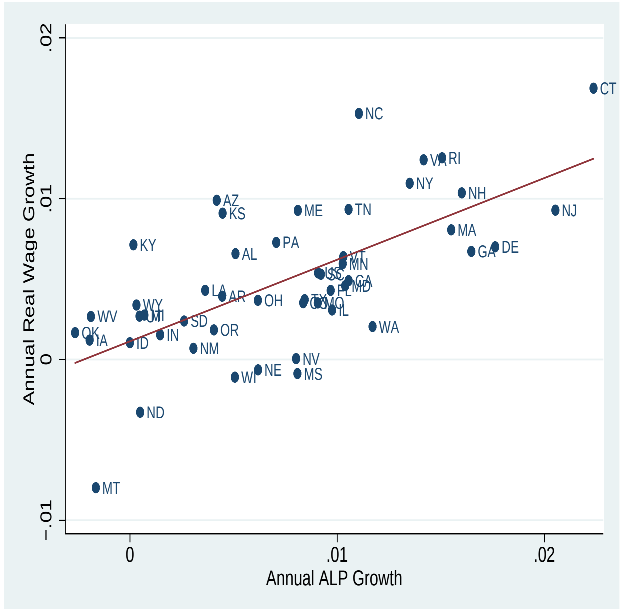


(b) Services (1998-2007)

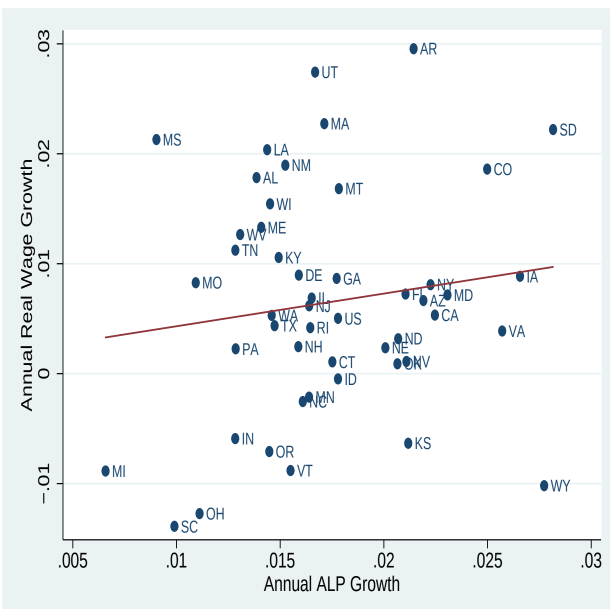


(c) Services (No Real Estate) (1998-2007)

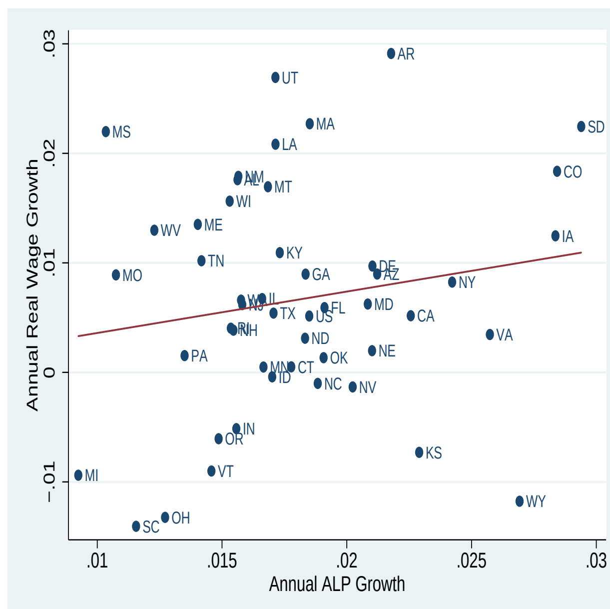
Figure 5: **Labor Productivity and Real Wage Growth (Services)**



(a) Services (1980-1997)

