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Renewable Energy Investment and Employment in China

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Abstract

The potential trade-off between environmental protection and employment stability has been a concern in the literature. However, in the case of China, the employment issue has not been adequately addressed despite government's big push on investing in renewable energy since 2007. This essay addresses the employment issue through estimating the relative employment impacts of renewable energy investments versus spending within the traditional fossil fuel sectors based on input-output modeling with China-specific data of sector and sub-sector weighting techniques. I find that spending within three segments of the renewable energy sectors—solar, wind and bioenergy, will produce in combination about twice as many jobs per dollar of expenditure than an equal amount of spending on fossil fuels. I also find that, more than 70% of jobs from renewable energy sectors are created in the informal economy. This raises questions about the quality of the jobs created through renewable energy investments.

Keywords: Sustainability, Renewable Energy, Job Creation, Informal Labor Markets
JEL Codes: Q56, J23, J46

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1 Introduction

In this paper, I estimate the impact on employment creation through investments in three renewable energy sectors in China, i.e. solar, wind and bioenergy. I also make comparable estimates for China's traditional fossil fuel sectors, i.e. coal, oil and natural gas.

China's big push on investing in renewable energy since 2007 implies a promising future of a greener economy in China. However, one of the concerns for building a renewable-based economy is the likelihood that a significant contraction of production within China's traditional energy sectors—i.e. coal, oil and natural gas—will lead to major employment losses in these traditional fossil fuel sectors. Such employment losses could potentially trigger further economic instability in a populous country like China. How to implement this structural change while guaranteeing a smooth transition in employment is thus highly relevant in discussing the feasibility of the renewable energy plan in case of China.

The potential trade-off between environmental protection and employment stability has been a concern in the literature regarding the economic impacts of substituting fossil fuel energy with renewable energy (Mehmet 1995; Rose and Wei 2006; Lehr et.al 2008; Moreno and Lopez 2008; Alvarez et. al 2009; Frondel et.al 2009; Pollin et. al 2009; Ragwitz et.al 2009; Mitchell 2011; Pollin et. al 2014). However, in the case of China, the employment issue has not been adequately addressed. To date, there are no reliable estimates of the employment impacts of renewable energy investments in China.

This essay addresses the employment issue through estimating the relative employment impacts of renewable energy investments versus spending within the traditional fossil fuel sectors. My estimates are based on input-output modeling with China-specific data of sectorial and sub-sectorial weighting techniques within China's input-output (I-O) model. This paper contributes to the literature in several ways. First, it focuses on the unique labor market structure of China. Second, working with China-specific data, it estimates the job creation in the renewable energy sectors as well as the traditional fossil fuel sectors, providing empirical evidence relevant to the feasibility of a transformation in China to a clean-energy based economy. Third, this study, examines employment generation in terms of formal and informal jobs within China. This enables us to also consider the issue of the quality of jobs being generated by clean energy investments, as opposed to focusing only on the quantity of jobs.

The remaining sections of the paper are organized as follows. In section 2, I present a brief overview of the existing literature regarding estimates of employment generation through investing in renewable energy sectors in China. In section 3, I introduce the input-output model. I also discuss the advantage and limitation of this methodology through comparing it with alternative approaches. In section 4, I discuss the data sources and data construction methods used for estimation. In section 5, I present the main results from my estimation exercises. Section 6 concludes the paper.

2 Literature Review

The existing employment estimates on renewable energy investment either lack a transparent methodological discussion or do not provide a clear definition of employment as a concept. They are therefore incapable of providing as a solid empirical evidence for policy discussions on building clean energy economies. Most of them, especially in the Chinese-language studies, appear in the official documents or think tanks affiliated to the government, mainly as a justification for the big push on renewable energy development. But even those have stopped appearing in the literature since 2012, exactly when the renewable energy investment plan began being implemented.

Table 1 summarizes the employment estimates of renewable energy investments in China from the recent literature. Specifically, I organize the literature as follows. Column 1 presents the methodology. Column 2 examines whether the kind of renewable energy technologies (i.e. wind, solar, or bioenergy) is specified in their employment estimates. Column 3 examines whether employment estimates are specified as formal or informal employment. Here formal employments refer to those jobs with regular working hours and benefits and are protected under state labor laws. By contrast, informal employment refers to jobs outside the formal economy, with low pay, little job security, few or no benefits, and no legal protection. The specification between formal and informal employment is crucial because although they can be treated equivalently in the quantitative sense, one job in the informal economy implies significantly lower job quality relative to one created in the formal sector. Column 4 examines whether employment estimates are identified as direct or indirect jobs. Direct jobs refer to the core activities in the energy sectors whereas indirect jobs refer to those jobs generated through the supply chains associated with renewable energy production. Distinguishing direct and indirect jobs helps to specify the composition of the employment opportunities in the renewable energy sectors. Column 5 presents information on the relative spending level for the employment estimates available in the examined studies. Column 6 categorizes the employment estimates in terms of stocks or flows and the last column shows the employment estimates.

[TABLE 1 BELONGS HERE]

A brief overview of the table shows a wide range of estimates over various time spans with no consistent methodology or definition for any systematic comparison. In terms of the methodology, almost half the studies do not specify their estimation base (CREIA 2009; China's 12th Five Year Plan 2011; CCICED 2011; NDRC 2012). Some studies resort to qualitative methods such as interviews or literature surveys (UNEP et.al 2008; IRENA 2011; REN21 2013). Only two studies discuss the quantitative methods they use and the relevant assumptions (CASS 2010; Greenpeace 2012) that are too general for a specific estimation of the China case.[1]

Most studies in this literature survey have specified the employment generation among wind, solar, and bioenergy sectors. However, it is still impossible to make comparisons among these estimates, as some studies focus only on one sector of their interest (Greenpeace 2012; NDRC 2012), yet others produce estimates for a combination of the three sectors as a whole (UNEP et.al 2008; REN21 2013) without fully specifying the employment estimates for each sector.

