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# Environmental Jobs and Growth in the United States

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**Abstract**

Green growth is increasingly being seen as a means of simultaneously meeting current and future climate change obligations and reducing unemployment. This paper uses detailed industry-level data from the Bureau of Labor Statistic's Green Goods and Services survey to examine how the provision of so-called green goods and services has affected various aspects of the US economy. Our descriptive results reveal that those states and industries that were relatively green in 2010 became even greener in 2011. To investigate further we include green goods and services in a production function. The results show that between 2010 and 2011 industries that have increased their share of green employment have reduced their productivity although this negative correlation was only for the manufacture of green goods and not for the supply of green services. In further analysis we investigate skill-technology complementarities in the production of green goods and services and show that industries that increased their provision of green goods and services grew more slowly, reduced their expenditure on technology inputs and increased their demand for medium educated workers, whilst simultaneously reducing their demand for lower skilled workers.

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

JEL Classifications: Q4; Q3.

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## 1. Introduction

Green growth is increasingly being seen by policymakers as the solution to problems of high unemployment and as a way to boost economic growth following the sluggish recovery from the 2007 financial crisis.[1] Green growth has the added benefit that it provides a means for governments to meet current and future climate change obligations. Such optimism comes from the widespread belief among academics and policymakers that the greening of the economy, coupled with technological innovation, can be a long-term driver of sustainable economic growth. As a result, governments around the world are attempting to implement policies to encourage a green recovery supported by institutions such as the OECD (2011) who argue that there is significant job creation potential from investment in green activities Examples of pro-green growth policies for the US include the 2007 United States Green Jobs Act that pledged $125 million to establish job training programs to promote growth in green industries and the 2009 American Recovery and Reinvestment Act (ARRA) that included provisions for new jobs in key renewable energy industries with a focus on 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 two million jobs in directly and indirectly affected sectors. According to the Bureau of Labor Statistics (BLS), green employment accounted for 3.1 million jobs or 2.4% of total employment in 2010 and 3.4 million jobs or 2.6% of total US employment in 2011.[2]

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[1] We acknowledge that our use of the terms "green growth", "green jobs" and "greening of the economy" could be considered part of the green rhetoric used in mainstream economics. In reality there is considerable debate surrounding the legitimacy of these concepts especially among ecological economists. For example. Czech (2008) and Czech (2013) discuss the relationship between economic growth and the environment using principles of ecology such as competitive exclusion and trophic levels. Czech (2013, pg. 196) states that *""Green growth" is one of the slipperiest shibboleths in recent memory. It's an oxymoron to rival "jumbo shrimp" and "old news"*.

[2] 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). In recent years the US government has made considerable investment in renewables (wind, solar, bio-fuels and thermal) and the energy efficiency sector (green construction and public transport). 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. Appendix A provides a brief summary of recent US environmental policy. In Europe, the European Commission (2007) pointed to a change in energy policy stating in its "An energy policy for Europe" communication that "*combating climate change, limiting the EU's external vulnerability to imported hydrocarbons, and promoting growth and jobs*".

The motivation of this paper is to provide an insight into the potential impact on US growth from the creation of new so-called green jobs sectorally and geographically such that our results may inform the debate on the use of future green stimulus plans. Our analysis uses a unique dataset collected by the Bureau of Labor Statistics (BLS) in 2010 and 2011 which surveys industries thought to contain workers that produce green goods and services. Using this data we examine how changes in the provision of green goods and services across US states and industries influenced key aspects of the US economy. An important element of the survey is the care taken to accurately define what constitutes a job that provides green goods and services.[3]

More specifically, the contribution of this paper is three-fold. First, we consider recent changes in worker and capital inputs for industries that have a relatively high share of green goods and service provision. Second, we estimate a production function to examine whether productivity growth differs according to the relative greenness of an industry. Third, we use cost share equations to examine potential skill-technology complementarities in production in order to get a better understanding of the skill level of labor that is required to maximise economic growth from future investment in green technologies. It should be noted that 2010 and 2011 represent a period of sluggish growth and high unemployment in the US although this time also marks the beginnings of a nascent recovery in the housing and construction industry (following the official end of the recession in June 2009). Our results, although they have a causal dimension, should really be considered to be correlations as it is difficult to draw rigorous inference from the results given the limited time dimension.[4]

To briefly summarise our results, we find that between 2010 and 2011 relatively green intensive industries become even greener. The research closest to our own in this regard is Pollack (2012) who 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. However, as we show later, these results were largely driven by a limited number of relatively small industries. Including data for 2011 also allows us consider some rudimentary dynamics. When we included green goods and services into a production function we find that within industries there is a negative correlation between productivity growth and green employment intensity. We also find that industries that increased their technology inputs and

[3] Research of this type was most recently encouraged by Deschenes (2013) who suggests that "*More careful and detailed empirical research is needed to assess the job creation potential of green policie*s."
[4] Unfortunately, the data mean we are not been able to identify whether relative changes in output and employment are a result of predominantly supply-side or demand-side factors (e.g. technological and regulatory changes would be expected to change supply whilst fiscal stimulus on green goods and services would be expected to increase their price.

grew relatively faster overall, have at the same time grown more slowly in terms of their production of green goods and services. Our findings broadly support the results of Becker and Shadbegian (2008 and 2009) who examine environmental product manufactures (EPMs) and find that EPM establishments did not perform differently in terms of wage, employment, output and exports than non-EPM plants.[5] Finally, we find industries that were green intensive in 2010 increased the quantity of workers demanded from the middle of the skill distribution at the same time as they reduced the quantity demanded for lower skilled workers which also supports the results of Becker and Shadbegian (2008) who find that the one significant difference between EPM and non-EPM plants is fewer production workers (but not higher wages for those remaining).

The remainder of the paper is organized as follows. Section 2 provides a brief background to the broader green jobs literature. Section 3 describes the BLS Green Goods and Services Survey data and explains how we merged these data with data on employment and productivity growth to permit an examination of correlations in the raw data which are presented in Section 4. Sections 5 and 6 provide estimates for industry level production functions and potential skill-technology complementarities, respectively. The final section concludes.

## 2. Literature Review

There is considerable debate on the effectiveness of green growth policies. In this section we briefly outline the key arguments and discuss the main issues of contention with the existing literature that this paper contributes. Note that although important, our review abstracts from the wider debate on the conflict between economic growth and environmental protection with a simplistic view of technical progress often being highlighted as the way to reconcile economic growth and biodiversity conservation (Weizsäcker *et al.* 1997).[6]

[5] Environmental product manufactures in the context of this paper is defined by a US government in their 1995 Survey of Environmental Products and Services (SEPS). As quoted in Becker and Shadbegian (2009) the environmental sector is defined as "the manufacture of products, performance of services and the construction of projects used, or that potentially could be used, for measuring, preventing, limiting, of correcting damage to air, water or soil.".

[6] For a discussion of the linguistics of use terms used in the ecological literature see Czech (2008). For example, "reconcile" suggests that technological progress can "maybe lessen" the impact of economic growth on biodiversity but not reverse it (with the use of the word maybe to allow for the uncertainty). Moreover, Czech (2013) suggests replacing the word "green" in the context of this paper with "brown" so instead of "green growth" we have "brown bloating".

