Green Beginnings or False Dawn: Green Jobs and Productivity Growth in the United States

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Abstract

The challenges of high unemployment and meeting climate change obligations means that the US economy will require significant restructuring in the next few years. One actively pursued strategy is the promotion of green growth achieved in part by encouraging a move to a low-carbon economy. In this paper we examine how the carefully defined share of workers that provide green goods and services in an industry has affected various aspects of the US economy in the previous ten to fifteen years. Our descriptive analysis finds that industries that are relatively green employment intensive in 2010 experienced relatively slower employment growth, slower capital structure accumulation and slower productivity growth. As part of the analysis we include green goods and services into a production function for the first time. Our regression results find significantly larger productivity effects for capital equipment in relatively green employment intensive industries in the Service sector but not in the Manufacturing sector. We also find that skill-technology complementarities exist for those industries that have a relatively greener employment structure. In the Manufacturing sector we find skill-technology complementarities for postgraduates which are larger for green employment intensive industries. In the Service sector we find skill-technology complementarities for college only graduates which are larger in green employment intensive industries. Given the considerable US investment in green growth in recent years, evidence of a double dividend of productivity growth and a cleaner environment is not particularly convincing.

JEL Keywords: Green Goods and Services; Productivity; Employment.

JEL Classifications: Q4; Q3.

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1. Introduction

In recent years green growth has increasingly been seen by policymakers as a panacea to address the problems of high unemployment, slow growth and popular concern about the environment and the global and domestic impact of climate change. Numerous academics and policymakers have proposed that the greening of the economy, coupled with technological innovation, can be a long-term driver of sustainable economic growth. As a result, many governments are trying to encourage a green recovery. For the US, examples include the United States Green Jobs Act in 2007 that pledged $125 million to establish job training programs to promote growth in green industries and the American Recovery and Reinvestment Act (ARRA) in 2009 that included provisions for new jobs in key renewable energy industries with a focus toward energy efficiency and more environmentally friendly practices. The commitment of the US government in demonstrated by the pledge by President Obama in his recent election campaign to invest $15 billion a year in renewable energy over the next decade with the aim of “…creating five million new green jobs that pay well, can’t be outsourced and help end our dependence of foreign oil”. Pollin et al. (2008) argue that a $100bn US fiscal stimulus spent on renewable energy related strategies could create 2 million jobs in directly and indirectly affects sectors. The OCED (2011) also suggest that there is significant job creation potential from investment in green activities.¹

In this paper we examine the impact of the provision of green goods and services on three key aspects of the economy for the previous ten to fifteen years: the labor market; capital accumulation; and productivity growth. Our motivation is to gain a greater understanding of the costs and benefits to the US economy from the creation of new so-called green jobs and to obtain a better grasp of how recently proposed additional green stimulus plans are likely to impact the US economy in the future. To do this we draw upon a unique dataset collected by the Bureau of Labour Statistics (BLS) in 2010 which surveys industries thought to contain workers that produce green goods and services. According to the BLS green employment accounted for 3.1 million jobs or 2.4 percent of total employment in 2010. The BLS provides us with the first well researched and carefully designed definition of a green job. This enables us to provide the first detailed study of the impact of green jobs on US productivity. Therefore, contribution of this paper is three-fold. First, we discuss how we measure economic growth taking into account green goods and services. Second, we investigate whether the provision of green goods and

¹The key initiatives related to the greening of the economy at both the state and federal level are derived from energy policy and energy efficiency (ILO 2011). Large investments in renewables (wind, solar, bio-fuels and thermal) and the energy efficiency sector (green construction and public transport) have been made by the US government in recent years. The Green Jobs Act of 2007 was “… to help address job shortages that are impairing growth in green industries, such as energy efficient buildings and construction, renewable electric power, energy efficient vehicles, and bio-fuels development.” The Green Jobs act was later extended by the ARRA.
services can be associated with positive labor and capital market growth. Third, we consider both skill complementarities and productivity effects by including green jobs into a production function for the first time.

By using the BLS green jobs sample we are able to provide the first robust evidence on the impact of the US policy on green jobs. To measure economic growth we look directly at productivity changes. We do this by using US state level output and industry level changes in gross value added. The first step is to consider recent changes in employment and capital factor inputs for industries that have a relatively high share of green goods and service provision. However, this only tells us something about factor growth. In the second stage we consider direct productivity effects by examining recent changes in state level and industry level output and correlate these with the provision of green goods and services.

Whilst it is useful to document the development of green industries it is important to examine whether these industries have improved their rates of productivity growth. Hence, we estimate a production function to see if the correlation of capital and labour inputs with productivity differs for relatively greener states and industries. Our solution is to include measures of green job intensity into the production function for the first time. We also look for potential skill-technology complementarities in production in order to identify the skill level of labour required in order to maximise economic growth from future investment in green technologies.

The results show that we are unable to confirm a positive relationship between employment growth and green intensity contrary to the findings of Pollack (2012). One of our main findings is that employment in green intensive industries actually grew more slowly on average once differences in industry size are taken into account. We also find that the accumulation of capital and economic growth was slower in relatively greener industries. Our regression analyses also reveal that in the manufacturing sector green technology is relatively less productive. However, these findings are reversed for the service sector. Finally, we find important skill-technology complementarities that differ across the manufacturing and service sectors. In manufacturing we find skill-technology complementarities for postgraduates which are larger for green intensive industries. In the service sector we find skill-technology complementarities for college only graduates which are again larger for green intensive industries. These findings highlight the importance of providing the right skills to the right sectors in order to maximise future green economic growth.
The remainder of the paper is organized as follows. The next section provides a brief background to the green jobs literature whilst section 3 describes the BLS Green Goods and Services Survey data and describes how we merged these data with other sources of data on job and productivity growth to allow us to examine correlations in the raw data which are presented in Section 4. Section 5 provides estimates from state and industry level production functions and explore potential skill-technology complementarities. The final section concludes.