Regarding the definition of employment, not a single study in this literature survey discusses its employment estimates for the Chinese case in terms of formal and informal employment categorizing, although the importance of an "inclusive green economy" has been recognized in the existing literature (Smit and Musango 2015). Only two studies (CASS 2010; REN21 2013) specify the employment estimates regarding direct or indirect jobs, despite a slight difference in the definition used in this paper.[2]

Almost half the studies do not specify the spending level with respect to the employment estimates, making it difficult to estimate how much employment is generated relative to certain spending level for each renewable energy sector. Finally, the use of stocks or flows for employment estimation is also inconsistent among the existing literature, making it hard to undertake direct comparisons.

In general, the existing studies have not provided any serious estimates for employment generation through renewable energy investment in China. They do not provide either a clear methodology for estimation or even a clear concept of the term "employment." It is therefore reasonable to conclude that, to date, there are no reliable estimates of the employment impacts of renewable energy investments in China, or any relative employment effects of renewable energy investments versus spending within the traditional fossil fuel sectors.

3 Methodology

3.1 Input-output model

This paper mainly builds on the Input-Output (I-O) model to estimate the employment impacts of renewable energy investment in China as is used in many case studies for other countries (Neuwahl et.al 2008; Pollin et.al 2009; Simas and Pacca 2014). A typical I-O model records detailed information on the supply and demand relationships between various industrial sectors and distinct categories of final demand in the economy.

[1] CASS (2010) uses the Input-Output model (I-O) at a very aggregated level. Multipliers are calculated for the interactions among only three sectors: agricultural, industrial and service sector (p 86-7). The calculations by Greenpeace (2012) are based on the assumptions that "for every new megawatt of capacity installed in a country in a given year, 14 person/years of employment is created through manufacturing, component supply, wind farm development, construction, and transportation" and "0.33 person/years" necessary "for operations and maintenance work at existing wind farms". Although this might be useful as a first approximation for a global estimate, they are incapable by nature to estimate the employment-output ratios for individual renewable energy sectors, and for specific countries.

[2] Note that definition of direct and indirect jobs in REN21 (2013) is slightly different from this paper whereas the former does not include R&D jobs as direct jobs.

A more detailed discussion of the I-O model and its methodological limitation is presented in the Appendix.

One challenge in using an I-O model is that these renewable energy sector activities are not as yet specified into distinct industrial sectors, such as "solar energy sector" or "wind energy sector." To solve this issue, I use information on the cost components of such investment from the existing literature and then use the existing sectors within the I-O model to construct a new renewable energy sector based on the weighting structure that reflects such cost composition.

The first step in the estimation is to calculate the output/investment ratio (O/I ratio), meaning how much change in output will be induced by a change in the investment level.[3] The second step is to calculate the employment/ output ratio (E/O ratio), which indicates how much employment is required to produce a certain output level of renewable energy goods. Assuming a linear model, the multiplication result of the row vector E/O and the matrix O/I implies the E/I ratio, suggests the total employment generation from investment in the renewable energy goods.

4 Data Construction and Discussion

4.1 Input-output data

Starting from 1987, the Chinese Statistics Bureau published the Input-Output Table of China every five years, with the most recent one in 2007.[4] This 2007 I-O table is the most detailed table since 1987, providing information on the 135-industry level basis.[5] A more recent I-O table would be preferable for more accurate prediction of employment generation but it is not available at the time when this paper is written. A 2010 I-O table is available at 54-sector, yet I choose the 2007 I-O table for its details that are most critical for the estimation. Data limitation issue will be addressed and compensated by discussion of productivity change in section 5.4.[6]

4.2 Importance of separating the formal and the informal sector employment

There are three main reasons to separate the formal and informal sectors in the discussion of employment impacts of investing in renewable energy.

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3 This O/I ratio corresponds to the Leontief inverse coefficient, generated through matrix manipulation on the raw I/O data.

4 The 2012 I-O table was not published by the time this paper is written.

5 The 135 sectors include five agricultural sectors; five mining sectors; 81 manufacturing sectors; three utilities sectors; one construction sector; nine transportation, storage and postal services sectors; three communication sectors, one retail sector, two hotel and restaurant sector, two finance sectors, one housing sector, and 22 other services sectors.

6 Lindner et.al (2012;2013) developed a rigid method to disaggregate the electricity production, heat and water distribution and supply sector (EPHWD) in the I-O table. This enables them to expand a 42 by 42 table from the World Input-Output Database (WIOD) to a 50 by 50 table. However in this paper, I focus on the employment impacts in the initial stage of building green economy: the research & development as well as production phases. Therefore I do not include this EPHWD supply in the weighting structure. Also the table I start with has 135 sectors, more detailed breakdown compare with the tables from WIOD. The results will not be affected if I disaggregate the sector in my calculation.

First, employment opportunities within the formal economy differ significantly from those in the informal economy in terms of job quality, even in the same industrial sector. Table 2 shows the average annual wage comparison between the urban unit employees (or the formal sector employees) and the rural migrant workers who constitute the majority of the urban informal economy. As we can see, the wage for the rural migrant workers are no more than just 60 percent of the pay received by regular urban labors, and this pattern has not changed at all since 2004. In addition to the gap in wage compensation, workers in the informal economy usually work over time while receiving little job security.[7]

[TABLE 2 BELONGS HERE]

Second, focus on the formal sector employment will leave out the entire employment population in the rural sector, which constitutes the preponderance of employment generated by investing in bioenergy.