Hence, abstracting from the caveat raised above, at a general level there is a growing literature that considers the employment consequences of expanding the proportion of renewables in the energy mix. For example, Kammen *et al.* (2004) finds that the renewable energy sector generates more jobs than the fossil fuel-based energy sector 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 and finds generally positive results. The German Ministry of the Environment (2006) concludes 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. For example, Barbier (2009) studies South Korea, Schwartz *et al.* (2009) examine various Latin American countries, Rutovitz (2010) looks at South Africa whilst Upadhyay and Pahuja (2010) examine the case for India. Fankhauser *et al.* (2008) discusses the green jobs debate within the context of time horizons (also conceptualised by Deschenes 2013) and argues that in the short term jobs may be lost in adversely affected sectors, in the medium term there will be jobs created and destroyed and in the long-term learning-by-doing should increase labor productivity from the promotion of green technologies.[7]

Other notable studies include Bowen (2012) who provides a detailed survey of the empirical literature and Bowen and Stern (2010) who discuss environmental policy in the context of the current economic downturn. Perhaps one of the more interesting recent studies is Becker and Shadbegian (2008 and 2009) who examine the characteristics and economic performance of green industries using establishment level data and look at the performance of environmental product manufactures (EMPs). For this study they use the 1995 Survey of Environmental Products and Services linked to the Annual Survey of Manufactures and the Census of Manufactures. Interestingly, Becker and Shadbegian (2009)

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[7] 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/protection where some studies find job losses (Henderson 1996, Khan 1997 and Greenstone 2002), others find virtually no employment effects (Berman and Bui 2001, Morgenstern *et al.* 2002 and Cole and Elliott 2007) while Bezdek *et al.* (2008) look at six states in the US and find a large positive jobs effects of environmental protection. More recently, Gray *et al.* (2013) examine whether EPA regulations affect labor demand in the pulp and paper industry whilst Walker (2012) examines how environmental regulations impact labor reallocation. A further strand of the literature considers compositional labor 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 defined by Innovas Solutions Ltd. (2009). From this they define 15 industries that are then regrouped 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.

do not find any evidence that EPMs performed any better that the average non-EPM in terms of employment, output, wage or export growth. EPMs may not be as exceptional as policymakers might have us believe. They do however, find that EPMs employ fewer production workers for a given level of output and factor usage and even paid, on average lower wages.

The green growth story is not straight-forward however. Employ-RES (2009) point out that whilst certain policymakers may believe in a positive relationship between renewable energy sources and jobs, other policymakers argue that once distribution and budget effects are considered the result can even be a negative overall employment effect. Such beliefs are supported by research from Álvarez (2009) and Morriss *et al*. (2009) who suggest 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*".[8]

When evaluating the existing literature, a consistent problem that arises which is to know exactly how to precisely define a green job. This remains an open question. The problem of definition is compounded by other difficulties. 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 data and provide some basic descriptive evidence of the patterns of green employment by US state and industry for 2010 and 2011.

## 3. US Green Employment in 2011

[8] 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 was invested for 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 that was created. Morriss *et al*. (2009) put the figure at $107,000 per new job in the renewables sector. However, they point out that the definition of a green job is not clear.

We take the definition of a green job from the Green Goods and Services Survey (GGS) which was undertaken for the first time by the Bureau of Labor Statistics in 2010 and repeated again in 2011 (and then discontinued). The GGS measures the employment associated with the production of green goods and services from sampled establishments at the state and 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. It is worth adding that the standard criteria for US environmental policy is the development of green jobs coupled with improvements in the environment. However, the quality of the jobs created is also an important part of the discussion. The implicit assumption is that green jobs as a result of green investment should be good jobs which is to say they should not be low wage or dangerous jobs (ILO 2011).[9]

As part of the data generating process the BLS reviewed a wide range of studies and consulted numerous stakeholders including Federal agencies, State labor 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. Our definition of a green job follows the BLS definitions and was also used by Pollack (2012) to document the employment trends associated with green employment intensity in 2010.

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*".[10] 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 reduction and removal, greenhouse gas reduction, and recycling and reuse; (4) Organic agriculture; sustainable forestry; and

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[9] The ILO (2013) also discuss the statistical definition of employment in the environmental sector. The environmental sector is defined as all economic units that carry out environmental activities (which are those that reduce or eliminate pressures on the environment or to make more efficient use of natural resources. The activities are grouped into environmental protection and resource management.

[10] For a detailed description of the survey see http://www.bls.gov/ggs/ggsoverview.htm. Appendix B 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.

soil, water, and wildlife conservation; (5) Government and regulatory administration; and education, training, and advocacy related to green technologies and practices.[11] In the GGS, green employment measures are derived from a survey of approximately 120,000 worksites for businesses classified by BLS among those industry sectors producing green goods or providing green services. The GGS 2010 data were converted to NAICS 2012 to allow for a comparison between the 2011 and 2010 surveys. The GGS State level data are available for the public and private sectors. We use total employment levels.[12]

We acknowledge that by using the BLS definition of green goods and services jobs that we are side-stepping the complexity surrounding how best to define green jobs. This is an issue that we gave lengthy consideration. For example, should we use our own index or include or exclude various job titles or sectors. It is understood that some sectors have a large number of green jobs because there is a lot of pollution to clean up. Likewise, public transport drivers are emitting pollution when the transport the public from one place to another. We believe that by using an existing categorization from the BLS this provides a justifiable starting point for future research to take forward.

We begin with a look at the geographical distribution of green jobs in 2011. Figure 1a shows that in 2011 California had by far the largest number of green jobs (360,245 jobs), although this is in part a consequence of its size. In Figure 1b we present the number of green jobs as a share of total employment and shows that the District of Columbia has the largest percentage of green jobs (5.06 percent) with California coming only 36$^{th}$ with 2.47 percent of state-wide jobs being green jobs. In 2011 the State with the smallest number of green jobs is North Dakota (9,481 jobs) whilst Florida has the smallest percentage (1.63 percent).

[Figure 1a and Figure 1b about here]

Figure 2 shows the change in green employment and percentages between 2010 and 2011. The best fit line is from the regression of the change in green employment on green employment in 2010 and

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[11] An important report in the green job literature by Dierdorff *et al.* (2009) identifies 12 sectors as the locus for occupations that should see an increase in demand from the greening of the economy. These are renewable energy generation; transportation; energy efficiency; green construction; energy trading' energy and carbon capture; research design and consulting services; environmental protection; agriculture and forestry; manufacturing: recycling and waste reduction; and governmental and regulatory administration.

