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COMMENT BY

VALERIE A. RAMEY This very interesting paper by David Popp and colleagues offers a comprehensive analysis of the employment effects of the transition from fossil fuels to green energy. A particular focus of the paper is assessing the extent to which green fiscal stimuli can mitigate the negative employment effects on fossil fuel workers. This question is important because government policies designed to convert energy production from fossil fuels to green energy may face political opposition from the potential losers.

The paper consists of four parts. The first part surveys the literature on the effects of environmental policies on employment, with attention to heterogeneity in skills and geography. The second part presents evidence comparing the skill requirements of green jobs with the skill endowment of workers in fossil fuel industries. The depth and breadth of the analysis of the various types of heterogeneity make these two parts a valuable resource for academics and policymakers. The third part analyzes the employment effects of the green spending in the 2009 American Recovery and Reinvestment Act (ARRA) at the commuting zone level. This part of the analysis is an ambitious undertaking since features of the data present multiple challenges to obtaining definitive answers. Finally, the fourth part discusses the policy implications of the findings of the paper.

Most of my comments concern the interpretation of the ARRA estimates. First, I discuss what the authors' local estimates imply about aggregate effects and what macroeconomic theory predicts about the aggregate effects of infrastructure spending. Second, I summarize the authors' green ARRA employment findings and compare them to the estimated effects of the highway spending components of the ARRA. Third, I discuss green incentives that were not included in the authors' analysis, specifically the effects of tax credits for rooftop solar, and how the effects of these incentives may confound the authors' estimates. I also discuss advantages that rooftop solar has over some alternatives. Finally, I return to the authors' motivating question

regarding potential employment losses and consider the broader impacts of the green transition on fossil fuel communities. I illustrate the challenges with the example of the mining towns in Asturias, Spain.

WHAT THEORY PREDICTS ABOUT THE EFFECTS OF INFRASTRUCTURE SPENDING

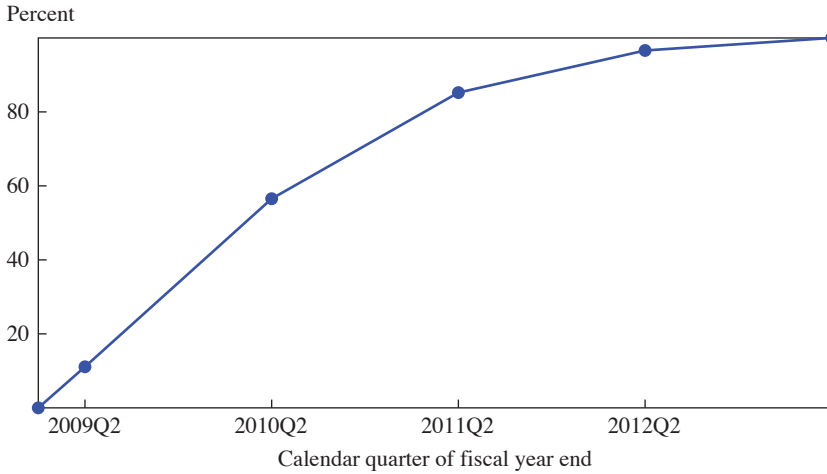
The authors present estimates of the employment effects of the green spending in the ARRA using variations across commuting zones. They consider the effects at a variety of horizons and find small effects in the first few years but then apparently permanent positive effects on job creation. Before using these estimates to guide policy, it is important to put these effects in context by considering some lessons from the recent fiscal literature and other literature that uses local data to answer macro questions.

The first lesson from the literature is that local effects, which the authors estimate, are not the same as aggregate effects (Nakamura and Steinsson 2014). Because the panel data estimation uses year-fixed effects, all aggregate effects are removed. Thus, the estimates of employment effects are *relative* effects that answer the following question: If commuting zone A receives $1 more than the other commuting zones, how much does employment change in commuting zone A relative to the average? This estimate is different from the aggregate effect in several ways. First, it does not incorporate the added general equilibrium effects due to tax or deficit financing. Second, it may be smaller or larger than the aggregate estimate: it may be smaller if there are positive spillovers across commuting zones, but it may be larger if there are "business stealing" effects across commuting zones.

A second insight that comes out of the infrastructure literature is the implication of time-to-spend and time-to-build delays that are inherent to infrastructure projects. Figure 1 shows the cumulative percentage of total ARRA infrastructure appropriations that were spent each year. Despite the emphasis on "shovel-ready projects," only 10 percent of appropriations were spent by summer 2009 and under 60 percent had been spent by the following summer. As I now demonstrate, if there were also delays in green infrastructure spending, then the minimal short-run effects estimated by the authors can be explained.