2. Background

There is a considerable debate on the effectiveness of green growth policies in the US and worldwide. In this section we briefly outline the key arguments and discuss the main issues of contention with the existing literature that this paper contributes.

There is a growing literature that considers the employment consequences of expanding the proportion of renewable energy in the energy mix. For example, Kammon et al. (2004) finds that the renewable energy sector generates more jobs than the fossil fuel-based energy sector this is due in part to the fact that the renewable energy sector is more labor intensive. Wei et al. (2010) review a number of studies that estimate employment effects from the promotion of various green technology policies with generally positive results. The German Ministry of the Environment (2006) concluded that the net job effect of investments in renewables in Germany was a clear and sustainable positive employment stimulus. There have also been a limited number of studies on the job creation effect of green policies in developing countries (Barbier 2009 looks at South Korea, Schwatz et al. 2009 considers various Latin American countries, Rotovitz 2010 looks at South Africa whilst Upadhyay and Pahuja 2010 examines the case for India). See Bowen (2012) for a detailed survey of the empirical literature and Bowen and Stern (2010) for a discussion of environmental policy in the economic downturn.²

² Berek and Hoffmann (2002) assess the employment impacts of environmental and natural resource policy and suggest five basic approaches to evaluating the effect of a policy action on employment. A related literature examines the employment effects of environmental regulation. A number of studies find job losses (Henderson 1996, Khan 1997 and Greenstone 2002) whilst others find virtually no employment effects (Berman and Bui 2001, Morgenstern et al. 2002 and Cole and Elliott 2007). A further strand of the literature considers compositional labour market effects. Bird (2009) and Bird and Lawton (2009) in a UK study identify the occupations that are likely to grow as a consequence of the transition to a low carbon economy based on a detailed list of job titles that are predicted to grow in the “emerging low carbon” and “renewable energy” sectors as defined by Innovas Solutions Ltd. (2009). From this they define 15 industries which they then regroup into five key growth sectors: Utilities; Construction; Manufacturing; Retail and Wholesale; and Business and Financial Services. They then use the 2008 Labour Force Survey (LFS) to analyse the pay, gender, occupational and qualification structure of these sectors.
However, more recently Álvarez (2009) and Morriss et al. (2009) have suggested that jobs are destroyed when green jobs are created using green programs. Michaels and Murphy (2009) also question whether the net benefits outweigh the costs of the push for green jobs. Hughes (2011) argues that it is wrong to see green growth as overwhelmingly positive and that there will inevitably be productivity-enhancing investments linked to rapid technological advances and the expansion of export opportunities. Hughes (2011) makes the case for the UK that there is “…no evidence that the UK can acquire a long-term comparative advantage in the manufacture of renewable energy equipment by any combination of policies that are both feasible and affordable”.

One constant in the existing literature is that there is an issue with what represents an appropriate definition of what is a green job. An additional difficulty with comparing the results of previous papers is that, as GHK (2009) point out in their report to the European Commission, previous studies have tended to use different time periods, different sector definitions and different assumptions regarding economic growth under business as usual policies.

In the next section we describe our definition of a green job and provide some basic descriptive evidence of the patterns of green employment by state and industry in the US in 2010. Our definitions follow the BLS definitions and although little used have been employed by Pollack (2012) who documents the employment trends associated with green employment intensity. Pollack shows that relatively green industries grew faster between 2000 and 2010 and had a larger increase in the share of workers without a college degree. As we shall see in the remainder of this paper our results contrast markedly from the Pollack (2012) results for important reasons.

3. US Green Employment in 2010

In this paper the definition of a green job is taken from the Green Goods and Services Survey (GGS) which was undertaken for the first time by the Bureau of Labour Statistics in 2010. As far as we are aware only Pollack (2012) has previously used this survey. The survey measures the employment associated with the production of green goods and services from sampled establishments at the state and

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3 The Álvarez (2009) research has been widely discussed and is similar in nature to Morriss et al. (2009). Both of these unpublished papers have been criticised for not explaining what the alternative was to the investment in renewable energy which makes a study of the net effects difficult. Álvarez (2009) found that 571,138 euros invested in each green job in Spain compared to only 259,000 euros per job in the general Spanish economy. He then concludes that 2.2 jobs are not created for each green job. Morriss et al. (2009) put the figure at $107,000 per new job in the renewables sector. However, they make it clear that the definition of a green job is not clear.
industry level and made publically available by the BLS. The BLS received funding beginning in the fiscal year 2010 to collect new data on green jobs.

Central to this paper and to place this research within the broader literature is the definition of green jobs employed in this paper. As part of the data generating process the BLS reviewed a wide range of studies and consulted numerous stakeholders including Federal agencies, State labour market information offices and industry groups. What was evident was that existing classification systems (the North American Industry Classification System and the Standard Occupational Classification) do not identify a green or environmental group of occupations or industries. Hence, the BLS developed a definition that was objective and measurable and based on these previous standard classifications.

The BLS defines green goods and service jobs in the GGS data as “jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources”. These green jobs fall into one or more of five categories: (1) Energy from renewable sources; (2) Energy efficiency equipment, appliances, buildings and vehicles, and goods and services that improve the energy efficiency of buildings and the efficiency of energy storage and distribution; (3) Pollution education and removal, greenhouse gas reduction, and recycling and reuse; (4) Organic agriculture; sustainable forestry; and soil, water, and wildlife conservation; (5) Government and regulatory administration; and education, training, and advocacy related to green technologies and practices. In the GGS, green employment measures are derived by surveying a sample of approximately 120,000 worksites of businesses classified by BLS among those industry sectors producing green goods or providing green services. The final list of industries that produce green goods or services includes 333 of the 1,193 industries classified in the 2007 NAICS. The GGS State level data are available for the public and private sector. We use total employment levels.