[12] 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.

the slopes and standard errors from these regressions are provided in the figures. The largest increase in employment terms has been in California (a gain of 17,366 jobs) whilst the largest fall was in Texas (a loss of 5,772 jobs). In percentage terms the largest increase was in Maryland (0.538) whilst the largest fall was in Minnesota (-0.184). Overall, Figure 2 shows that greener states have grown faster in employment terms between 2010 and 2011 since the statistically significant slope parameter (standard error) of 0.033 (0.007) shows divergence. However, panel (b) also shows that there is no such persistence for the growth in the percentage of green jobs at the state level.[13]

[Figure 2 about here]

Of course 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.[14] Panel (a) shows that the Manufacturing sector is the largest provider of green jobs in the private economy, with 507,168 green jobs, whilst the Financial Activities sector is the smallest with 475. 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 the Financial Activities sector is still the smallest with a percentage of green jobs of 0.002%.[15]

[Figure 3 about here]

Figure 4 shows that between 2010 and 2011 the industry that had the largest growth in green employment was Construction, both in absolute terms (101,932 jobs) and in percentage terms (1.88%) reflecting a nascent recovery in construction following the subprime induced housing crisis in the US where house prices fell up to 50% in some States. The Information industry lost the largest number of green jobs (3,909 jobs) although in percentage terms the loss was larger in Transport/Warehousing (-0.25%). Green jobs in manufacturing increased by 14,183 jobs (0.04%) making it the 4$^{th}$ largest growing sector in absolute terms and the 7$^{th}$ in percentage terms. Overall, at the broad industry level

[13] Note that the lines of best fit do not take into account other factors that would have impacted on growth during this period which followed the financial crisis.

[14] Figure 3 is the 2011 equivalent of Figure C in Pollack (2012) using 2010 data. The industry descriptions can be considered to be roughly equivalent to two-digit NACE 2007 sectors. Figure A1 uses the same (unrevised) 2010 data used in Pollack (2012). It should be noted that the fact that these figures are identical confirms that we have used the same coding method as Pollack (2012). It also means that the results for 2010 and 2011 are comparable.

[15] Panel (b) of Figure 3 is the 2011 equivalent to Figure E in Pollack (2012). The 2010 equivalent is provided in panel (b) of Figure 1 of Appendix C.

we see statistically significant persistence in green employment both in absolute terms and percentage terms. In aggregate, it appears therefore that the greenest industries are getting relatively greener.

[Figure 4 about here]

The GGS industry data are also available at a more disaggregated three-digit industry level. This provides us with a total of 29 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" and "Broadcasting & Other Services" whilst we lose "Motion Picture & Sound Recording" from our sample because of disclosure issues. The Transport/Warehousing sector is split between "Transit/ground passenger transport" and "Water Transport". Figure 5 reveals substantial variation in green intensity within Manufacturing. Construction is still the largest individual source of green employment although "Transit/ground passenger transport" has by far the largest percentage of green employment (55%), followed by "Transport Equipment Manufacturing" (16%) and "Utilities" (13%). Financial activity remains at the bottom of the distribution.

[Figure 5 about here]

In Figure 6 we compare the growth in the percentage of green employment between 2010 and 2011 at the more detailed industry level. The first panel (a) includes all 29 industries and here we find little evidence of persistence between green intensity in 2010 and subsequent growth in green intensity (in contrast to our findings at the broad industry level in Figure 4). However, in the second panel (b) we exclude the very green industry "Transit/ground passenger transport" which also exhibited the largest fall in green intensity (-2.16%). The finding now is for statistically significant divergence between green intensity in 2010 and subsequent growth in 2010-2011. In the main, even at a disaggregated level greener industries are getting greener.

[Figure 6 about here]

However, the divergence between relatively green industries and the others is perhaps not surprising. What is important is how the greening of an industry affects indicators of relatively performance such as employment growth, capital intensity growth and growth which we now investigate in Section 4.

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

In this section we explore whether industries that can be considered to be relatively intensive in terms of their provision of green goods and services have grown faster in terms of their factor inputs and productivity. In Figure 7 we plot the change in total employment (in logs) between 2010 and 2011 against green employment intensity in 2010. We do this for all 29 industries in panel (a) and then exclude "Transit/ground passenger transport" in panel (b). Figure 8 repeats the exercise for green employment growth (rather than total employment growth). We plot the change in the log of employment against green intensity in order to take account of persistence in our data. Hence, because we know that the initially greener industries are growing faster we might want to take account of the higher initial levels. The changes can therefore now be interpreted as proportional changes. The best fit line is from a 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. Overall, we find no evidence that greener industries grew proportionately faster than less green industries, both in terms of overall employment and in terms of green employment. Excluding "Transit/ground passenger transport" makes little difference to this result.

[Figures 7 and 8 about here]

### *4.1 Green intensity, capital stock and productivity*

Using a similar approach we can search for correlations between green employment intensity 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 provides two types of capital stock data. First, the capital incorporated within physical structures (consisting mainly of buildings, plant and large machinery) and second, the capital incorporated within a company's total equipment (including computer software). The latter can be thought of as a measure of technological capital.

Figure 9 presents the capital-labor ratios for equipment and structures separately, 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 in terms of equipment is

"Textile Product Mills" (0.57) and in terms of structures it is "Management of Companies" (0.73).[16] As expected, there is a positive correlation between equipment and structural capital.

[Figure 9 about here]

In figures 10 and 11 we examine the relationship between capital equipment and capital structures and the percentage of green employment in 2010. We find no evidence of a significant relationship between green employment intensity and changes in capital stock (capital equipment and capital structures) with and without the transit/ground passenger transport sector between 2010 and 2011 (to be consistent with the employment figures). In additional estimations, regressing capital-labor 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. Regressing the 2010-2011 changes in capital labor 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. Regressing the 2010-2011 change in capital equipment on green intensity in 2011 provides a slope (standard error) of -0.0005 (0.0007) and for capital structures this is 0.001 (0.001).

[Figure 10 and 11 about here]

Having considered the relationship between green employment intensity and changes in total employment or capital stock we are now able to progress to the next stage of the paper which is to establish whether those industries that can be considered to be relatively greener have higher productivity growth. Figure 12 plots industry changes in annual log Gross Value Added (GVA) between 2010 and 2011 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 "Water Transport" (0.229 log points) and the smallest was for "Textile Mills" (-0.113 log points). The relationship between green intensity and log productivity growth is negative but not statistically significant overall, regardless of whether we include the "Transit/Ground Passenger Service" sector.

[16] The BLS describes the management of companies 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."

[Figures 12 about here]

In short, in terms of employment we find that there is no evidence on average that green employment intensive industries grew proportionately more slowly between 2010 and 2011. We also find no evidence of significantly different capital deepening, growth in capital stock (equipment or structures) or productivity growth for the relatively greener industries. Of course, looking at the raw productivity changes fails to take into consideration the biases associated with the omission of important factors that are correlated with productivity growth and green intensity.