Third, it is important to note the possibility that a rise in final demand might not increase employment in the informal economy as much as in the formal economy. This is especially relevant to those self-employed who would work more to address the rising demand instead of hiring more employees. It could also apply to others working in the informal economy that are underemployed to some extent and would be willing to work more hours to receive higher earnings instead of having their employers hire another worker.

4.3 Employment data: formal sector employment

The 2007 employment data are compiled from Table 3-1 in the 2008 China Labor Statistical Yearbook on a 90-industry level basis. The only employment data available at this level of detail are for the urban unit employment (*danwei jiuye renyuan*, 单位就业人员), a concept different from urban employment (*chengzhen jiuye renyuan*，城镇就业人员).[8] Two major groups of population are excluded from the statistical definition of urban unit employment: first, the entire employment population in the rural sector, which was about 62 percent of the total national employment in 2007 and 52 percent in 2012; second, those working in the urban sector but in the private enterprises, or as self-employed or simply unregistered in the national statistics.[9] This population was 22 percent or 28 percent of the entire employment population across for year 2007 or 2012

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[7] See *National report on rural migrant workers in 2013*, published on May 12th, 2013 and retrieved on October 5, 2014. See http://www.stats.gov.cn/tjsj/zxfb/201405/t20140512_551585.html.

[8] Note that according to the statistical definition available from the China Bureau of Statistics, those who work in the Township and Village Enterprises (*xiangzhen qiye*，乡镇企业) are counted as rural employment, therefore not included in urban employment from Table 3-1. The urban and rural division here is in the administrative sense, unrelated to the household registration status of the worker.

[9] The percentage estimation is calculated based on Table 1-1 from the 2008 and 2013 China Labor Statistical Yearbook.

respectively.[10]

Compared to urban employment data, urban unit employment data are more strictly defined in the sense that they only include employment in three types of officially registered enterprises, or units (*danwei*,单位). They are the state-owned units (*guoyou danwei*, 国有单位), urban collectively-owned units (*chengzhen jiti*, 城镇集体), and other ownership units (i.e. mixed ownership, or enterprises funded by foreign investment, or by investments from Hong Kong, Macau, and Taiwan).[11] This type of employment is often associated with regular wage, normal working hours, standard benefits and job security, thus providing the best available estimates for urban formal sector employment in China.

Table 3 presents the relationships among these statistical concepts for years 2007 and 2012. As is shown, the urban unit employment (or formal sector employment), which aggregates employment from the three types of units, represents about 41 percent of total urban employment, and this percentage does not change significantly from the 2007 data used in this paper to the latest available employment data in 2012.

[TABLE 3 BELONGS HERE]

4.4 Employment data: informal sector employment

In this paper, employment in the informal sector refers to those working in the urban sector yet either employed by the small and medium private enterprises, or as self-employed, or not formally counted by the national statistics. Table 3 shows that the share of urban informal employment as of total urban employment (about 59 percent) is relatively stable from 2007 to 2012.

The concept of private enterprises here does not imply all nongovernment enterprises as in the US context; they are instead defined as enterprises owned by "natural persons" (*ziranren,* 自然人), therefore do not include "limited liability corporations" or "share-holding corporations limited" that have corporate "legal person" (*fa ren,* 法人) status (Huang 2009). They are mostly small businesses. In 2012, there were a total of 10.9 million such enterprises registered with a total of 113 million workers (including those registered in both urban and rural areas thus the number is greater than 75.6 million in the urban private enterprises presented in Table 1), making for an average of only 10 workers per enterprises, including the employers of such enterprises. The average number for 2007 is 13 workers per enterprise, suggesting that the size of the urban private enterprises has a declining trend.[12] Workers in such small-scale enterprises usually enjoy little benefits or job security or labor law protection (Huang 2009). Although informal employment usually includes those working in micro-enterprises according to

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[10] Ibid.

[11] State-holding enterprises refer to those mixed-ownership enterprises where the government has a larger share of the equity capital than any other shareholder. See "Explanatory Notes on Main Statistical Indicators" in the China Labor Statistical Yearbook.

[12] China Statistical Yearbook (2008) and (2013)

Organization for Economic Cooperation and Development (OECD), an enterprise of average size of 10 people cannot be counted as micro enterprises (which strictly require number of employees as no more than 10 people, instead of on average) based on the European Commission standard (Jutting et. al 2008). However, in this paper, I still include this category based on a consensus in the literature on Chinese informal economy.

The self-employed persons (e.g. small-shop and stall owners, artisans and apprentices, proprietors of small eateries and food stalls, repair shop owners, etc) represent about 86.3 million over 41 million entities, making for an average of 2.1 employed persons per entity—usually the person registered together with a relative or friend. This number does not change much from 2007 with about 2 employed persons per entity.[13] Not surprisingly this group of people do not enjoy benefits and job security (Huang 2009).

Finally, there are about 90 million unregistered urban informal employees (recorded as “not formally counted” in Table 3), who are working as domestic helps, delivery workers, street vendors, and the like, with even lower levels of job security (Huang 2009).

The three main groups of the urban informal economy (private enterprises, the self-employed, and the unregistered) add up to a composite picture of low pay, little job security, few or no benefits, and no protection under state labor laws. These characteristics are consistent with the features of informal economy defined by the International Labor Organization (ILO).[14]

4.5 Constructing employment-output (E/O) ratios for the informal sector

Constructing the employment data for the informal economy mainly rely on three sources. First, I refer to the employment data on the three strata of the economy (i.e. primary, secondary and tertiary).[15] Second, I use the employment data on the urban private enterprises and self-employment for seven industrial sectors.[16] Third, I also use the urban employment composition in Table 3 as a reference to disaggregate employment for industrial sectors that only have very high level of aggregation.