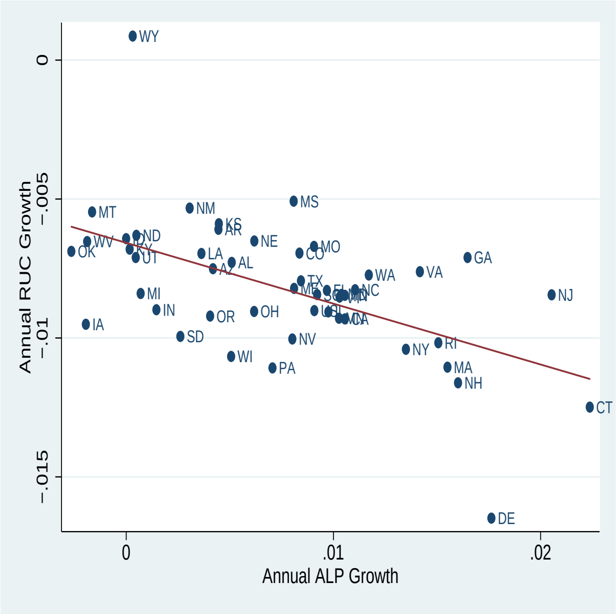


(b) Services (1998-2007)

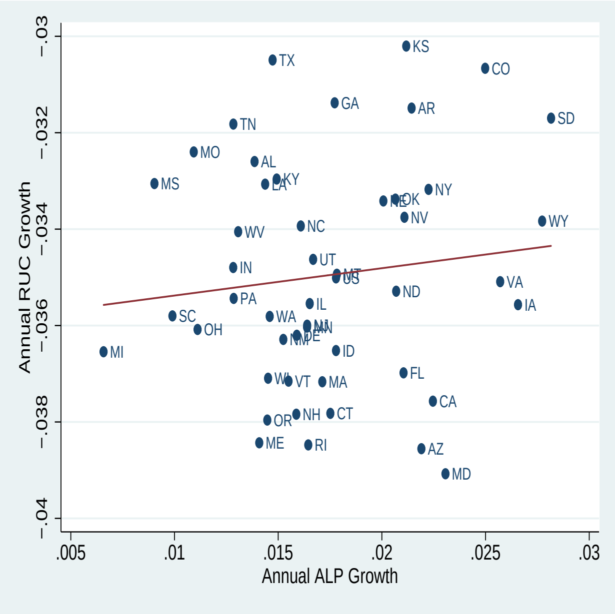


(c) Services (No Real Estate) (1998-2007)

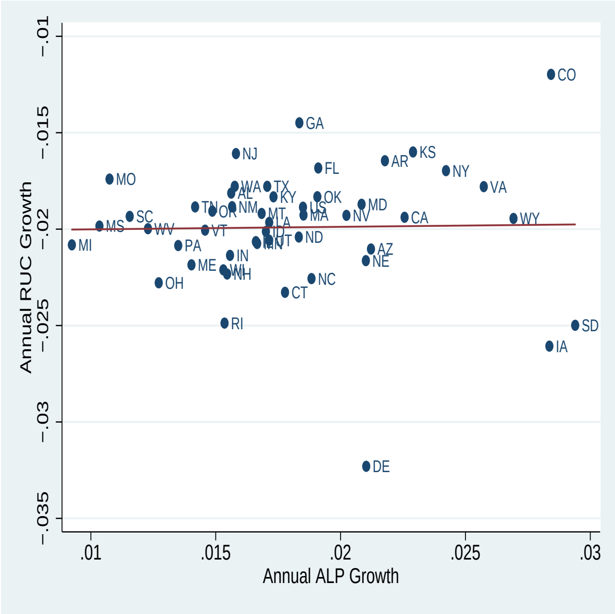
Figure 6: **Labor Productivity and Real User Cost Growth (Services)**



(a) Services (1980-1997)

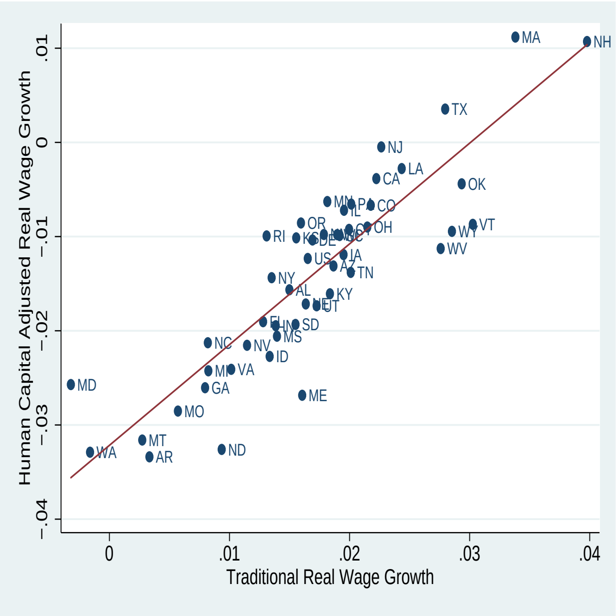


(b) Services (1998-2007)