## 5. Estimating a green production function

In Section 5 we investigate the underlying green productivity mechanism. Even though the productivity growth effects of green goods and service provision are negative and not statistically significant in the aggregate we are still interested in understanding how capital and labor inputs interact with green employment intensity to explain productivity. We do this by estimating production functions using panel data, again for the one year change between 2010 and 2011 for our 29 industries.[17]

We use the NIPA productivity and capital stock data, as well as CPS MORG (CPS Merged Outgoing Rotation Groups) employment data at the three-digit level. We begin by estimating standard production functions which we then augment with the GGS green employment intensity. Output, our two capital stock variables, and employment are measured in logs so the parameters on the factor inputs provide estimated elasticities.[18]

The standard Cobb-Douglas production function is estimated in OLS using:

$$\ln Y_{it} = \alpha + \beta_l \ln L_{it} + \beta_k \ln K_{it} + \varepsilon_{it}$$

[17] For a summary of the how green growth more generally fits within modern growth theory (dynamic general equilibrium models) see Withagen and Smulders (2012).

[18] The CPS is the monthly household survey conducted by the BLS to measure labor force participation and employment with 50-60,000 households questioned. The Outgoing Rotation Groups simply reflects the fact that households are questioned for four months, ignored for eight months and then interviewed again for four months. It is only the final interview results that are included in the CPS MORG.

Where Y is GVA, L is labour, K is capital and ε is the error term. The subscripts *t* and *i* represent time and industries respectively. The terms α, $\beta_l$ and $\beta_k$ are the parameters to be estimated. In our estimation we augment the standard production function above by including two capital variables (structures and equipment) and our measure of green intensity. The error term will include technology differences and measurement errors and other variation in external factors. With the fixed effects estimator we include dummies for each industry.

Table 1 provides the OLS and fixed effects estimates of the production function parameters for our 29 industries between 2010 and 2011. Our dependent variable is the log of real gross value added (GVA) which we use as our measure of productivity. All the regressions are weighted using industry CPS employment shares. The OLS specification (the first column) shows increasing returns to scale since the sum of the parameters on the factor inputs are above unity. The capital equipment elasticity of production is 0.940 and the labor elasticity is 0.285 (although this value appears a little low while the capital equipment variable looks a little high they are both within acceptable ranges and similar to for example, Pavcnik 2002). The second column introduces green intensity into the production function and shows that the correlation with productivity is not statistically significant once we condition on capital and employment inputs.

The third column of Table 1 provides our fixed effects results which control for industry-level unobserved heterogeneity (for example industries may differ in how efficiently they use factor inputs). We are now estimating "within" industry changes although we acknowledge that we only have a very short time period of two years. One concern is that we now lose all the cross-sectional variation on capital and labor which could help identify coefficients.[19] This concern notwithstanding, our results show that within an industry, green intensity appears to be negatively correlated with real GVA (-0.165), although it is just outside the ten percent statistical significance level. The final two columns make a distinction between the production/manufacturing sector and the service sector. The results reveal a negative and significant within-industry correlation between real GVA and green employment intensity for the production of green goods (-0.031). However, the large standard error suggests minimal change over time. Ideally we would like to instrument for green intensity to take into account endogeneity concerns.

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[19] The "within" transformation reduces the signal to noise ratio so measurement error is more of a concern (and will bias estimates towards zero).

With acknowledgment of a number of caveats, our results suggest that the extent of employment in green goods and services is not significantly correlated with productivity although our fixed-effects results tell us that within an industry this correlation is negative for the manufacturing sector. Taken at face value with would imply that industries that increased their share of green employment reduced their productivity between 2010 and 2011 although this negative correlation was only for the manufacturing sector. Likewise, given the short time period and possible lag effects we must be careful not to place too much weight on these results.

**6. Green-Technology Complementarities**

In the final section of the paper we search for potential green-technology complementarities in production. To do this we first consider the correlation between changes in green employment and factor inputs and second, we estimate cost-share equations to investigate whether skill demand shifts between 2010 and 2011 were correlated with changes in the production of green goods and services. To measure skill demand shifts we use changes in the wage bill share by education group. Thus, we follow the standard literature on task-biased technological change and assume a Cobb-Douglas production function where the elasticity of substitution between skill groups is assumed to be unity. Autor *et al.* (2003) use, for tractability an aggregate, constant returns to scale Cobb-Douglas production function with routine and non-routine labor inputs and computer capital. The basic idea proposed by Autor *et al.* (2003) is that the falling price of information technology led to the substitution of technology capital for routine labor. As routine tasks tend to be performed in jobs situated in the middle of the job quality distribution, economies with access to information technology have witnessed decreasing employment shares in the middle of the skill distribution. Consequently, employment has polarized into high paid and low paid jobs with the consequence that inequality increases. This process become known as task-biased technological change (TBTC) first introduced by Autor *et al.* (2003) in their more refined treatment of skill biased technical change (SBTC).

In this paper we estimate how the change in the industry percentage of green employment depends upon changes in log capital equipment expenditures (our technology measure), the change in log capital expenditures on structures, the change in log GVA and controls for the 2010 shares of females (column 1) and share of females and graduates (column 2). The results from column 2 show that once we condition on other factors that are correlated with green employment growth, industries that increased their percentage of green employment between 2010 and 2011 also reduced their technology inputs by way of capital equipment (38.78 percent) and had lower productivity growth (11.38 percent). These findings are consistent with the productivity equation results in section 5. Finally, we also find that the industries that grew the most in terms of green employment tended to be male intensive in 2010. One possibility is that green jobs are less technological intensive that traditional employment in the sector.

Table 3 provides estimates from four cost-share equations where we regress the change in the wage bill share by skill group on changes in factor inputs and the change in the percentage of green employment in an industry (and the level of green employment in 2010). As we are using a Cobb-Douglas production function the sum of the changes in shares is zero (any difference from zero is simply a rounding issue). Again, we also control for the initial 2010 level of the female share of employment. The change in our technology measure (log of capital equipment expenditure) is positively correlated with the change in the demand for high school drop outs and graduates but only significant for the former. This is broadly supportive of the literature on the polarisation of skill demand shifts. The coefficients are, with the exception of high school drop outs, not quite statistically significant which we attribute to measurement error (which attenuates the parameters to zero).

We find no evidence of correlation between the change in the percentage of green employment intensity (row 1) and skill demand shifts although the largest positive change is for graduates. However, we do find that industries that had a higher percentage of green employment in 2010 (row 2) increased their demand for some college workers and reduced their demand for high school graduates and high school drop outs, though the parameters are small. This suggests a pattern of demand that differs from the polarisation of the task biased technological change literature which shows that demand shifts favour very high and very low skilled workers. In our case, it is College graduates who gain the most from the expansion of green jobs.

## 7. Conclusions

Drawing upon new and novel survey data from the BLS we include green goods and services employment into the production function for the first time. Our limited time period means that any causal inference should be taken with caution and that these results should really be considered as tentative at this stage. It should be noted that we are not testing distinct hypotheses but are more accurately providing a detailed description of a number of correlations that we find in the data. However, our results appear to raise a number of important questions. Our initial observation is that we find divergence (rather than convergence) in green employment levels and green intensity between 2010 and 2011. The relatively green states and industries are getting greener. However, it is important to note that industry size (since green intensive industries tend to be relatively small) is an important part of the story. The inclusion (or not) of the particularly green "Transit/Ground Passenger Services" sector also effects the results because, in this case, it happened to experience negative employment growth between 2010 and 2011. Future research on a longer time period would be useful for disentangling these short term macro effects from the broader picture especially when the time period in this study was a time when the US was just beginning to recover from the 2007 financial crisis.