Constructing informal employment data for agricultural-related sectors is straightforward. The three strata data provides the total employment of agricultural-related activities. When this data is subtracted by the formal employment in agricultural-related activities we used for calculating the formal employment-output ratio, then we will have the informal employment data for the five aggregated-related sectors

13 Ibid.
14 See http://ilo.org/global/topics/employment-promotion/informal-economy/lang--en/index.htm.
15 See Table 4-4 from China Statistical Yearbook (2008). The primary industry includes agriculture, forestry, animal husbandry and fishery; Secondary industry includes mining, manufacturing, power sector and construction sector; Tertiary industry includes everything else.
16 See Table 4-13 from China Statistical Yearbook (2008). The seven industrial sectors are manufacturing; construction; transport, storage &post; wholesale and retail trades; hotel and catering services; leasing and business services; services to households and other services.

including cropping, forestry, animal husbandry, fishery and service sector related to the these four sectors. To get an average informal employment-output ratio for the five agricultural-related sectors, we divide the total informal employment by the aggregated gross output for these five sectors.

Constructing informal employment for non-agricultural sectors are more complicated. In order to take advantage of all the available information regarding Chinese informal economy, I break down the calculation of informal employment into two categories: the group of people working in private enterprises or as self-employed (P&S), as well as the group of those not formally counted.

For those working in the P&S, data are available for only seven sectors of high level of aggregation, amounting to 70 million in total. They are manufacturing; construction; transport, storage &post; wholesale and retail trades; hotel and catering services; leasing and business services; services to households and other services. The difference between the 70 million and the 78.9 million (see Table 3) of total employment in the P&S is the P&S employment for the remaining sectors in addition to the seven sectors, or 98 sectors by the details of aggregation as in the I-O model by 135 sectors. Then these 8.9 million workers are allocated to the remaining 22 non-agricultural sectors in the I-O model according to the formal employment composition in these 22 sectors.[17] Thus we have the informal employment for all the non-agricultural sectors.

The second category of workers who are not formally counted in the national statistics amounts to 94.4 million in total (Table 3). They are allocated to the 130 non-agricultural sectors according to the composition of P&S employment in those 130 sectors calculated from the previous step.[18] The two categories of workers constitute the whole urban informal economy this paper focuses on estimating. Dividing this employment estimate by the gross output for each of the 130 sectors will give the informal employment-output ratio for these sectors.

4.6 Weighting the energy sectors

This section focuses on estimating the cost components of three kinds of renewable energy, namely, solar power, wind energy and bioenergy, as well as the fossil fuel energy sectors.[19] Table 4 presents the aggregated information on their respective weighting structures.

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[17] This allocation method assumes relatively similar formal and informal employment ratio in different sectors. Although the assumption might not hold for certain sectors, this is the best available method given the data limitation in the Chinese informal economy. 22 is the result of subtracting 135 sectors by the 5 agricultural-related sectors and the 98 sectors with data available on the private enterprises.

[18] This allocation method assumes relatively stable ratio between those not formally counted in the national statistics and those counted as working for private enterprises or as self-employment in all the non-agricultural sectors. Although this assumption might still not hold for certain sectors, it is a more realistic assumption than the one I use for allocating the employment group of private enterprises and the self-employed. And again, this is the best available method given the limited information on the Chinese informal economy.

[19] This paper focuses on the employment effects of solar PV, on-shore wind and low-emission bioenergy. They are chosen based on their relatively significant employment impacts. See more details in the author's dissertation.

4.6.1 Solar PV

According to the IRENA (2012a) definition, the PV module cost is determined by raw material costs, notably silicon prices, cell processing/manufacturing and module assembly costs. The BOS cost includes the cost of the structural system (e.g. structural installation, racks, site preparation and other attachments), the electrical system costs (e.g. the inverter, transformer, wiring and other electrical installation costs) and the battery or other storage system cost in the case of off- grid applications (p 15).[20] Since the average selling price of solar PV modules has already converged among nations including China, the cost structure among countries should not vary significant.[21] The real cost differences between countries lie in the installation costs. Therefore I construct the weighting structure for solar energy with China-specific information on the installation costs.[22]

4.6.2 Wind

Wind energy in China consists of two main categories: onshore and offshore wind power. According to IRENA (2013), offshore wind power installation usually has a much higher construction cost share than the onshore wind power installation (25 percent versus 10 percent). However, since offshore wind power constitutes less than 1 percent of the total installed wind power in China, the analysis in this paper will focus on the onshore wind power case.[23]

I use the world average statistics on wind energy structure from IRENA (2012b) and IRENA (2013) to work out the China's specific cost structure through combining the information on China's total installed costs of on-shore wind energy.[24]

4.6.3 Bioenergy

For the purpose of estimating meaningful employment opportunities, this paper focuses the estimation for biofuel.[25]

The costs for generating bioenergy power include three critical components (IRENA 2013). The first part occurs in the process of growing biomass feedstocks. Feedstock cost usually represents 40 percent to 50 percent of the total cost of electricity produced by biomass technologies, varying by the transportation costs, labor costs involved and the quality of the biomass sources (IRENA 2013, p66). Prices for the biomass sources range

[20] Note that the use of BOS is slightly different in IRENA (2013, p51), where BOS are used to refer all costs excluding both the module costs and the installation costs. Here we still use BOS as including the installation costs for convenience.