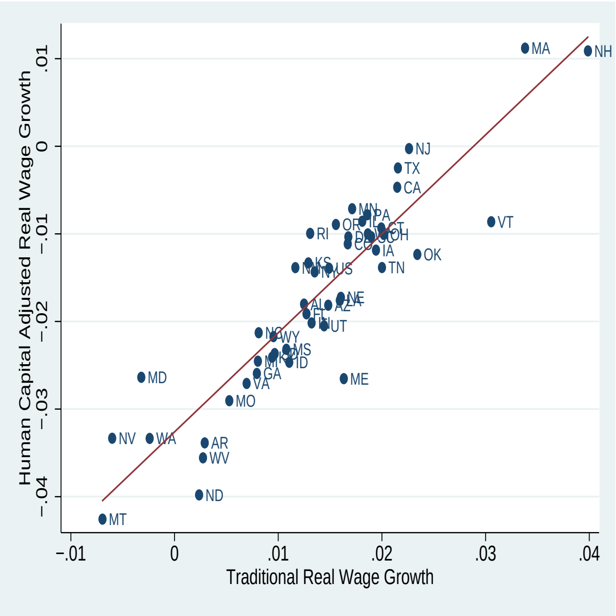


(c) Services (No Real Estate) (1998-2007)

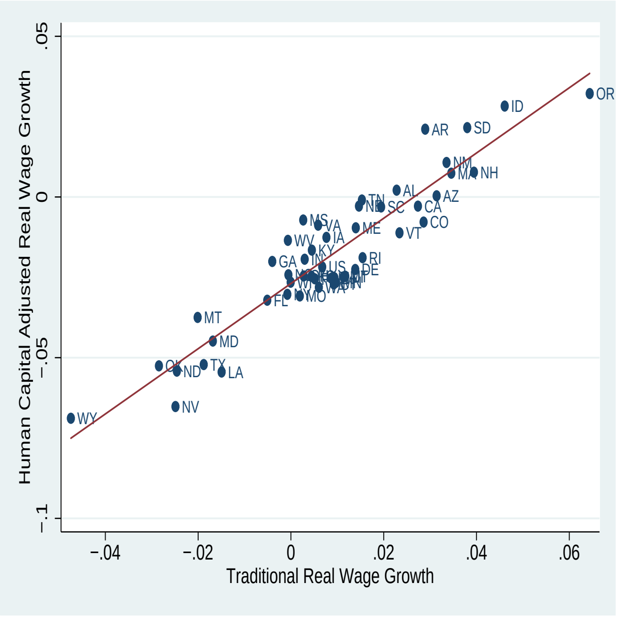
Figure 7: **Traditional and Human Capital Adjusted Real Wage Growth (Goods)**



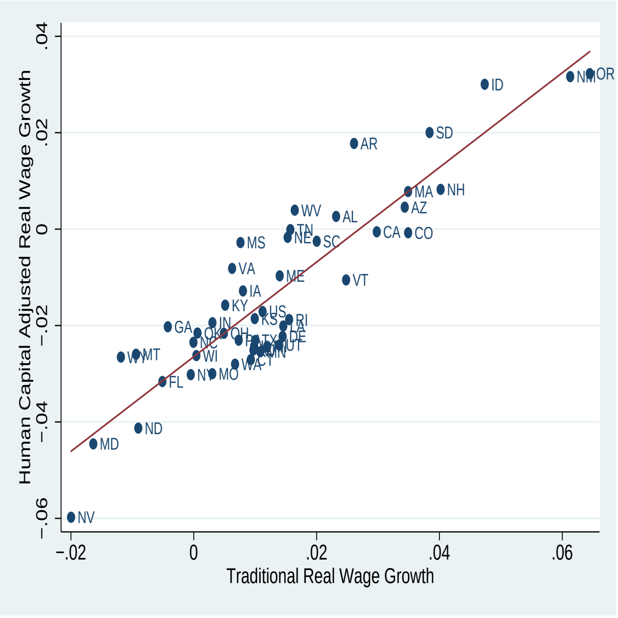
(a) Goods (1980-1997)



(b) Goods (No Mining) (1980-1997)