We begin with a look at the geographical distribution of green jobs in 2010. Figure 1 shows that in 2010 California had by far the largest number of green jobs (338,445 jobs), although this is in part a consequence of its size. In Figure 2 we present the number of green jobs as a share of total employment

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4 For a detailed description of the survey see [http://www.bls.gov/ggs/ggsoverview.htm](http://www.bls.gov/ggs/ggsoverview.htm). Appendix A provides a summary of this GGS survey. The BLS also adopt a second “process” approach to measuring green jobs where these are defined as “jobs in which workers’ duties involve making their establishment’s production processes more environmentally friendly or ensuring that they use fewer natural resources”. Following Pollack (2012) we focus on the GGS data because it provides an industry breakdown which is more relevant to the issues of green intensity, employment and productivity growth than the process approach which provides an occupational breakdown.

5 The GGS only includes firms that pay unemployment insurance and therefore excludes the self-employed. Moreover, the GGS sample excludes industries in which firms generally receive less than half of their revenue from green goods or services. Hence, any green jobs in those industries are not included in the total count of 3.1 million green jobs.
and shows that Vermont that has the largest percentage of green jobs (4.4 percent) with California coming only 30th with 2.35 percent of green jobs. The State with the smallest number of green jobs is Delaware (7,978 jobs) whilst Florida has the smallest percentage (1.35 percent).

[Figure 1 about here]

It should be noted however that the green intensity of a state is a function of the industrial structure of the State in question. Hence, it is important to consider sectoral differences in green job intensity. At the industry level we use GGS data for the private sector only. Figure 3 presents the number and percentage of green jobs at the broad industry level for the private economy. Panel (a) shows that the Manufacturing sector is the largest provider of green jobs in the private economy, with 461,847 green jobs, whilst the Financial Activities sector is the smallest with only 190. Panel (b) shows that although Manufacturing has the largest number of green jobs, the Utilities sector has the largest percentage of green jobs (12%) whilst Finance has the smallest percentage of green jobs (0.002%).

[Figure 3 about here]

The GGS industry data is also available at a more disaggregated three-digit industry level. This provides us with a total of 30 industries that can be consistently matched across a number of other datasets we use in this paper. Most of the disaggregation occurs in the Manufacturing sector, but the Information sector is also disaggregated into “Publishing”, “Broadcasting & Other Services” and “Motion Picture & Sound Recording”, whilst the Transport/Warehousing sector is further split between “Transit/ground passenger transport” and “Water Transport”. Figure 4 reveals substantial variation in green intensity within Manufacturing. Construction is now largest individual source of green employment although “Transit/ground passenger transport” has by far the largest percentage of green employment (58%), followed by “Primary Metal Manufacturing” (18%), “Electrical Equipment Manufacturing” (13%). Finance remains at the bottom of the list.

[Figure 4 about here]

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6 Figure 3 is identical to Figure C in Pollack (2012). The industry descriptions can be considered to be roughly equivalent to two-digit NACE 2007 sectors. It should be noted that the fact that these figures are identical confirms that we have used the same coding method as Pollack (2012) which has the benefit of allowing us to compare results.

7 Panel (b) of Figure 3 is identical to Figure E in Pollack (2012).
In the following section we look at the relationship between green employment intensity and employment growth, capital accumulation and productivity growth.

4. Green employment intensity and employment, capital and productivity growth

4.1 Green employment intensity and employment growth

In order to assess whether those industries that can be considered to be relatively intensive in the provision of green goods and service industries have grown faster in terms of their employment levels we match the GGS industry level green intensity measures to two other sources of data that allow us to capture changes in employment over time. The first source comes from the BLS (2012) employment projections also used by Pollack (2012). The second source comes from the CPS Merged Outgoing Rotation Groups (MORG) weighted micro data. The CPS micro data is used to generate other human capital and socio-economic measures required for the productivity analysis which follows later in the paper. We focus on changes between 2000 and 2010 for two reasons. Firstly, we are interested in analysing the productivity effects of green goods and services provision which is likely to be a more recent phenomenon. Secondly, before 2000, the industries in the CPS MORG are coded using the 1990 Census definitions which are difficult to consistently concord to the NAICS 2007 definitions used in the GGS. Thirdly, restricting ourselves to these dates allows us to compare our results with Pollack (2012).

Figure 5 compares the GGS total employment (used in the denominator of the percentage shares in Figure 2) to data from the BLS (2012) and the CPS MORG data for 2010. Panels (a) and (b) show that, although not identical, the GGS and BLS (2012) employment levels are very similar. The inclusion of the self-employed in the BLS (2012) is the likely explanation for the difference. The CPS micro data are based solely on workers (not jobs) in the private sector and exclude the self-employed.

[Figure 5 about here]

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8 The BLS (2012) employment projections data are for wage and salaried workers from the BLS Current Employment Statistics survey which counts jobs, whereas self-employed, unpaid family workers, and agriculture, forestry, fishing, and hunting are from the CPS (household survey) which counts workers.