When we looked at the relationship between productivity and green goods and services within industries, our results show green intensity to be negatively correlated with productivity growth. Between 2010 and 2011 we find productivity fell for industries that increased their production of green products (but not for those that have increased their production of green services). We also find that industries that increased their technology inputs through increased capital expenditure on equipment have also grown more slowly in terms of the production of green goods and services. Finally, we find industries that were green intensive in 2010 increased the quantity of workers demanded from the middle of the skill distribution (those with some college as their highest education level) between 2010 and 2011 and reduced their demand for lower skilled workers (those with high school diplomas and who dropped out of school). This is contrary to the effects from TBTC which predict polarisation in the form of growth in the quantity of workers demanded and the very top and bottom of the skill distribution but is a similar finding to Becker and Shadbegian (2009). Our results hint at the possibility that green employment growth could provide a solution for the displacement of medium skilled workers that can arises from TBTC, although only for those with some college education.

Ideally, we would have a longer time period of data to allow us to look more carefully at the causal influence of green goods and services employment on industry performance taking into account the endogeneity concerns. Given the emphasis being placed on green growth in its various guises, it is important that policymakers get a good understanding of the relationship between environmental action and economic performance. Our results suggest that governments cannot take it for granted that the greening of a sector will lead to higher productivity although we acknowledge that much remains to be done to better understand the complex linkages between industry performance and measures of greenness of the sector, not least in the careful classification of green goods and services employment.

Figure 1a. State Level Green Employment Levels in the GGS, 2011

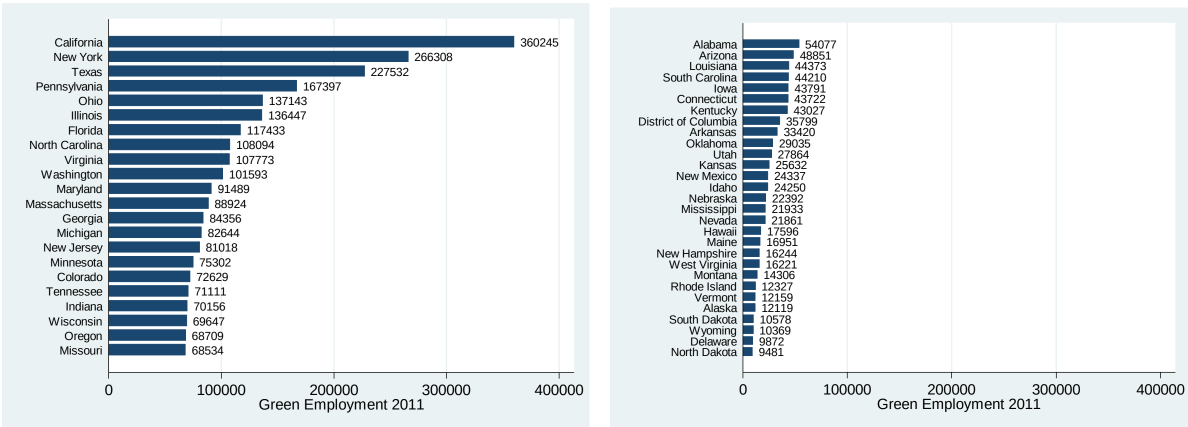



Figure 1b. State Level Green Employment Percentages in the GGS, 2011

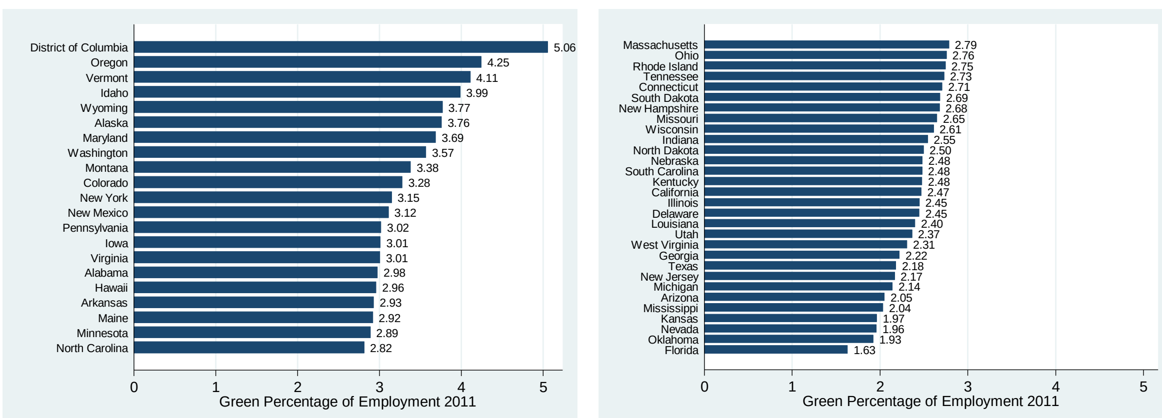
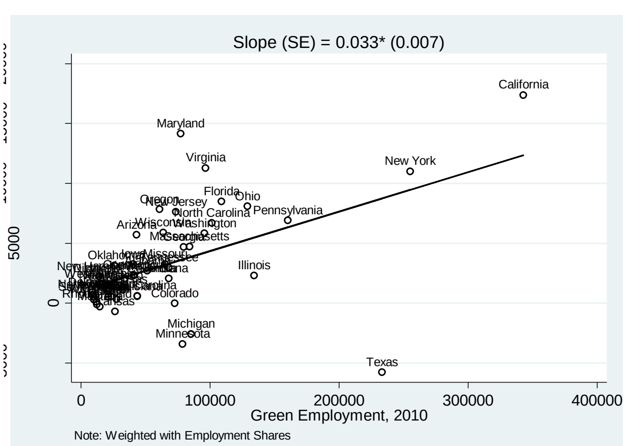