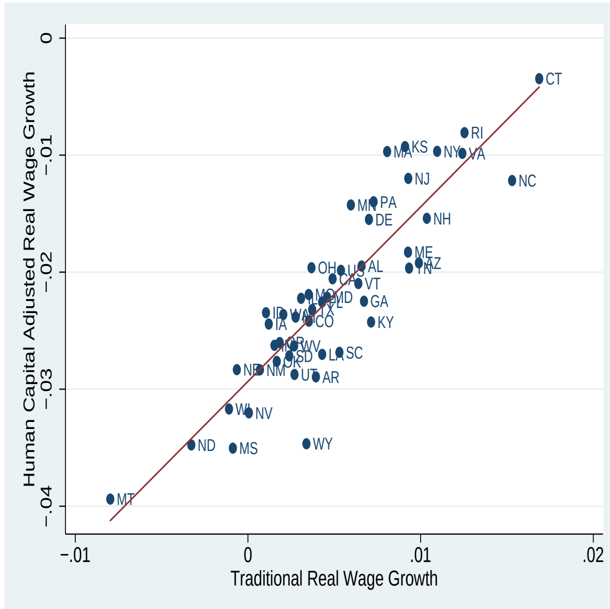


(c) Goods (1998-2007)

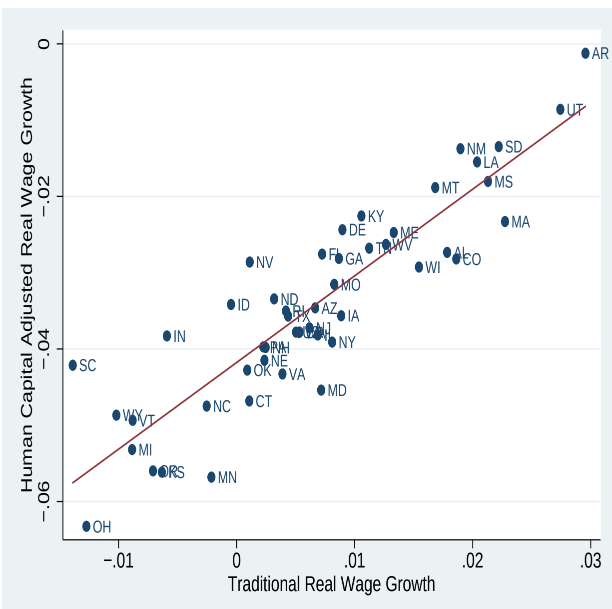


(d) Goods (No Mining) (1998-2007)

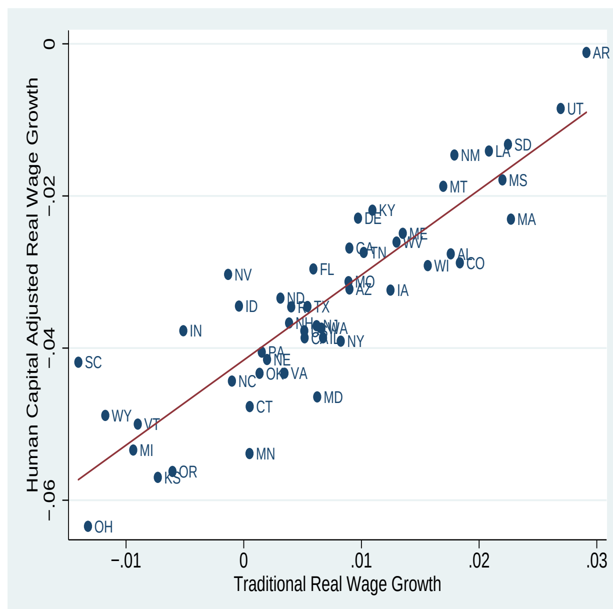
Figure 8: **Traditional and Human Capital Adjusted Real Wage Growth (Services)**



(a) Services (1980-1997)



(b) Services (1998-2007)



(c) Services (No Real Estate) (1998-2007)

A Data Appendix

This section documents the data sources and construction procedure for the variables used in the paper. Our paper uses data on the goods producing sector and the service sector for all the US states for 1980-1997 in Standard Industrial Classification (SIC) and for 1998-2007 in North American Industry Classification System (NAICS). Our major data source is Bureau of Economic Analysis (BEA) unless stated otherwise. In SIC, the data is collected on eight major industrial divisions, namely: a) Mining, b) Construction, c) Manufacturing, d) Transportation, Communication and Public Utilities, e) Wholesale Trade, f) Retail Trade, g) Finance, Insurance and Real Estate, h) Services. In NAICS, the data is collected for eighteen two digit industries, namely: a) Mining, b) Utilities, c) Construction, d) Manufacturing, e) Wholesale Trade, f) Retail Trade, g) Transportation and Warehousing, h) Information, i) Finance and Insurance, j) Real Estate and Rental and Leasing, k) Professional, Scientific and Technical Services, l) Management of Companies and Enterprises, m) Administrative and Waste Services, n) Educational Services, o) Health Care and Social Assistance, p) Arts, Entertainment and Recreation, q) Accommodation and Food Services, r) Other Services. The goods sector includes mining, construction and manufacturing industries and all other industries constitute the service sector in both the classification.[43] The nominal series are converted to real series using the price indices with base year 1997. The data construction procedure at the national level is analogous to the state level construction procedure. So, for the sake of brevity, we do not repeat the discussion at the national level unless it is required.