[21] Solarbuzz November 30, 2012: Installed PV system continue to exhibit strong global variations. http://www.solarbuzz.com/resources/analyst-insights/installed-pv-system-costs-continue-to-exhibit-strong-global-variations

[22] See more about the calculation of weighting structure in the author's dissertation.

[23] See China unable to achieve 5GW offshore wind goal by 2015 (http://www.windpowermonthly.com/article/1187293/analysis---china-unable-achieve-5gw-offshore-wind-goal-2015) & China National Renewable Energy Center.

[24] See details in the author's dissertation.

[25] Ibid.

between USD 10/tonne to USD 160/tonne (IRENA 2013, p67).

The second cost component arises when biomass feedstocks are transformed into the energy form that will be used to generate heat and/or electricity, or in most cases, when biomass is transformed into biofuel. This includes the cost for the equipment (prime mover and fuel conversion system), fuel handling and preparation machinery.

The last cost component is generated during the use of power generation technologies, including engineering, construction and planning costs. It also includes grid connection, roads and new infrastructure required for the project (IRENA 2013, p68). For non-OECD countries, such costs are estimated to be in the range of USD 600 to USD 1400/kW (IRENA 2013,p68).

Based on the statistics for some non-OECD countries, I use an average of the costs to represent the cost breakdown for China.[26]

4.7 Traditional fossil fuel sectors

4.7.1 Coal

UNEP et. al (2008) found that modern coal-fired power plants are becoming much less labor-intensive than a decade ago. However, developing countries are still lagging behind advanced nations in applying the technology to reduce the labor-intensiveness in the coal sector.

The coal sector in China distinguishes itself in its heavily weighted component of transportation costs. Since most coal mining activities are conducted in the western and northern part of China while major coal demand occurs in the eastern and southern part of China, coal transportation cost usually makes up about 55 percent to 60 percent of the consumer-end electricity costs (Mao et. al 2008). In addition to the transportation costs, coal-fired energy production costs include production costs on the coal-mining sites as well as the actual electricity generation costs occurred in the coal-fired power plant. Xie et.al (2011) show that 88 percent of the coal-fired power generation costs come from the coal products (including the mining, processing and transportation) and the rest (i.e. electricity distribution and other related services) only constitute 12 percent.[27]

4.7.2 Oil/Natural Gas

The reason to combine oil and natural gas in the same industry, although they have a slight difference in their cost structure to produce energy, is that they are also combined in the input-output table. The process of using oil/natural gas to produce energy mainly depends on activities in mining, transportation, refining and chemical product manufacturing, as well as management-level activities (Cui et.al 2008). The weighting structure presented in Table 4 is based on two case studies from Bing et.al (2008).[28]

[26] Ibid.
[27] Ibid.
[28] Ibid.

[TABLE 4 BELONGS HERE]

5 Results and discussion

5.1 Employment generation per million of USD

Table 5 and Table 6 present the results in terms of job created per $1 million USD spent in both renewable energy and fossil fuel sectors.

As we can see (Table 5), the bioenergy sector generates highest number of jobs with a given amount of spending level, with 224 direct jobs per $1 million. This contrasts with a range of about 27-29 for solar and wind energy due to the significant amount of agricultural-related activities involved in bioenergy production. It is also significantly higher than the direct jobs generation in the fossil fuel sectors, with range between 30 to 70 jobs per $1 million. In terms of indirect jobs—those jobs generated through the supply chains associated with renewable energy production—the three kinds of renewable energy sectors show relatively consistent estimates, about 60-70 jobs per $1 million. This is substantially higher than the fossil fuel sectors with range between 40 to 50 jobs per $1 million.

[TABLE 5 BELONGS HERE]

If equal weights are assigned across the three renewable energy sectors and the two fossil fuel sectors respectively, then results suggest that spending $1 million on renewable energy generates about 162.3 jobs, including 93.1 direct and 69.2 indirect jobs on average. This contrasts with only 96.7 jobs, including 49.5 direct and 47.1 indirect jobs, generated from $1 million overall spending on both coal and oil/gas.

The results suggest that, for China, spending on the clean energy economy (with a combination of the three kinds of renewable energy focused in this paper) will produce nearly 70 percent more jobs per dollar of expenditure than an equal amount of spending on fossil fuels. Thus a clean energy investment strategy will not destabilize the overall employment level in China relative to the investment strategy biased towards the fossil fuel energy sectors.

5.2 Composition of Employment

Table 6 presents the composition of employment in terms of formal and informal employment. As we can see, the bioenergy sector is constituted mostly (261 jobs or 90 percent of jobs) by employment in the informal economy. Those are the people growing or logging for bioenergy feedstock, as well as workers engaged in manufacturing equipment and machinery to transform feedstocks into the energy form that will be used to generate heat and/or electricity.

[TABLE 6 BELONGS HERE]

On the other hand, three quarters of employment (or about 75 jobs per $1 million) created by solar and wind energy sectors are within the informal economy. Workers in the construction sector constitute a significant portion. Specific manufacturing sectors also contribute to the informal component of jobs in these two sectors. They include manufacturing of power transmission equipment and mining machinery for the solar energy sector (i.e. for the mining of polycrystalline silicon materials crucial for building solar panels), as well as manufacturing of metal products and other sectors related with building wind turbines.

The fossil fuel energy sectors also have a high level of informal employment composition. In the oil and natural gas sector, 20.9 jobs (or 81 percent of the jobs) generated from $1 million spending are within the informal economy. These are mostly workers on the field extracting oil and natural gas, corresponding to the informalization of the state-owned oil and natural gas enterprises in the recent decade. With respect to the coal energy sector, 78.6 jobs (or 70 percent of the jobs) generated from $1 million spending are within the informal economy. These are mostly workers in the railway transportation, mining and coking sectors.