9 The CPS MORG data are for private sector employees only and weighted using personal weights.
Although the numbers are much larger in the CPS (these are weighted to be nationally representative) the industry relativities are similar which is shown in Figure 6 where we compare employment shares. We find that green intensive industries are relatively smaller, on average, and so when we draw upon both BLS (2012) and CPS employment data throughout the paper we use the appropriate employment share weights to account for differences in industry size.\textsuperscript{10}

[Figure 6 about here]

Figure 7 plots the relationship between green employment intensity and employment growth between 2000 and 2010. Panels (a), (c) and (e) use BLS (2012) annual log job growth, whilst panels (b), (d) and (f) use CPS annualised log worker growth. The regression line is estimated from the regression of the change in log employment on green employment intensity and the slopes and standard errors from these regressions are provided in the figures. In panel (a) and (b) the data plots and regressions are un-weighted, whilst panels (c) to (f) use the relevant industry employment share weights. We argue that weighting the regressions is important if we are to ascertain how relevant these employment shifts are in the aggregate.

Together panels (a) and (b) show that the green employment intensity of an industry between 2000 and 2010 is not significantly correlated with employment growth. Panels (c) and (d) show that weighting the regressions to take account of industry size implies a negative but not statistically significant correlation. In panels (e) and (f) we omit the very green intensive “Transit/Ground Passenger Service” sector (which is relatively small and accounts for 0.5 percent of total employment). The correlation between green intensity and employment growth is now negative and statistically significant for both the BLS (2012) and CPS annualised employment shifts. This result suggests that a one percentage point increase in the green intensity of an industry is associated with a 0.003 log percentage point (0.3 percent) fall in employment growth per year using the CPS sample (which counts workers and excludes the self-employed) which is equivalent to a fall of approximately 3 percent over the 10 years of this sample.\textsuperscript{11}

It is also possible to examine differences in the skill content of labour by plotting changes in the share of graduate employment over time against green employment intensity. Figure 8 shows that the most skill

\textsuperscript{10} A regression of the BLS employment share on green employment intensity gives an estimated slope parameter (standard error) of -0.0012 (0.009) and if we omit Transit/Ground Passenger Services this is -0.004* (0.002). For the CPS employment shares the corresponding correlations with green employment intensity are -0.0012 (0.0009) and -0.004* (0.002).

\textsuperscript{11} In contrast, using four-digit industry definitions Pollack (2012) finds a 0.034 percentage point increase in annual employment growth between 2000 and 2010 for every one percent increase in the green employment intensity of an industry.
intensive industries are “Educational Services” and “Professional and Technical Services”. However, the regression slope is statistically insignificant and remains so even for an un-weighted regression or if we exclude “Transit/Ground Passenger Services”. Separating out college only graduates and postgraduates makes little difference to this result. Hence, we fail to find any evidence that the change in the skill intensity of labour for any given industry is significantly different for green intensive industries relative to non-green industries.

[Figure 8 about here]

4.2. Green employment intensity and capital stock growth

In the same way as we looked for correlations between employment growth and the number of workers employed in the green goods and services provision, we can also look for correlations between green employment intensity and changes in and capital stock. To measure capital stock we draw on the National Income and Product Accounts (NIPA) fixed assets accounts data for real capital stock. These are for non-residential private fixed assets measured in millions of US dollars in 2005 prices. The NIPA provide two types of data on the capital stock. First, the capital stock incorporated into structures (this consists mainly of buildings, plant and large machinery) and second, the capital stock of total equipment (including computer software). The latter might be thought of as a measure of technological capital.

Figure 9 presents the capital-labour ratios for capital equipment and structures, ranked in descending order of green employment intensity with Trans/ground passenger transport at the top and financial activities at the bottom. The most capital intensive industry is the management of companies. This is in terms of both the stock of equipment (0.98) and structures (1.71). Figure 8 reveals that most industries are labour intensive (the capital-labour ratios are less than one). However, one can clearly see from Figure 8 that there is no obvious relationship between factor intensity and green employment intensity. We also find no evidence of capital deepening differences by green employment intensity.

[Figure 9 about here]

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12 The BLS describes this sector as “(1) establishments that hold the securities of (or other equity interests in) companies and enterprises for the purpose of owning a controlling interest or influencing management decisions or (2) establishments (except government establishments) that administer, oversee, and manage establishments of the company or enterprise and that normally undertake the strategic or organizational planning and decision making role of the company or enterprise.”

13 Regressing capital labour ratios in levels on green employment intensity provides slope parameters (standard errors) of 0.002 (0.003) for capital structures and 0.0008(0.001) for capital equipment.

14 Regressing the 2000-2010 changes in capital labour ratios on green employment intensity provides slope parameters (standard errors) of 0.0004 (0.0001) for capital structures and 0.00002(0.00003) for capital equipment.
In terms of changes in capital stock, Figure 10 plots the 2000-2010 change in capital equipment and capital structures against green employment intensity. Again the regressions are weighted using CPS employment shares. For both types of capital stock we observe a small negative relationship between green employment intensity and changes in capital stock although this negative relationship is only statistically significant for the growth in capital structures. Results dropping transit/passenger services (not shown) are more strongly negative and significant with a slope (SE) of -0.0012 (0.0006) for capital structures and -0.002 (0.0011) for capital equipment. The weighted results dropping transit/passenger services are similar.

In short then we find that green employment intensive industries grew more slowly, on average, in terms of their employment (but only if we exclude Transit/Ground Passenger Services) and capital structure inputs. We find no evidence of significantly different capital deepening or skill upgrading for these relatively greener industries. We now consider green productivity differences.

4.3. Green employment intensity and productivity growth

Having considered the relationship between green employment intensity and changes in total employment, the skilled labour provision or capital stock we are now able to progress to the main aim of the paper which is to establish whether those industries that can be considered to be relatively greener are more productive. We begin by looking at the raw correlations between green employment intensity and productivity growth at the State and three-digit industry level. For the state-level analysis we use real gross output from 1996 to 2006 made available by Chrinko and Wilson (2009). This is from a sample of manufacturing firms only. For the industry-level analyses we use gross value added (GVA) from the National Income and Product Accounts (NIPA) which are made available through the Bureau of Economic Analysis. The real output and GVA data are for non-residential private industries measured in millions of US dollars in 2005 prices.