A.1 Labor Income Share

A.1.1 Gross Domestic Product by State (SGDP)

The BEA publishes data on the industry-wise SGDP for each state in its Regional Economic Accounts section.[44]The SGDP for any industry in any state is the value added in the production process in that industry. SGDP includes three components: compensation of employees, taxes on production and imports less subsidies, and gross operating surplus.[45]

A.1.2 Compensation of Employees (CE)

The BEA Regional Accounts produced estimates on compensation of employees include wages and salaries of employees and supplements to wages and salaries for each state industry wise. The data is published as a component of SGDP by the BEA Regional Accounts. Wages and salaries are measured on “when earned” basis.

A.1.3 Taxes on Production and Imports less Subsidies (ITS)

The ITS includes both taxes on production and imports, and subsidies. Taxes on production and imports for a state includes taxes on production and imports at federal, state and local level. State and local level taxes include non-personal property taxes, licenses and sales taxes and federal taxes

[43]We also report the results for the goods sector excluding the mining industry in both time periods and for the non real estate service sector for 1998-2007. For convenience, we index the state level component with subscript ‘s’, the two major sectors: goods and services are indexed by subscript ‘i’, and the major industries are indexed by subscript ‘j’.

[44]`http://bea.gov/regional/index.htm`

[45]The industry-wise data on GDP, compensation of employees, and taxes on production and imports less subsidies for the US are also collected from the BEA Regional Accounts. This data can also be accessed at the BEA Industrial Accounts.

include excise taxes on goods and services. Subsidies include subsidies given by the government to private business or other government agencies. The data is published as a component of SGDP by the BEA Regional Accounts.

A.1.4 Full-time Equivalent Wage and Salary Employment (FTE_WE)

The BEA published data on the wage and salary employment is the average annual number of jobs in each area by place of work. This series includes both full time and part time wage and salary employees with equal weight. The state Annual Personal Income Table numbers SA 27 and SA 27N in the BEA Regional Accounts provide the data on wage and salary employment.

But for our purposes, we need the data on full time equivalent wage and salary employment. Though the BEA does not provide this data at state level, but it furnishes the data on Full Time Part Time Employees (FTPTE) and Full Time Equivalent Employees (FTEE) industry-wise for the US in the section (6) of the National Income and Product Accounts (NIPA) of the BEA.[46] So, we apply an adjustment to the state level data which assumes that the FTEE and FTPTE ratio for each state is equal to its national ratio for each industry annually. This can be rephrased as the conversion rate of FTPTE to FTEE in an industry is same for all the states for that industry. The equation given below yields us full time equivalent wage and salary employment (FTE_WE) for each industry at the state level.

$$\frac{FTEE_{j,i,t}}{FTPTE_{j,i,t}} = \frac{FTE\_WE_{j,i,s,t}}{FTPT\_WE_{j,i,s,t}} \Longrightarrow FTE\_WE_{j,i,s,t} = \frac{FTEE_{j,i,t}}{FTPTE_{j,i,t}} FTPT\_WE_{j,i,s,t} \tag{19}$$

A.1.5 Adjusted Total Employment (Adj_TE)

The total employment data provided by the BEA includes full time and part time wage and salary employment which is by place of work and proprietors employment which is nearly by “place of residence”. The industry wise data for each state is available at the State Annual Personal Income Table numbers SA 25 and SA 25N in the Regional Accounts. For the proprietors employment, the data on non-farm sole proprietorship is by “place of residence” but the non-farm partnership data may be by “place of residence” or “place of work”. So, the BEA defines the series on total employment is by ”place of work” with little error.