Figure 2. Growth in State Level Green Employment in the GGS, 2010-2011

(a) Green Employment




(b) Green Percentage of Employment

Figure 3. Industry Green Employment in the GGS, 2011

(a) Green Employment (b) Green Percentage of Employment

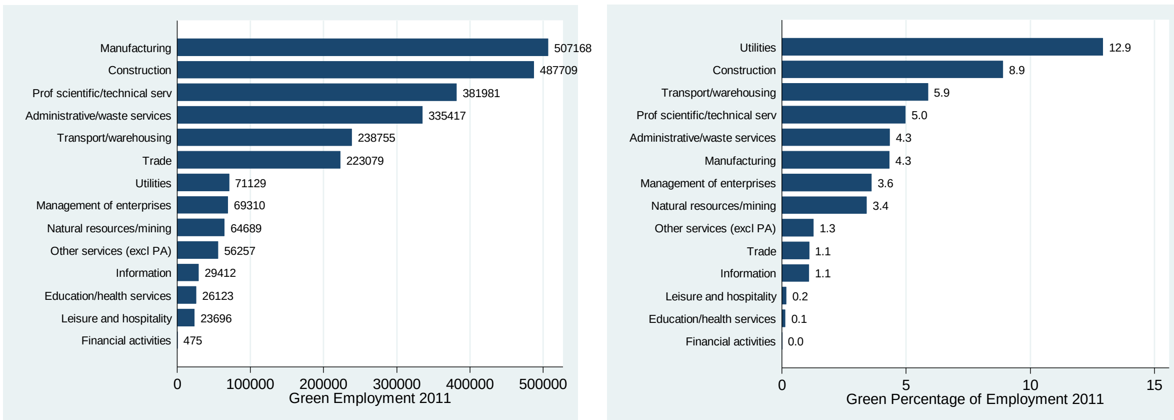



Figure 4. Growth in Industry Green Employment in the GGS, 2010-2011

(a) Green Employment (b) Green Percentage of Employment

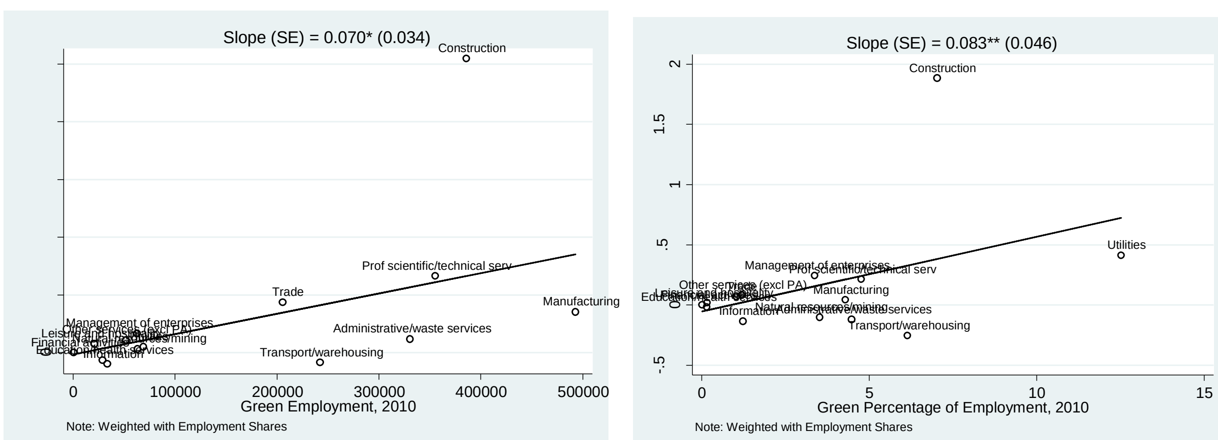


Figure 5. Detailed Industry Green Employment in the GGS, 2011

(a) Green Percentage Employment (b) Green Employment

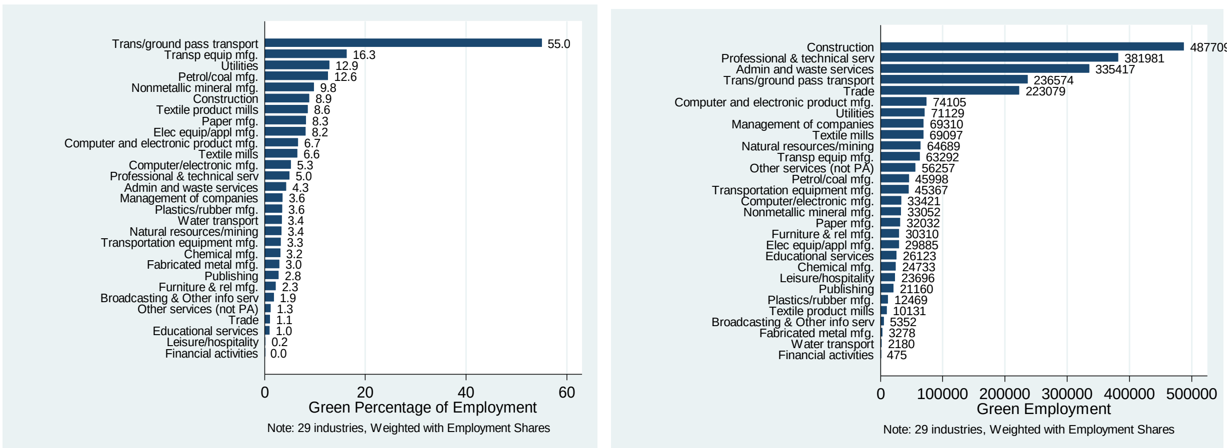



Figure 6. Green Employment Intensity in 2010 and Growth 2010-2011

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

Figure 7. Green Employment Intensity in 2010 and Log Employment Growth 2010-2011

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

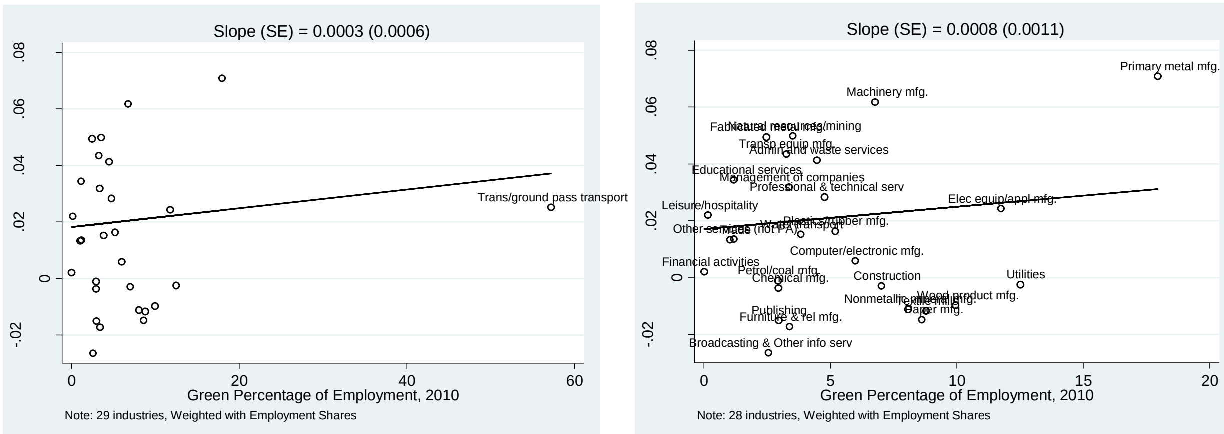



Figure 8. Green Employment Intensity in 2010 and Log Green Employment Growth 2010-2011