Figure 11 presents that relationship between state level productivity growth and green employment intensity and reveals a negative, although never statistically significant, relationship regardless of whether we control for state size by weighting the data using CPS employment shares (panel b) or if we do not control for initial levels by not taking logs (panels c and d). The states with the fastest productivity
growth are the Southern States but this is largely a consequence of higher initial conditions. Indeed panels (c) and (d) show that State productivity shifts in levels (not logs) which are much larger for Texas and California, whilst at the same time these states have relatively low green employment shares (2.35 and 2.26 percent respectively).

[Figure 11 about here]

Figure 12 plots industry level changes in annual log GVA between 2000 and 2010 against green employment intensity in 2010 including “Transit/Ground Passenger Service Sector” in panel (a) and excluding this sector in panel (b), where all regressions are weighted to take account of industry size. The largest productivity growth was in “Computer and Electrical Manufacturing” which has only 3.9 percent of its workers employed in green goods and service provision. Other large growth industries are “Water Transport and Petrol/Coal Manufacturing”, where green intensity is 5.1 and 2.8 percent respectively.

[Figure 12 about here]

Panel (b) shows that the statistical significance of the relationship between economic growth and green employment intensity largely depends on the omission of the highly green “Transit/Ground Passenger Service” sector, so that a one percent increase in green employment intensity appears to result in a decrease in productivity of 0.004 log percentage points (0.4 percent) per year or 4 percent over the last 10 years. To contextualise this, the average change in productivity over the full sample of 30 industries was $3,006 million so this translates into a loss of around $120 million over this period. Overall then, green goods and services provision appears to be associated with slower economic growth although the effects are relatively small.

5. Productivity Equations

In this section we now investigate potential underlying green productivity mechanisms. Even though the productivity growth effects of green goods and service provision are negative and small and not statistically significant in the aggregate we are still interested in understanding how capital and labour inputs interact with green employment intensity to explain productivity. That is, is the correlation between factor inputs and productivity larger or smaller in green intensive sectors? We do this by
estimating production functions using panel data, again at both the state and industry level. We begin by estimating standard production functions which we then augment with the interactions between factors of production and GGS green employment intensity in 2010, as well as with measures of human capital. Output, capital stock and employment are always measured in logs so that the parameters on the factor inputs provide estimated elasticities of production.

For the state level analysis we use ten years of productivity data from 1996 to 2006 made available by Chriniko and Wilson (2009). This provides a measure for real gross output and capital stock, the original source being from the National Income and Product Accounts. We take our state level employment and human capital measures for manufacturing from the CPS. For the industry level analysis we use the NIPA productivity and capital stock data, as well as CPS employment data at the three-digit level, for the ten years between 2000 and 2010. Given we have no time variation in green employment intensity we can only interact our green employment intensity measure (job percentages for the provision of green goods and services) with the capital and labour inputs to look for direct productivity effects that differ for high/low green goods and service providers.

5.1 State Level Results

Table 1 provides the OLS and fixed effects estimates of the production function parameters for 50 states between 1996 and 2006. All the regressions are weighted using the relevant CPS employment shares. The fixed effects estimates look for within rather than between state differences and therefore sweep out any state level un-observables that remain fixed over time. Our estimates for capital and labour have the expected positive signs and in the pooled OLS specification (column 1) the elasticities sum to 0.980 roughly supporting constant returns to scale, although labour inputs are not quite statistically significant at the five percent level. The fixed effects estimates (column 2) are smaller with productivity elasticities of 0.243 on real capital stock and 0.016 on labour although both are now statistically significant. The interaction terms (column 3) shows that green employment intensity appears to be complementary to labour inputs and substitutable for capital inputs. Moreover, the negative relationship between capital in those sectors with a high green employment share and productivity is considerably larger than the positive relationship between green intensive labour and productivity. Hence, overall productivity is lower in those states that have relatively more workers employed in green goods and service provision.

15 For both the industry and state level analysis we also estimated first differences but we found evidence of serial correlation and thus estimated fixed effects models throughout to avoid misspecification biases. We also do not report GMM models for similar reasons although the results are available from the authors upon request.
and this appears to be a consequence of production substitutabilities between green labour inputs and capital stock.

[Table 1 about here]

The final two columns in Table 1 augment the state level production functions with human capital shares, distinguishing between college only graduates and postgraduates. The estimates fail to show any statistical significance for graduate employment shares until they are interacted with green employment intensity. Column (5) shows that there are significant productivity complementarities between postgraduate employment shares and green employment intensity whilst these are statistically insignificant for college only labour inputs. This is a potentially important results as it suggests that the accumulation of higher levels of human capital may be necessary if the US is to maximise productivity growth during any transition to a greener economy.

5.2 Industry Level Results

In an analogous way to the state level estimates, we now estimate production functions for our 30 industries between 2000 and 2010. All the regressions are weighted using industry value added shares and we now split the sample into the production/manufacturing sector (17 industries) and the service sector (13 industries). This split allows us to distinguish between the productivity effects for the provision of green goods separately from the provision of green services.

Table 2 provides the results for the production/manufacturing sector. The OLS specification (column 1) shows increasing returns to scale since the parameters on the factor inputs sum to 1.23. However, in the fixed effects model these parameters become statistically insignificant until they are interacted with the green intensity measure in 2010 in which case the capital equipment variable becomes positive and statistically significant. The familiar pattern observed at the state level is also there at the industry level with a capital equipment elasticity of production of 0.735 which is lower for green employment intensity by around 22 percent.