As Leeper, Walker, and Yang (2010) and others have argued, these delays severely reduce the short-run stimulus effects of infrastructure investment. In Ramey (2021), I show that even in a medium-scale New Keynesian model, calibrated to give high multipliers for government consumption spending, infrastructure spending with time-to-spend and time-to-build delays offers little short-run stimulus. To illustrate the effects, figure 2 shows the simulations from a version of the New Keynesian model used in my work. The graphs show the effects of either a shock to government

Figure 1. Federal Highway Administration Outlays from the ARRA: Cumulative Percentage Spent of Total Appropriation

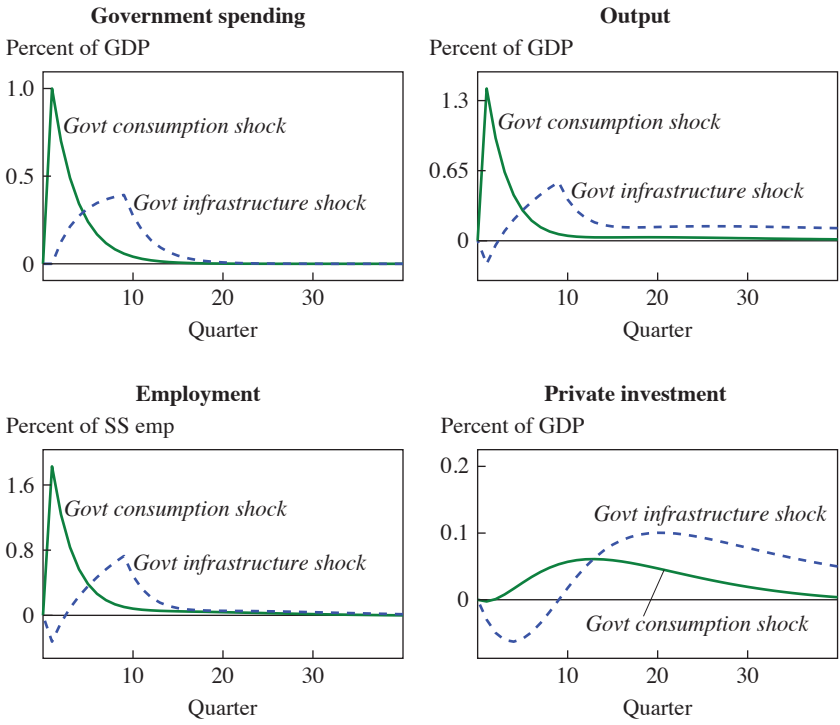


Source: Leduc and Wilson (2017).
Note: State-level data from replication files are aggregated to the national level.

consumption or government infrastructure investment appropriations. In both cases, the appropriations process is assumed to be serially correlated so that the initial bump to appropriations is followed by smaller additions to appropriations until they return to zero after about three years. In the case of government consumption spending, appropriations translate immediately into government spending. However, in the case of government infrastructure spending, there are both time-to-spend and time-to-build delays. In particular, a one-unit rise in appropriations is spread out equally over the next eight quarters. In addition, infrastructure does not become productive until eight quarters after the beginning of construction.

Figure 2 shows the paths of government spending, output, employment, and private investment for each of the two experiments. These graphs show that a shock to government consumption appropriations equal to 1 percent of GDP leads output to rise by more than 1.3 percent, implying an impact multiplier above 1.3. Employment rises 1.7 percent relative to its steady state. Private investment builds up slowly because of the assumption of adjustment costs to investment. Overall, the rise in government consumption has significant short-run stimulus effects in this New Keynesian model. As discussed in Ramey (2021), the three most important features of the model for the short-run stimulus effects are adjustment costs on private

Figure 2. Macroeconomic Effects of Government Consumption Spending versus Infrastructure Spending with Delays in a New Keynesian Model



Source: Ramey (2021).

Note: These graphs show impulse responses to a shock to government appropriations destined to either government consumption or government infrastructure investment. The impulse responses are based on simulations of the medium-scale New Keynesian model.

investment (which prevent the standard crowding out), the presence of "hand-to-mouth" households which always consume 100 percent of their income, and that employment is mostly determined by labor demand and not labor supply.

The effects are very different for infrastructure spending because of the time-to-spend and time-to-build lags. Because of the spending delays, output and employment do not rise on impact and in fact fall slightly. Without the government spending, firms do not demand more labor, so the hand-to-mouth households do not experience rises in income and hence do not consume more. Once spending ramps up, there is a slow rise in output and employment. Private investment falls in the short run and then rises more in the intermediate run. The first lesson from these simulations is that

time-to-spend and time-to-build delays prevent government infrastructure spending from acting as a short-run stimulus.

The second lesson from the simulations is the theoretical prediction about the long-run effects on employment. As figure 2 shows, output is predicted to remain above its steady state out through ten years (forty quarters) because of the higher level of public capital. However, employment returns to its steady state after four years. Both a standard neoclassical model and a New Keynesian model predict that a relatively transitory rise in either government consumption or government investment should have no noticeable effect on long-run employment. This result should be kept in mind when considering the plausibility of the authors' estimates suggesting more permanent employment effects.