The Industry Economic Accounts and section (6) of NIPA tables of the BEA provide industry-wise data on the Persons Engaged in Production (PEP) and FTEE for the US. The industry-wise data on

self employed is backed out using PEP and FTEE. Similarly, we back out the proprietors employment (PE) by deducting wage and salary employment from the total employment for each industry and each state. The sum of proprietors employment over all the states for each industry is different from the self employment (SE) data reported at the industry level for the US. So for congruence, we adjust the proprietors employment (PE) data, using the following formula:

$$\frac{SE_{j,i,t}}{\sum_s PE_{j,i,s,t}} = \frac{adj\_PE_{j,i,s,t}}{PE_{j,i,s,t}} \Longrightarrow adj\_PE_{j,i,s,t} = \frac{SE_{j,i,t}}{\sum_s PE_{j,i,s,t}} PE_{j,i,s,t} \tag{20}$$

So, for our purpose, total adjusted employment is the sum of full time equivalent wage and salary employment (FTE_WE) and adjusted proprietors employment ($adj\_PE_{j,s,t}$) which is the state level equivalence of persons engaged in production (total labor).

[46] This data can also be accessed at the industry accounts section of the BEA.

A.2 Real Wage Growth

To calculate the data on wages and weeks worked, we use the data on the March Current Population Survey (CPS) from the Integrated Public Use Microdata Series (IPUMS)-CPS of Minnesota Population Center. This survey data is collected through the monthly household surveys conducted by U.S. Census Bureau and the Bureau of Labor Statistics (BLS). The data is collected for 1980-2008. Below, we describe the steps to process the data set to compute the wages and average weeks of work. The numbers in the parenthesis refer to the codes in the sample.

- Any person below 16 years and above 66 years of age is dropped from the sample.
- EDUC variable contains information on the educational attainment which combines information on the educational attainment from HIGRADE (till 1991) and EDUC99 (post 1991). Any person with missing educational attainment (999) and below grade 1 is dropped from the sample. We divide the sample into four educational categories: less than high school, high school graduate, some college and college graduate.
- The data on years of schooling for the Mincerian adjustment to real wages is constructed using the HIGRADE variable which reports the highest grade completed for each worker in the sample for 1980-1991. Post 1991, the schooling attaintment is reported through a categorical variable EDUC99. The years of schooling for each worker is then calculated from the categorical variable using the conversion table in Park (1994).
- LABFORCE variable indicates whether the person in the sample was a part of the labor force in the preceding week or not. Anybody who was not part of the labor force (0 and 1), is dropped from the sample.
- EMPSTAT indicates whether the person in the sample was working or unemployed. We retain those people who were at work (10), had a job but did not work last week (12) and armed forces (13). These three groups are categorized as employed by IPUMS-CPS.
- IND1950 provides information information on the industry in which the person was employed. For our analysis, industry codes between 200 to 500 were classified as the goods sector and between 500 and 900 were classified as the service sector.
- CLASSWKR indicates whether the person is employed in the private industry or government sector or self employed. We drop the self-employed from the sample. Since our exercise deals with goods sector and private services, we only retain those workers who work in the private industry for wage and salary (22).
- WKSWORK1 variable reports the number of weeks the worker worked in the preceding year. We assume anybody working less than 40 weeks a year is not a full time employee. So, we drop all the workers with less than 40 weeks of work.
- UHRSWORK variable provides information on the number of hours per week that the worker usually worked if they worked during the previous year. As per IPUMS-CPS, any person is categorized as a full time worker if he has worked 35 hours per week or more. So, we drop those respondents who have worked less than 35 hours per week.
- INCWAGE variable provides information on pre tax wage and salary income in the previous year. We use this variable to construct our variable on wage. Any person with code 999999 (Not in Universe), 999998 (Missing information) and zero income is dropped from the sample.

- Our measure on Average Labor Productivity (ALP) is RGDP per weeks worked. Though the BEA provides information on total employed persons. The information on weeks worked is not available. We calculate the mean weeks worked for a sector 'i' and 's' from the IPUMS-CPS processed data. While calculating the mean weeks worked, each person is weighted by the sampling weight variable "PERWT". The "WKSWORK1" variable refers to the numbers of week worked in the preceding year. So, we forward the time one year ahead to arrive at the average weeks worked for the current year.

- To calculate the mean weekly wage for each labor group, we calculate the total weeks worked and total income wage by summing over all the individuals for that group for sector 'i' and state 's' every year. While computing the total weeks worked and total income wage, we apply the sample weight "PERWT" to each person. Mean weekly wage for each group is calculated by dividing total income wage by total weeks worked. This mean wage is forwarded one time period ahead as the information on wage income belongs to the previous calendar year.

- The nominal wage growth for a sector is calculated by weighting the wage growth of each group by their labor income share. The labor income share is calculated by dividing the total income of a group by total income of the sector.

- The real weekly wage growth is calculated by subtracting the growth rate of the SGDP deflator from the nominal weekly wage growth.