It is important to note that the amount of informal employment generation might be overestimated either due to the inclusion of small and medium scale private enterprises, or the fact that the final demand is only raising earnings instead of generating new employment especially for the self-employed population.

5.3 Output-Investment Ratio (output multipliers)

In this section, I compare the output multipliers over time to show their relative stability for all energy sectors in the past decade.[29] The output multipliers tell the amount of output increase as a result of increase in final demand therefore providing information on the production relationships between sectors in the I-O table. The data was taken from the World Input-Output Database (WIOD), a project of the European Commission, which produces annual national I-O tables for a selected number of countries. For China, the WIOD tables are more aggregated (i.e. 35 sectors) than the one I used to produce the employment estimates in this paper (i.e. 135 sectors). I use the same weighting schemes that were applied to produce employment estimates to estimate output multipliers for synthetic sectors of both renewable and fossil fuels—the energy sectors that are not readily available in the original I-O tables. Table 7 presents the results.

[TABLE 7 BELONGS HERE]

As we can see, for all the energy sectors, the annual average percentage changes in

[29] Output multipliers are calculated from the Leontief inverse for each of the four countries. The Leontief inverse matrix is given by $L=(I-A)^{-1}$ in which L is the Leontief inverse matrix, I is the identify matrix, and A is the matrix of I-O coefficients derived from the WIOD tables.

the output multipliers from 1995 to 2007 are negligible.[30] This concludes that the production relationships between the domestic sectors in China did not change significant over the 12-year period between 1995 and 2007. This conclusion addresses the concerns for not incorporating dynamic elements in the model. It is now reasonable to assume that output multipliers would change only at a modest pace over the next two decades for which employment projection will be made. It also implies that it is reasonable to think that the employment estimates will not be improved much by using the 2011 I-O table with only information on 35 aggregated sectors than to use the 2007 I-O table (with a detailed breakdown of 135 sectors) as this paper does.

5.4 Productivity and declining Employment-Output (E/O) ratio

Since I-O table also provides information on gross output by sectors, lack of more updated I-O table with comparable level of details as in the 2007 I-O table means that even though more recent data are available for employment by sector, they are not compatible with the 2007 industry data and therefore cannot be utilized to calculate a more updated E/O ratio at a desired level of detail.

To compensate for the lost information, I calculate the E/O ratio for period 2007 to 2011 to show its general pattern in the post-2007 years, although it is defined more loosely and at a more aggregated level with a different unit compared with the E/O ratio I use for the major estimation.[31] Note that the E/O ratio is simply the inverse of labor productivity therefore an increase in labor productivity will reduce the E/O ratio. I use the same weighting scheme to aggregate relevant sectors to synthetic energy sectors of interest to this paper.[32] The results are presented in Table 8.

[TABLE 8 BELONGS HERE]

As we can see, the coal sector has the most significant productivity gain among all energy sectors, almost twice the productivity gain for all renewable energy sectors. This increasing productivity suggests that for the same spending level, the employment generation in the coal sector will be much smaller now than five years ago. Although we observe that coal sector show comparable employment generation per $1 million relative to the renewable energy sectors in terms of both formal and informal employment, this result suggests that the coal sector will very quickly lose its "advantage" in terms of labor intensiveness. The oil and gas sector does not show productivity gain as dramatic as the other energy sectors, yet it is already the least labor-intensive energy sector among all.

30 I intentionally choose year 2007 as end point to avoid cyclical complication by the 2008 economic crisis.
31 Note that the latest China Statistical Yearbook 2013 did not publish estimates gross output value or the annual average persons by industrial sector consistent with those published in previous yearbooks. Thus I exclude the 2012 data for comparison.
32 Note that gross output data are not available for all the sectors relevant for the energy sectors (such as R&D and Transportation). Under such circumstances, it is assumed that these sectors with missing information will experience the same productivity changes as the weighted average of productivity changes in other relevant sectors for producing the same kind of energy.

Thus it is reasonable to conclude that renewable energy sectors, compared with fossil fuel energy sectors, have the advantage over fossil fuel energy in terms of job creation in the long run.

6 Conclusion

This paper addresses the impacts of a transformative renewable energy investment program for China. It focuses on estimating the relative employment impacts of investments in three renewable energy sectors in China, i.e. solar, wind and bioenergy, versus spending within China's traditional fossil fuel sectors i.e. coal, oil and natural gas.

I find that the bioenergy sector generates the highest number of jobs from a given level of spending. That is, I estimate that China's bioenergy sector generates 224 direct jobs per $1 million of spending. This contrasts with a range of about 27-29 for solar and wind energy. The large difference here is the result of the significant amount of agricultural-related activities involved in bioenergy production. It is also significantly higher than the direct jobs generated through spending within China's fossil fuel sectors, which generate about 30 to 70 jobs per $1 million of spending. In terms of indirect jobs, the three kinds of renewable energy sectors show relatively consistent estimates, about 60-70 jobs per $1 million, and are much higher than the fossil fuel sectors with range between 40 to 50 jobs per $1 million. If equal weights are assigned across the three renewable energy sectors, then results suggest that spending $1 million on renewable energy generates about 162.3 jobs. This contrasts with only 96.7 jobs generated from $1 million overall spending on both coal and oil/gas. I also show that the coal industry is likely to lose its "advantage" over some renewable energy sources in terms of job creation as productivity increases in the near future.

In terms of formal and informal employment, with China's bioenergy sector, to begin with, job creation is heavily weighted toward informal jobs—specifically, about 90 percent, or 261 jobs per $1 million will be informal jobs. The proportions of informal jobs are somewhat lower—at about 75 percent—with the solar and wind energy sectors. Within China's fossil fuel energy sectors, informal job creation is about 81 percent in the oil and gas sector and 70 percent in the coal sector.