[Table 2 about here]

Columns (4) and (5) in Table 2 augment the production function with measures for human capital in the form of college only and postgraduate employment shares. Columns (4) and (5) provide the fixed
effects estimates first without the green employment intensity interactions and then including them. We can clearly see the correlation between postgraduate shares and productivity in the production/manufacturing sector although we cannot say anything here about causality. Interacting the factor inputs with green employment intensity shows no significant differences for the human capital shares. That is to say, the productivity correlation with postgraduate share is the same regardless of green employment intensity. This again supports the notion of promoting postgraduate educational attainment more generally in order to maximise future economic growth.

We now turn to our estimates for the Service sector and these are provided in Table 3. The OLS specification shows increasing returns to scale since the parameters on the factor inputs add up to 1.12. The fixed effects estimates are smaller with elasticities of production of 0.067, 0.611 and 0.042 for capital equipment, capital structures and labour inputs respectively. With services, capital equipment is statistically significant and remains so when we interact it with green employment intensity (column 3) although in the service sector the elasticity is now negative overall (-0.445) and significantly less negative for green service provision by around 7 percent. So the negative correlation between equipment inputs in productivity for relatively greener industries observed at the state level holds only for the provision of green goods and not for the provision of green services (where the correlation with green intensity is positive). Unlike in Manufacturing, the Service sector elasticity of capital structures is also significant (0.868) and this is larger for green employment intensive industries (0.155).

Finally, we look for potential skill-technology complementarities in production in the Manufacturing and Service sectors. To do this we include in the production function interactions between graduate shares and capital equipment inputs and this is done separately for college only workers and postgraduate workers. Columns (1) and (2) in Table 4 refer to the Production/Manufacturing sector and columns (3) and (4) refer to the Service sector. In column (1) the elasticity of production for capital equipment is negative (-1.106) except when it is interacted with postgraduate share (10.152). This suggests skill-technology complementarities in the Production/Manufacturing sector for postgraduates. In the Service sector the elasticity of production is statistically insignificant on capital equipment (-0.532) but and is only statistically significant when interacted with the college only share (0.962). This suggests skill-technology complementarities in the Manufacturing sector for Postgraduates whilst in the Service sector these complementarities appear to hold only for college only graduates.
Columns (2) and (4) include further interactions between the skill-capital measures and green employment intensity. Again there is some evidence of complementarities between technology and skilled labour that are larger for green employment intensive industries, but only for postgraduates. In the Service sector, there are larger skill-technology complementarities for the provision of green services for college only graduates and postgraduates.

6. Conclusions

Drawing upon new and novel survey data from the BLS we enter green goods and services employment into the production function for the first time. Our results raise a number of important questions. Our initial observation is that we find slower employment growth, capital structure accumulation and economic growth in those industries that are considered to be relatively greener or at least green employment intensive. However, we find that the results are sensitive to whether or not one takes into account industry size since green intensive industries tend to be relatively small and is part of our explanation for our results differing from Pollack (2012).

Importantly, we find that capital equipment in relatively green employment intensive industries (or green technology) has been more productive in the Service sector than in the Production/Manufacturing sector where it is relatively less productive, compared to relatively less green employment intensive industries. We also find that the capital structures in green intensive industries are relatively more productive in the Service sector but not in Production/Manufacturing.

Finally, we find evidence of important skill-technology complementarities that differ by sector. In the Production/Manufacturing sector we find skill-technology complementarities for postgraduates which are larger for green employment intensive industries. In the Service sector we find skill-technology complementarities for college only graduates which are larger in green employment intensive industries. These findings will hopefully help policy makers to assess any future quantitative opportunities of investment in green technology.
Figure 1. State Level Green Employment Levels in the GGS, 2010

Figure 2. State Level Green Employment Percentages in the GGS, 2010
Figure 3. Industry Green Employment in the GGS, 2010
(a) Green Employment
(b) Green Percentage of Employment

Figure 4. Detailed Industry Green Employment in the GGS, 2010
(a) Green Employment
(b) Green Percentage of Employment
Figure 5. BLS and CPS Employment in 2010

(a) GGS Employment (jobs)

(b) BLS (2012) Employment (jobs)

(c) CPS Employment (workers)

Figure 6. BLS and CPS Employment Shares (jobs and workers) in 2010

(a) BLS (2012) Employment Shares (jobs)

(b) CPS Employment Shares (workers)
Figure 7. Green Employment Intensity and Employment Growth 2000-2010

(a) BLS Annual Job Growth

(b) CPS Annual Log Job Growth

(c) BLS Annual Job Growth (weighted)

(d) CPS Annual Log Job Growth (weighted)

(e) BLS Average Job Growth (29 Industries)

(f) CPS Annual Log Job Growth (29 Industries)

Notes: Panels (e) and (f) exclude Transit/Ground Passenger Services.
Figure 8. Green Employment Intensity and Growth in the Graduate Share 2000-2010

![Graph showing change in annual log capital structures and equipment.](image)

Note: Using CPS 2010 Employment Shares as Weights

Slope (SE) = -0.002 (0.006)

Figure 9. Capital Intensity in 2010

(a) Capital Equipment/Labour Ratio

(b) Capital Structures/Labour Ratio

![Graph showing capital equipment and structures ratios.](image)

Figure 10. Green Employment Intensity and Growth in Capital Stock 2000-2010

(a) Capital Equipment

(b) Capital Structures

![Graph showing change in annual log capital structures and equipment.](image)

Note: Using CPS 2010 Employment Shares as Weights

Slope (SE) = -0.0004 (0.0006)

Slope (SE) = -0.0007 (0.0003)
Figure 11. Green Employment Intensity and State Productivity Growth 1996-2006

(a) Un-weighted
(b) Weighted

Figure 12. Green Employment Intensity and Industry Productivity Growth 2000-2010

(a) Full Sample
(b) Excluding Transit/Ground Passenger Transport

Notes: Panel (b) excludes Transit/Ground Passenger Services.
Table 1: State Level Pooled OLS and Fixed Effects Production Functions, 1996 to 2006.