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

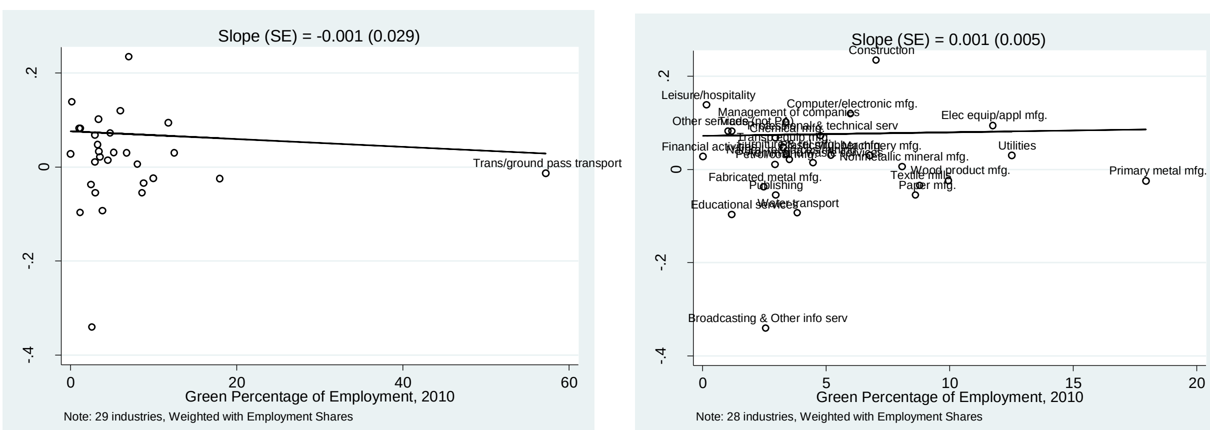


Figure 9. Capital Intensity in 2011 by sector

(a) Capital Equipment/Labor Ratio (b) Capital Structures/Labor Ratio

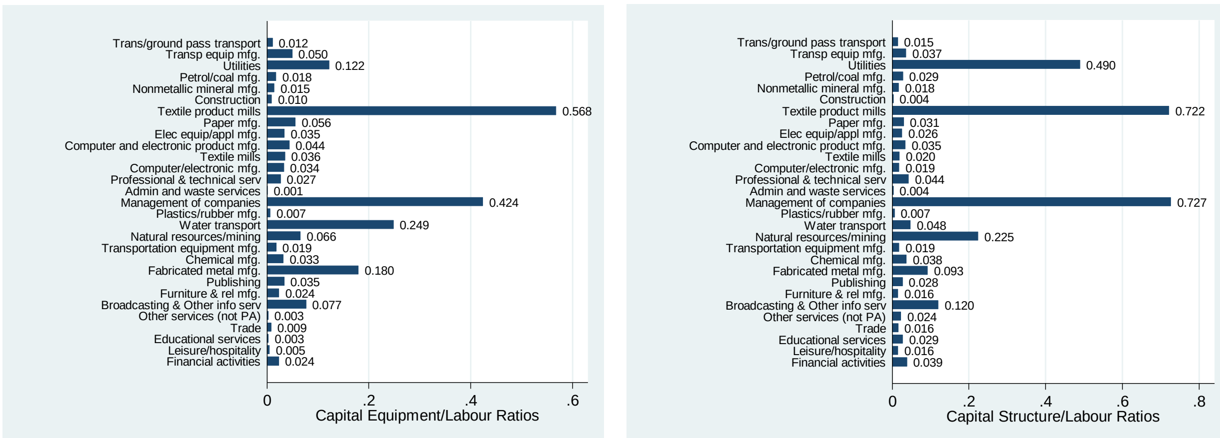



Figure 10. Green Employment Intensity and Industry Capital Equipment 2010-2011

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

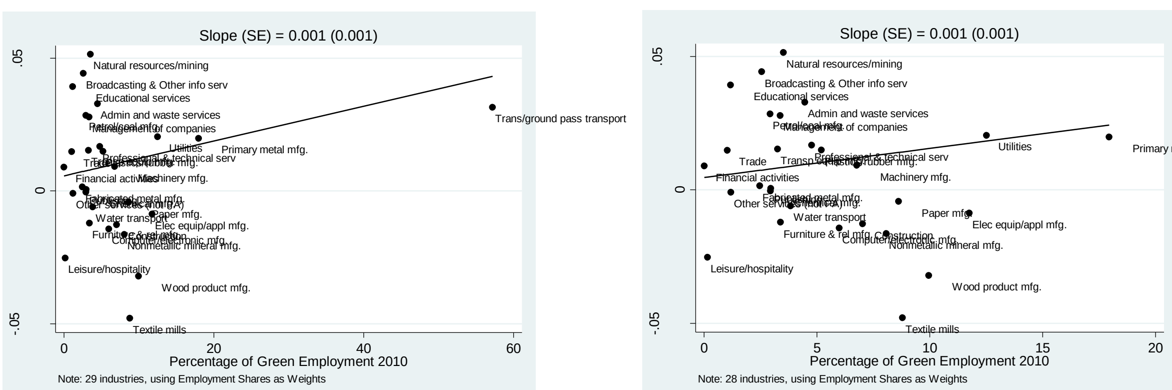


Figure 11. Green Employment Intensity and Industry Capital Equipment 2010-2011

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

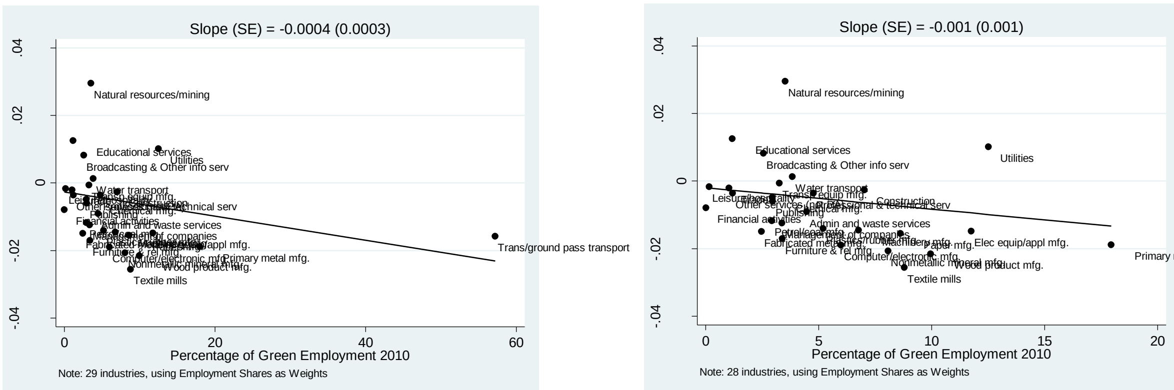



Figure 12. Green Employment Intensity and Industry Productivity Growth (GVA) 2010-2011

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

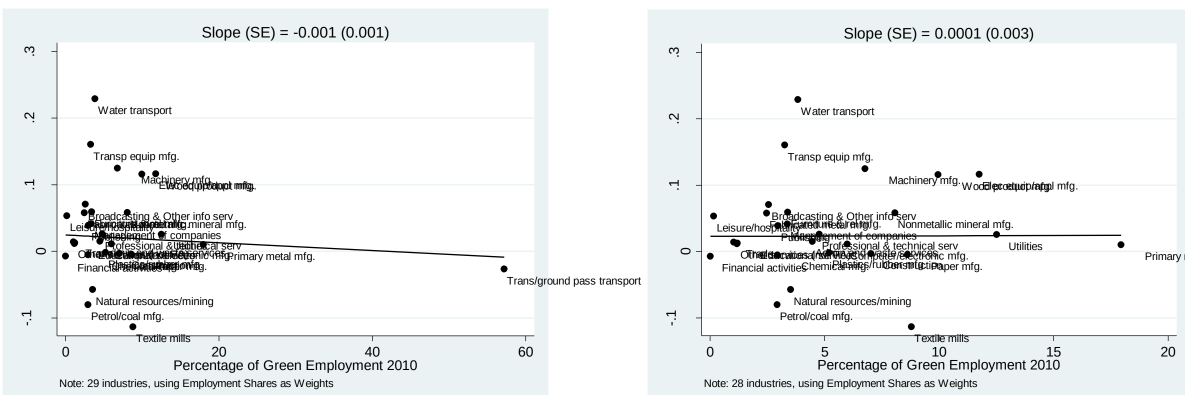


Table 1: Production Functions, 2010-2011.