The overall implication of this study is that a clean energy investment strategy will not destabilize the overall employment level in China relative to the investment strategy biased towards the fossil fuel energy sectors. The challenges of raising job quality standards in China's energy economy will nevertheless remain substantial.

Tables and Figures

Table 1. Employment estimates of investing renewable energy in the existing literature

Studies	Methodology	Specify sectors	Specify formal or informal employment	Specify direct or indirect jobs	Specify job creation relative to spending level	Stock or flow	Total employment generation for renewable energy investment (million)
UNEP et.al (2008)	Interview officials and experts	Wind, solar and biomass	No	No	No	Stock; "by 2007"	0.9
CREIA (2009)	NA	NA	No	No	No	Flow; 2008	1.1
CASS (2010)	2005 I-O table of three aggregated levels	Wind and solar	No	Yes	580 billion RMB	Stock; 2008-2011	30
China's 12th Five Year Plan (2011)	NA	Bioenergy	No	No	1.8 trillion RMB	Stock; 2011-2015	3.6
CCICED (2011)	NA	NA	No	No	$909 billion	Stock; 2011-2015	10.6
IRENA (2011)	Literature survey	Wind, solar thermal and solar PV[33]	No	No	No	Stock; "by 2010"	0.3
Greenpeace (2012)	Assuming 14 person/years of employment for every new megawatt and €23 billion of annual investment	Wind	No	No	Annual average of €23 billion	Stock; by 2020	0.3
NDRC (2012)	NA	Wind	No	No	1.8 trillion RMB	Stock; by 2050	0.7
REN21 (2013)	Literature survey	Wind, solar and biomass	No	Yes	No	Stock; 2009-2012	1.7

Source: Author's compilation.

[33] Solar thermal technology first translates the sun's light to heat and then to electricity, while solar PV directly converts the sun's light to electricity. Therefore solar PV technology is only effective during daylight hours as storing electricity is not a particularly efficient process as compared to heat storage.

Table 2. Annual average wage (RMB) comparison between urban unit employees and rural migrant workers

	Urban unit employees	Rural migrant workers	Rural wages as a share of the Urban Wages
2008	28,898	16,080	56%
2009	32,244	17,004	53%
2010	36,539	20,280	56%
2011	41,799	24,588	59%
2012	46,769	27,480	59%

Source: Table 4-11 China Statistical Yearbook 2013 and National report on rural migrant workers in 2013.

Table 3. Urban employment and urban units employment in 2007 and 2012 (in millions)

Category	2007	%	2012	%
Urban employment (million)	293.5	100	371.0	100
Urban units employment	120.2	**41.0**	152.4	**41.1**
State-owned Units	64.2	21.9	68.4	18.4
Collective-owned Units	7.2	2.5	5.9	1.6
Other Ownership Units	48.8	16.6	78.1	21.1
Urban informal employment	173.3	**59.0**	218.6	**58.9**
Urban private enterprises	45.8	15.6	75.6	20.4
Self-employment	33.1	11.3	56.4	15.2
Not formally counted	94.4	32.2	86.6	23.3

Source: China Labor Statistical Yearbook 2008 and 2012, Table 1-1. Details of urban private enterprises and self-employed are retrieved from Table 4-14 and Table 4-15 in China Statistical Yearbook (2008); Table 4-8 and Table 4-9 in China Statistical Yearbook (2013).

Table 4. Industries and Weights for Renewable and Fossil Fuel Energy in the I-O Models

Energy Source	I-O Industry	Weight (%)
Solar Energy	Mining of Non-Ferrous Metal Ores	17.1
	Smelting of Non-Ferrous Metals and Manufacture of Alloys	8.5
	Manufacture of Equipments for Power Transmission and Distribution and Control	11.1
	Manufacture of Other Electronic Equipment	12.7
	Manufacture of Special Purpose Machinery for Mining, Metallurgy and Construction	15.2
	Research and Experimental Development	12.7
	Construction	22.7
Wind Energy	Research and Experimental Development	13
	Construction	22
	Manufacture of Synthetic Materials	10
	Manufacture of Boiler and Prime Mover	7
	Manufacture of Metal Products	30
	Manufacture of Equipments for Power Transmission and Distribution and Control	10
	Production and Supply of Electric Power and Heat Power	8
Bioenergy	Agriculture	25
	Forestry	20
	Manufacture of Lifters	36
	Construction	15
	Manufacture of Equipments for Power Transmission and Distribution and Control	3
	Research and Experimental Development	1
Coal	Mining and Washing of Coal	28
	Manufacture of Special Purpose Machinery for Mining, Metallurgy and Construction	27
	Transport Via Railway	23
	Other Services	22
Oil and Gas	Extraction of Petroleum and Natural Gas	50
	Processing of Petroleum and Nuclear Fuel	20
	Transport Via Pipeline	5
	Other Services	25

Source: The weighting structures for all energy sectors are calculated by the author based on information from existing literature. These studies include Li et. al (2007), IRENA (2012) Figure 4.2 and 4.5, IRENA (2013), p52-55; IRENA 2012b, p19&p24; IRENA (2013); Mao et.al (2008) and Xie et.al (2011); Bing et.al (2008). See more details regarding the weighting construction in the author's dissertation.