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>Fixed Effects</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.384 (0.705)</td>
<td>2.260* (0.427)</td>
<td>2.120* (0.416)</td>
<td>2.258* (0.441)</td>
<td>1.817* (0.427)</td>
</tr>
<tr>
<td>Log(K)</td>
<td>0.902* (0.062)</td>
<td>0.243* (0.130)</td>
<td>1.221* (0.359)</td>
<td>0.244* (0.129)</td>
<td>1.313* (0.352)</td>
</tr>
<tr>
<td>Log(L)</td>
<td>0.077 (0.062)</td>
<td>0.016* (0.028)</td>
<td>-0.075* (0.028)</td>
<td>0.016* (0.011)</td>
<td>-0.103* (0.032)</td>
</tr>
<tr>
<td>College Only Share</td>
<td>-</td>
<td>-</td>
<td>0.044 (0.262)</td>
<td>-0.595 (1.046)</td>
<td></td>
</tr>
<tr>
<td>Postgraduate Share</td>
<td>-</td>
<td>-</td>
<td>0.101 (0.399)</td>
<td>-6.008* (1.477)</td>
<td></td>
</tr>
<tr>
<td>Log(K)*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>-0.390* (0.139)</td>
<td>-</td>
<td>-0.430* (0.132)</td>
</tr>
<tr>
<td>Log(L)*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>0.039* (0.011)</td>
<td>-</td>
<td>0.059* (0.013)</td>
</tr>
<tr>
<td>College Only Share*Green</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.349 (0.380)</td>
</tr>
<tr>
<td>Postgraduate Share*Green</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.610* (0.587)</td>
</tr>
<tr>
<td>Year Dummies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry Dummies</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>50 states</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Dependent variable is the log of Output. The OLS includes a full set of year dummies and clusters standard errors on industry. Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively.

Table 2: Production/Manufacturing Production Functions, 2000 to 2010.

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>Fixed Effects</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.851 (1.138)</td>
<td>10.829 (7.785)</td>
<td>10.403 (10.10)</td>
<td>8.036 (6.74)</td>
<td>11.540 (9.890)</td>
</tr>
<tr>
<td>Log(K Equipment)</td>
<td>0.874* (0.299)</td>
<td>0.442 (0.298)</td>
<td>0.735* (0.413)</td>
<td>-0.250 (0.287)</td>
<td>0.751 (0.499)</td>
</tr>
<tr>
<td>Log(K Structures)</td>
<td>-0.146 (0.154)</td>
<td>-0.149 (0.580)</td>
<td>-0.182 (0.961)</td>
<td>0.162 (0.509)</td>
<td>-0.653 (1.052)</td>
</tr>
<tr>
<td>Log(L)</td>
<td>0.360* (0.169)</td>
<td>0.353 (0.332)</td>
<td>-0.065 (0.440)</td>
<td>0.359 (0.297)</td>
<td>0.153 (0.367)</td>
</tr>
<tr>
<td>College Only Share</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.065 (1.290)</td>
<td>1.386 (2.572)</td>
</tr>
<tr>
<td>Postgraduate Share</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.183* (2.654)</td>
<td>7.773* (3.977)</td>
</tr>
<tr>
<td>Log(K equipment)*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>-0.224* (0.063)</td>
<td>-</td>
<td>-0.202* (0.075)</td>
</tr>
<tr>
<td>Log(K Structures)*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>0.047 (0.089)</td>
<td>-</td>
<td>0.108 (0.108)</td>
</tr>
<tr>
<td>Log(L)*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>0.080* (0.037)</td>
<td>-</td>
<td>0.038 (0.032)</td>
</tr>
<tr>
<td>College Only Share*Green</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.252 (0.248)</td>
</tr>
<tr>
<td>Year Dummies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry Dummies</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>17 Industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Dependent variable is the log of Output. The OLS includes a full set of year dummies and clusters standard errors on industry. Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively.
Table 3: Service Sector Production Functions, 2000 to 2010.

<table>
<thead>
<tr>
<th></th>
<th>OLS (1)</th>
<th>Fixed Effects (2)</th>
<th>Fixed Effects (3)</th>
<th>Fixed Effects (4)</th>
<th>Fixed Effects (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.445 (1.653)</td>
<td>-5.138 (3.159)</td>
<td>7.198 (3.823)</td>
<td>-4.892 (3.025)</td>
<td></td>
</tr>
<tr>
<td>Log(K Equipment)</td>
<td>0.654* (0.156)</td>
<td>-0.445* (0.145)</td>
<td>-0.438* (0.147)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(K Structures)</td>
<td>0.464* (0.199)</td>
<td>0.868* (0.268)</td>
<td>0.596* (0.267)</td>
<td>0.970* (0.292)</td>
<td></td>
</tr>
<tr>
<td>Log(L)</td>
<td>-0.005 (0.045)</td>
<td>-0.068* (0.039)</td>
<td>-0.024 (0.027)</td>
<td>-0.059 (0.042)</td>
<td></td>
</tr>
<tr>
<td>College Only Share</td>
<td>-</td>
<td>0.365 (0.277)</td>
<td>0.009 (0.329)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postgraduate Share</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(K equipment)*Green Intensity</td>
<td>-</td>
<td>0.070* (0.015)</td>
<td>-</td>
<td>0.059* (0.019)</td>
<td></td>
</tr>
<tr>
<td>Log(K Structures)*Green Intensity</td>
<td>-</td>
<td>0.155* (0.044)</td>
<td>-</td>
<td>0.139* (0.043)</td>
<td></td>
</tr>
<tr>
<td>Log(L)*Green Intensity</td>
<td>-</td>
<td>0.024 (0.016)</td>
<td>-</td>
<td>0.021 (0.016)</td>
<td></td>
</tr>
<tr>
<td>College Only Share*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.058 (0.084)</td>
<td></td>
</tr>
<tr>
<td>Postgraduate Share*Green Intensity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.264 (0.225)</td>
<td></td>
</tr>
</tbody>
</table>