| | All Sectors | | | Prod/Manufact. | Services |
|---|---|---|---|---|---|
| | OLS | | Fixed Effects | Fixed Effects | Fixed Effects |
| Intercept | -3.456* (1.012) | -3.606* (1.193) | 19.567 (14.44) | 16.210 (18.687) | -1.795 (20.368) |
| Log (K Equipment) | 0.940* (0.117) | 0.935* (0.113) | -0.748* (0.194) | -3.085* (1.150) | -0.666* (0.249) |
| Log (K Structures) | 0.052 (0.087) | 0.062 (0.095) | -0.325 (0.899) | 0.841 (1.578) | 1.754 (1.364) |
| Log (L) | 0.285* (0.070) | 0.289* (0.068) | 0.516 (0.641) | 1.678** (0.845) | 0.090 (0.559) |
| Green Intensity | - | 0.004 (0.011) | -0.165 (0.010) | -0.031** (0.157) | -0.015 (0.025) |
| Year Dummies | Yes | Yes | Yes | Yes | Yes |
| Industry Dummies | No | No | Yes | Yes | Yes |
| N = 29 Industries | 58 | 58 | 58 | 34 | 24 |

Notes: Dependent variable is the log of real gross value added (GVA). The OLS includes a full set of year dummies and standard errors clustered at the industry level. Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively. Green intensity is the green percentage in employment. Weighted using CPS employment shares.

Table 2: Green-Employment Intensity and Capital-Skill Complementarities.

| | Change in the Percentage of Green Jobs 2010-2011 | |
|---|---|---|
| Intercept | 1.268*(0.539) | 1.226*(0.478) |
| Change in Log (K Equipment) | -31.054* (13.257) | -38.781* (13.041) |
| Change in Log (K Structures) | 25.202 (31.122) | 30.349 (28.165) |
| Change in Log (GVA) | -10.72* (4.993) | -11.389* (4.481) |
| Female share in 2010 | -1.987** (0.966) | -2.471** (0.951) |
| Graduate share in 2010 | - | 1.004* (0.463) |
| N | 29 | 29 |

Notes: Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively. Weighted using CPS employment shares.

Table 3: Cost Share Equations: Skill-Capital Complementarities and Green Employment Intensity.

| | Change in the Wage Bill Skill Shares 2010-2011 | | | |
|---|---|---|---|---|
| | Graduates | Some College | High School Graduate | High School Dropout |
| Change in Percentage of Green Jobs | 0.004<br>(0.002) | -0.004<br>(0.002) | -0.001<br>(0.002) | 0.001<br>(0.001) |
| Percentage of Green Jobs in 2010 | 0.0001<br>(0.0002) | 0.0004**<br>(0.0002) | -0.0005*<br>(0.0001) | -0.0002*<br>(0.0001) |
| Change in Log (K Equipment) | 0.118<br>(0.136) | -0.209<br>(0.178) | -0.071<br>(0.094) | 0.163*<br>(0.062) |
| Change in Log (K Structures) | -0.407<br>(0.348) | 0.304<br>(0.379) | 0.269<br>(0.236) | -0.166<br>(0.113) |
| Change in Log (GVA) | -0.042<br>(0.082) | 0.069<br>(0.063) | 0.017<br>(0.079) | -0.044**<br>(0.024) |
| Female share in 2010 | 0.008<br>(0.013) | 0.008<br>(0.0128) | -0.014<br>(0.008) | -0.002<br>(0.004) |
| Intercept | -0.005<br>(0.007) | -0.002<br>(0.007) | 0.007<br>(0.004) | -0.0001<br>(0.002) |
| N | 29 | | | |

Notes: Robust standard errors are in parentheses and * and ** denote statistically significant at the 5 and 10 percent level respectively. Weighted using CPS employment shares.

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## Appendix A: US environmental policy

It is useful to outline the major elements of the US energy focussed environmental strategy. These are to regulate industry and power plant emissions, waste disposal, reducing vehicle emissions, allow for the building of new power plants and to promote renewable energy. Tax subsidies and other financial incentives for energy conservation, transportation and alternative energy development are also an important part of US policy. The latter are administered by the Department of the Treasury. Tax and subsidy programmes have been part of US environmental policy for thirty years. The 2008 legislation HR 1424: The Energy Improvement and Extension Act signed by President Bush in 2008 extended these subsidies. The total ten-year cost for these provisions is estimated by the Senate Finance Committee to be between 15-15 billion dollars between 2008 and 2016.

Environmental policy in the US is enacted primarily at the state and local level.

The most significant funding activities under the ARRA and the Energy Improvement and Extension Act include:

1. 18.7 billion for Energy Efficiency, building the Renewable Energy Industry, restructuring Transportation, and fundamental research in the sciences related to energy.
2. 13-17 billion to support incentives and tax credits related to Renewable Energy, Energy Efficiency, Housing Retrofits and other activities.
3. 4.5 billion for the Greening of Federal Buildings.
4. 600 million directly for Green Workforce Training – up to 10 billion for other economy-wide workforce investments.

There is also a direct response to developing green skills in the workforce. The ARRA contains a 60 million allocation to the US Department of Labor for education and training programmes related to the expansion of green skills through the labor force. These funds are available through a large number of channels including non-profit and government organisations as well as private companies.

**Appendix B: 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.

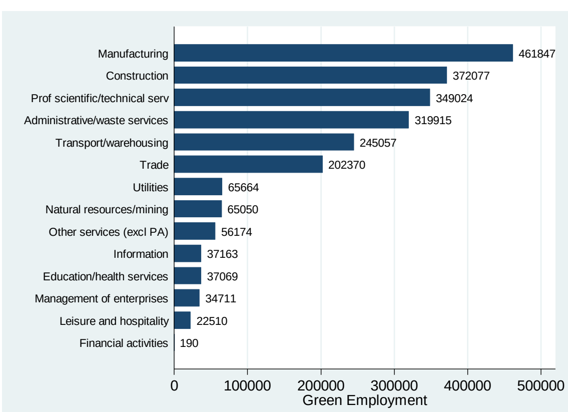
*Sample and estimation methodology*

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.

**Appendix C.**

Figure 1. Industry Green Employment in the 2010 GGS (2007 NAICS).

(a) Green Employment




(b) Green Percentage of Employment