A.3 Real User Cost of Capital

A.3.1 Nominal Interest Rate (i)

We use Moody's Seasoned AAA Corporate Bond Yield for our analysis which is available at monthly frequency at Federal Reserve Bank, St. Louis web site. For any year, the nominal interest rate is a twelve-month average of this yield.

A.3.2 Depreciation Rate (δ)

Following Gilchrist and Zakrajšek (2007), the depreciation rate for industry 'j' is constructed as

$$\delta_{j,i,t} = \frac{D_{j,i,t}}{K_{j,i,t-1}} \tag{21}$$

where $D_{j,t}$ is real depreciation cost at time 't' and $K_{j,t-1}$ is real stock of capital at time (t-1). $D_{j,t}$ is calculated using "Current Cost Depreciation of Private Fixed Assets" and "Chain-type Quantity Index for Depreciation". $K_{j,t-1}$ is calculated using "Current Cost Net Stock of Private Fixed Assets" and "Chain-type Quantity Index for Net Stock Private Fixed Assets". The BEA publishes data on private fixed assets by industry at annual frequency from 1947-2001 in SIC classification and 1947-2007 in NAICS classification. The standard fixed assets tables in SIC and NAICS can be found at "`http://www.bea.gov/National/FAweb/Index2002.htm` " and "`http://bea.gov/iTable/index_FA.cfm`" respectively.

A.3.3 Present Value of Depreciation Allowance (z)

To calculate the present value of depreciation deductions, we follow the double declining balance method proposed by Hall and Jorgenson (1967). To use this method, we assume that the life time of capital (assets) for tax purposes is $t_{j,i,t} = \frac{1}{\delta_{j,i,t}}$. Given this, present value of depreciation deductions can be calculated as

$$z_{j,i,t} = \frac{\frac{2}{t_{j,i,t}}}{i + \frac{2}{t_{j,i,t}}}[1 - e^{-(i+\frac{2}{t_{j,i,t}})t^{+}_{j,i,t}}] + \frac{1 - e^{-(\frac{2}{t_{j,i,t}})t^{+}_{j,i,t}}}{i(t_{j,i,t} - t^{+}_{j,i,t})}(e^{-it^{+}_{j,i,t}} - e^{-it_{j,i,t}}) \quad (22)$$

Following Gilchrist and Zakrajsek (2007), we set the nominal interest rate i to be 7 percent. The optimal switch over point $t^{+}_{j,i,t}$ which maximizes this depreciation deduction is $\frac{t_{j,i,t}}{2}$.

A.3.4 Investment Price Deflator (P^I)

We use the industry-wise data on "Investment in Private Fixed Assets" and its "Chain type Quantity Index" from the standard fixed assets tables of the BEA to construct $P^I_{j,i,t}$ in SIC and NAICS. The base year for this series is 1997.

A.3.5 Inflation Rate (π)

Following Gilchrist and Zakrajsek (2007), our constructed inflation rate is a five year moving average lagged inflation rate of the investment price deflator. So, we can write the inflation rate as

$$\pi_{j,i,t} = \frac{1}{5}\sum_{k=1}^{5} ln(\frac{P^I_{j,i,t-k-1}}{P^I_{j,i,t-k-2}}) \quad (23)$$

A.3.6 Corporate Income Tax Rate (τ_{st})

We follow Chirinko and Wilson (2008) to construct the state specific effective corporate income tax rate. This method can be summarized as follows. Since some states give tax deductions for the corporate taxes paid to the federal government while filing state corporate income taxes, the legislated state corporate income tax rate would be different the effective corporate income tax rate. The state effective tax rate can be written as

$$\tau^{ES}_{st} = \tau^{LS}_{st}(1 - d_{st}\tau^{EF}_{st}) \quad (24)$$

Similarly people get tax deductions against the corporate taxes paid to the state government while paying federal corporate income taxes. So, effective federal tax rate for the state would be different from the legislated federal corporate tax rate.

$$\tau^{EF}_{st} = \tau^{LF}_{st}(1 - \tau^{ES}_{st}) \quad (25)$$

where E=effective, L=legislated, S=state, F=federal and d= tax deductibility

Given these two equations, the effective tax rates τ^{ES}_{st} and τ^{EF}_{st} can be solved as

$$\tau^{ES}_{st} = \frac{\tau^{LS}_{st}(1 - d_{st}\tau^{LF}_{st})}{1 - d_{st}\tau^{LS}_{st}\tau^{LF}_{st}} \quad (26)$$

$$\tau^{EF}_{st} = \frac{\tau^{LF}_{st}(1 - \tau^{LS}_{st})}{1 - d_{st}\tau^{LS}_{st}\tau^{LF}_{st}} \quad (27)$$