Table 5. Total employment generation in renewable energy and fossil fuel energy sectors (unit: jobs per $1 Million)

	Direct	Indirect	Direct+ Indirect
Renewables (average)	93.1	69.2	162.3
Solar PV	28.1	72.0	100.1
Wind	27.1	73.0	100.1
Bioenergy	224.0	62.5	286.4
Fossil Fuels (average)	49.5	47.1	96.7
Coal	68.0	43.6	111.6
Oil/Natural Gas	31.0	50.7	81.7

Source: Author's own calculation

Table 6. Formal and informal employment share in total employment in renewable energy and fossil fuel energy sectors

	Total employment (jobs per $1 Million)	Formal employment share	Informal employment share
Renewables			
Solar PV	100.1	26%	74%
Wind	100.1	25%	75%
Bioenergy	286.4	9%	91%
Fossil Fuels			
Coal	111.6	30%	70%
Oil/Natural Gas	81.7	19%	81%

Source: Author's calculation.

Table 7. Output multipliers and percentage changes in energy sectors in China, 1995-2011

	1995	2007	2011	**1995 to 2007**	**2007 to 2011**
Renewables				Annual average % increase	
Solar	2.41	2.56	2.64	0.5%	0.7%
Wind	2.40	2.56	2.58	0.6%	0.2%
Bioenergy	2.17	2.31	2.41	0.5%	1.1%
Fossil fuels					
Coal	2.05	2.15	2.14	0.4%	-0.1%
Oil and Natural Gas	2.18	2.17	2.06	-0.1%	-1.3%

Source: Author's calculation based on World Input-Output Database.

Table 8. Productivity changes in energy sectors in China

Measured as the inverse of productivity: Number of persons 1 million of RMB

	2007	2011	**2007 to 2011**
Renewables			Annual Average Percentage change
Solar	3.19	2.03	-9.1%
Wind	3.19	2.02	-9.2%
Bioenergy	3.23	2.14	-8.4%
Fossil fuels			
Coal	2.67	1.22	-13.6%
Oil and Natural Gas	0.91	0.78	-3.6%

Source: Author's calculation based on Table 13-2 or 14-2 Main Indicators of Industrial Enterprises above Designated Size by Industrial Sector from China Statistical Yearbook 2008-2012. Price index based on Table 9-1, China Statistical Yearbook 2012. Data for productivity for construction sector is calculated based on Table 15-34 CSY 2012 and Table 14-36 in CSY 2008.

Appendix

The Input-Output model is as follows:

$$X_i = a_{i1}X_1 + a_{i2}X_2 + \cdots + a_{ij}X_j + D_i \quad (1)$$

$$X = AX + D \quad (2)$$

$$(I - A)X = D \quad (3)$$

$$X = (I - A)^{-1}D \quad (4)$$

In the first equation, X_i indicates the output produced by the ith sector; a_{1i} indicates the required input from the ith sector to produce output for the jth sector. Equation (2) contains the same information as in equation (2), only is written in the vector form, where notation A indicates an i by j matrix containing all elements of a_{i1} through a_{ij}. Equation (3) is a re-writing of equation (2) where notation I indicates an identity matrix. Equation (4) expresses X in terms of all the other components in the equation with the assumption that *(I-A)* is invertible.

The assumption of a linear I-O model creates some limitations that need to be addressed. To put it into the context of this paper, linearity here suggests that the employment impacts of a \$1 billion renewable energy investment project will be exactly 1000 times greater than a \$1 million spending on the same project. However, this assumption might not be able to generate the most accurate estimates in some situations.

First, the basic linear I-O model does not incorporate any supply constraints that might occur from investing, for example, 1,000 times more in the same project. Yet within the current context of the Chinese economy, which is operating with substantial overcapacity especially after the 2008 global economic recession, it is reasonable to assume that supply constraints are less binding than demand constraints in the short and intermediate term.

Second, the basic linear I-O model also assumes that relative prices are fixed regardless of any changes in demand. For example, if demand for solar panels declines due to the economic recession, then prices of the panel will fall. This could provide incentives for purchasing more solar panels therefore raise the demand again. This issue could be addressed in a more fully specified model such as in Computable Generable Equilibrium (CGE) model yet with its own limitation as discussed later.

Third, when applying basic linear I-O model, productive relationships are assumed to be stable over the period of analysis. This assumption would seem especially relevant in employment estimation of the renewable energy investment. However, when put into the context, it only implies that productive relationships such as those between the manufacturing sector and construction sector in building solar energy are fairly stable, which is realistic to a certain extent. In Section 5.3, I compare the output-investment ratio I-O tables from 1995 to 2011 to show that productive relationship among sectors could be realistically assumed to be fairly stable in the context of China.

Fourth, the static I-O model does not incorporate the treatment of time dimension either. It is certainly realistic to think that investment and employment generation occurs over a reasonable amount of time period rather than happening at one fixed point in time. A dynamic model would address this concern more accurately yet it is not necessary for this paper since the estimates cover an intermediate term rather than a specific year.

The advantage of a relatively simple and transparent I-O approach is seen more clearly by comparing it with the Computable Generable Equilibrium (CGE) model, which is a relatively more complex modeling framework. In the CGE models, price dynamics, supply constraints and technological change are incorporated into the basic I-O structure through assumptions on a variety of price elasticities and equilibrium conditions. Critically, most CGE models operate with an assumption of full-employment. Despite the crucial roles these assumptions play in the model, they are almost impossible to be identified. In addition, these models are usually proprietary. This proprietary nature generally presents independent verification of the logic of the model. Also, the assumption that the economy operates at full employment at all times is unrealistic and inherently contrary to the purpose of using the model, which is to estimate the number of job creation through investments. Compared with the CGE model, the I-O model has critical benefits in terms of its relative simplicity, clarity, minimum number of behavioral assumptions and ability to handle details more fully as a result.

In general, a basic linear I-O model is still the most effective available tool for estimating the employment effects of a large-scale renewable energy investment project in a national economy.

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