Year Dummies: Yes
Industry Dummies: No
N = 17 Industries: 143

Notes: Dependent variable is the log of Output. The OLS includes a full set of year dummies and clusters standard errors on industry. Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively.

Table 4: Fixed Effects Industry Production Functions (with Skill-Capital Complementarities), 2000 to 2010.

<table>
<thead>
<tr>
<th></th>
<th>Production/Manufacturing (1)</th>
<th>Service Sector (2)</th>
<th>Service Sector (3)</th>
<th>Service Sector (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(K Equipment)</td>
<td>-1.016* (0.281)</td>
<td>-1.124* (0.276)</td>
<td>-0.532 (0.157)</td>
<td>-0.538* (0.155)</td>
</tr>
<tr>
<td>Log(K Structures)</td>
<td>-0.168 (0.403)</td>
<td>-0.220 (0.406)</td>
<td>0.618* (0.252)</td>
<td>0.946* (0.290)</td>
</tr>
<tr>
<td>Log(L)</td>
<td>0.482* (0.245)</td>
<td>0.535* (0.239)</td>
<td>-0.041 (0.025)</td>
<td>-0.038 (0.026)</td>
</tr>
<tr>
<td>College Only Share*Log(K Equipment)</td>
<td>1.050 (1.028)</td>
<td>0.002 (0.022)</td>
<td>0.962* (0.339)</td>
<td>0.933* (0.349)</td>
</tr>
<tr>
<td>Postgraduate Share*Log(K Equipment)</td>
<td>10.152* (2.348)</td>
<td>0.932* (0.045)</td>
<td>0.342 (0.380)</td>
<td>-0.167 (0.452)</td>
</tr>
<tr>
<td>College Only Share*Log(K Equipment)</td>
<td>0.002 (0.219)</td>
<td>0.018* (0.008)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Green Intensity
Year Dummies: Yes
Industry Dummies: Yes
N = 187

Notes: Dependent variable is the log of Output. The OLS includes a full set of year dummies and clusters standard errors on industry. Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively.


Deutsche Bank (2008), Economic stimulus: the case for “green” infrastructure, energy security and “green” jobs.


Employment Development Department, State of California (2010), *Green Analyses of Occupations and Industries*. 

25


UKERC (2010), Low Carbon Jobs: the evidence for net job creation from policy support for energy efficiency and renewable energy.


Appendix A: The Green Goods and Services Survey

The BLS data is derived from a sample of 333 North American Industrial Classification System (NAICS) industries that had previously been identified as potential producers or providers of green good or services. For a full list of industries see www.bls.gov/ggs.

The BLS Green Jobs Definition

A. Jobs in businesses that produce goods and provide services that benefit the environment or conserve natural resources. These goods and services are sold to customers, and include research and development, installation, and maintenance services. This definition will be used in the BLS survey of establishments in industries that produce green goods and services.

Green goods and services fall into one or more of five groups:

1. Energy from renewable sources. Electricity, heat, or fuel generated renewable sources. These energy sources include wind, biomass, geothermal, solar, ocean hydropower, and landfill gas and municipal solid waste.

2. Energy efficiency. Products and services that improve energy efficiency. Included in this group are energy-efficient equipment, appliances, buildings, and vehicles, as well as products and services that improve the energy efficiency of buildings and the efficiency of energy storage and distribution, such as Smart Grid technologies.

3. Pollution reduction and removal, greenhouse gas reduction, and recycling and reuse. These are products and services that:
   a. Reduce or eliminate the creation or release of pollutants or toxic compounds, or remove pollutants or hazardous waste from the environment.
   b. Reduce greenhouse gas emissions through methods other than renewable energy generation and energy efficiency, such as electricity generated from nuclear sources.
   c. Reduce or eliminate the creation of waste materials; collect, reuse, remanufacture, recycle, or compost waste materials or wastewater.

4. Natural resources conservation. Products and services that conserve natural resources. Included in this group are products and services related to organic agriculture and sustainable forestry; land management; soil, water, or wildlife conservation; and stormwater management.

5. Environmental compliance, education and training, and public awareness. These are products and services that:
   a. Enforce environmental regulations.
   b. Provide education and training related to green technologies and practices.
   c. Increase public awareness of environmental issues.

Sample and estimation methodology

BLS selected approximately 120,000 GGS establishments per year from the Quarterly Census of Employment and Wages (QCEW) program. A Horvitz-Thompson estimator is used to estimate GGS employment. GGS percentage estimates are relative to the QCEW employment of all industries contained within a particular estimation cell's NAICS code and not just within the 333 industries included in the GGS. Dividing the GGS estimate a 12-month average of QCEW employment gives the
GGS employment percentages. According to the BLS there is about a 90% chance that the true population of GGS employment is within 56,000 of the GGS estimate.