$$\tau_{st} = \tau^{EF}_{st} + \tau^{ES}_{st} \quad (28)$$

τ_{st} is the effective corporate income tax rate for the state. We obtain τ_{st}^{LF} from the Tax Foundation.[47] The data on τ_{st}^{LS} and d_{st} are obtained from various editions of the "Book of the States" published by the Council of the State Governments. Till 2001, the Book of States publishes data on the corporate income tax rates every alternative years as of January 1st. So, we assume that if the data published is for January 1 ,1985, the corporate tax rate is applicable for year 1984 and 1985. But post 2001, the book of the states has come up with yearly publications of state level corporate income tax as of January 1st. We assume that if the data published is for January 1 ,2002, the corporate tax rate is applicable for year 2002. The national level effective tax rate is obtained by weighting each state's effective corporate tax rate by its GDP share in national GDP.

A.3.7 SGDP Deflator (P^Y)

The BEA Regional Accounts publishes data on SGDP, real SGDP (RSGDP) and quantity indices. The state-industry specific implicit price deflators are derived using these data.

A.3.8 Price of Capital (P^K)

The implicit price index for existing capital stock ($P_{j,i,t}^{K}$) is constructed using the "Current Cost Net Stock of Private Fixed Assets" and "Chain-type Quantity Index for Net Stock of Private Fixed Assets" from the BEA fixed assets tables.

A.3.9 The BEA Marginal Product of Capital (MPK_{BEA})

The marginal product of capital for industry 'j' at the national level is calculated using the following equation:

$$MPK_{BEA,t} = \alpha_{K,t}\frac{Y_t}{K_t} \tag{29}$$

where ($\alpha_{K,t} = 1 - \alpha_{L,t}$). The data is collected from the earlier discussed sources from the BEA. The growth rate in the sectoral MPK is a weighted average of the growth rates in the industrial MPK where the assigned weights are the two period average of the capital income share of industry 'j' in sector 'i'.

A.3.10 The BLS Marginal Product of Capital (MPK_{BLS})

The multi-factor productivity section of the Bureau of Labor Statistics (BLS) publishes data on the real capital input and capital income for three digit NAICS industries based on the following asset types: equipment, structures, rental residential capital, inventories and land.[48] We use this data to construct a quality adjusted growth rate of capital at the two digit NAICS industry level 'j'. The industrial growth rate in MPK_{BLS} is calculated using the following equation:

$$\widehat{MPK_{BLS}} = \hat{\alpha_K} + \hat{Y} - \hat{K} \tag{30}$$

where α_K and $\hat{Y}$ are calculated using the previously mentioned industry level data from the BEA and $\hat{K}$ is the quality adjusted growth rate of capital for industry 'j' from the BLS. The growth rate in the sectoral MPK is a weighted average of the growth rates in the industrial MPK where the assigned weights are the two period average of the capital income share of industry 'j' in sector 'i'.

---

[47] http://www.taxfoundation.org/taxdata/show/2140.html

[48] http://www.bls.gov/mfp/

A.4 Primal Measures

The primal measures of MFP growth for a sector 'i' are obtained by subtracting the share weighted growth rates in labor and real capital input from the output growth where the assigned weights are two period average of factor income share in total output. This can be illustrated using the following equation:

$$MFPG_i = \hat{Y}_i - \bar{\alpha_{K_i}}\hat{K}_i - \bar{\alpha_{L_i}}\hat{L}_i \tag{31}$$

The BEA based primal measures utilizes the persons engaged in production as the labor input and industry specific real capital stock data as capital input. The data is collected from the earlier discussed sources from the BEA. The sectoral growth rate in real capital stock is a share weighted average of industrial real capital growth where the assigned weights are two period average of capital income share of industry 'j' in sector 'i'. It can be recalled that capital income is capital share times GDP. Similarly, the sectoral output or RGDP growth rate is a share weighted average of industrial RGDP growth rates where the assigned weights are GDP share of industry 'j' in sector 'i'. Construction procedure and data sources for α_L and α_K follows from our earlier discussion in A.1.

To construct the BLS based primal measures, we use data on real capital input and capital income for five asset types: equipment, structures, rental residential capital, inventories and land. This data is available at three digit NAICS industries levels at the BLS Multi-Factor Productivity section from 1987 onwards. We utilize this data to construct a composition (quality) adjusted growth rate in real capital input at the two digit industry level. After obtaining the industrial growth rates for real capital input, we follow the exact same procedure and data from the BEA to construct the BLS based primal measures.