SUMMARY OF THE AUTHORS' ESTIMATES WITH A COMPARISON TO THE EFFECTS OF THE ARRA HIGHWAY CONSTRUCTION SPENDING Popp and colleagues show (in their figure 2) the estimates of the relative employment effects of the green spending in the ARRA based on their commuting zone data. Their estimates imply about ten jobs created per $1 million in the first year of the ARRA in 2009, gradually rising to a plateau of about twenty-five jobs per $1 million by 2017. They conclude that the ARRA green spending, which was temporary, may have led to permanent job creation.

This pattern of slowly rising effects of jobs created at longer horizon contrasts with results for highway spending. For example, Garin (2019) studies the job creation effects of the road and highway spending part of the ARRA at the county level. Focusing first on construction employment, he finds that the spending raises highway construction employment little the first year (2009), creates a peak of two jobs per $1 million in 2010, and then slowly tapers back to zero. When he studies total payrolls (in dollars), he finds no effect the first several years, then a rising effect that peaks in 2013 before declining again. Thus, the authors' finding of an ever-rising job creation rate contrasts with Garin's (2019) results for the highway construction parts of the ARRA. One possible source of the permanent estimates in the authors' analysis is the presence of pre-trends. As they highlight, and is evident in their figure 2, it appears that there are significant pre-trends. Thus, the estimates of the long-run effects could reflect that the commuting zones that received more green energy spending had a higher trend rate of employment growth irrespective of the ARRA green spending.

In contrast, the authors' estimates of employment effects by category are on firmer ground, since there are no significant pre-trends. Employment in manual occupations, green jobs, and construction jobs share a similar pattern: little or no effect for the first three years after the initial spending

but then rising to a higher plateau from around 2012 through 2017. These higher intermediate-run effects are quite different from the more transitory effects Garin (2019) finds for highway spending.

These more persistent effects on employment categories at the commuting zone level found by the authors are not necessarily at odds with the dynamic general equilibrium analysis shown above. The dynamic general equilibrium analysis shows that the effects on *aggregate* employment should last only during the transition. That does not mean, however, that there cannot be permanent reallocations of employment across job categories or geographic levels. The next section, however, suggests that an important additional green program may be confounding the effects.

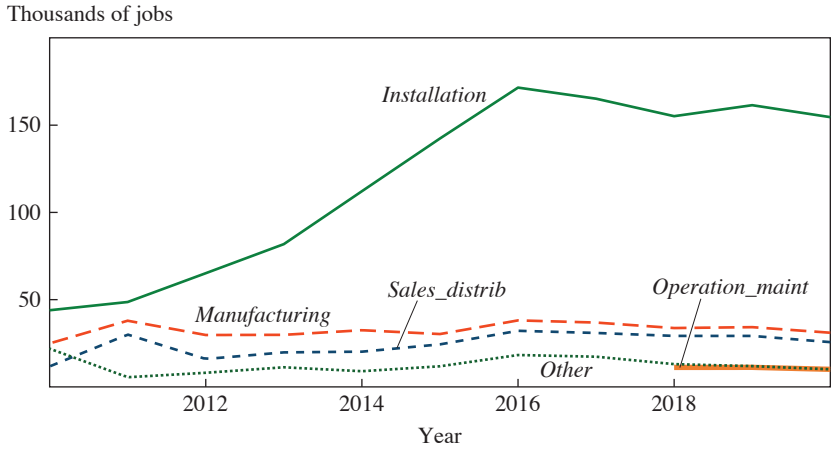
SOLAR TAX INCENTIVES: POSSIBLE CONFOUNDING EFFECTS AND JOB CREATION POTENTIAL The authors focus on the green spending elements of the ARRA but do not consider tax incentives for green energy since such are beyond the scope of the paper. I believe that these additional incentives cannot be ignored because they are likely to confound the estimates of the effects of the spending program.

Residential and commercial investment federal tax credits for rooftop solar were adopted in the mid-2000s and subsequent legislation has extended them multiple times. The tax credit was 30 percent of the installation cost of rooftop solar until recently, when it was reduced to 26 percent.[1] Thus, the tax incentive regime completely overlaps the period of analysis by the authors. Moreover, the price of photovoltaic cells fell 70 percent in the last decade, leading to an upward trend in the incentive to take advantage of the rooftop solar tax incentives (Solar Energy Industries Association 2021).

Figure 3 shows the growth of solar jobs by category from 2010 to 2020 from the National Solar Jobs Census (Solar Energy Industries Association 2021). The graph shows that solar installation jobs are the dominant source of both the level and growth of total solar jobs. Installation jobs currently account for two-thirds of all solar jobs. Important to note is the time pattern: job growth was slow initially and then took off after 2012, reaching a plateau starting around 2016. This pattern is very similar to the pattern of estimates by the authors for the effects of the ARRA green spending. They interpret their results as indicating that the ARRA appropriations led to

1. The history through 2016 is summarized on the Solar Energy Industries Association website, https://www.seia.org/sites/default/files/resources/History%20of%20ITC%20Slides.pdf, and the more recent extensions are discussed at Office of Energy Efficiency and Renewable Energy, "Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics," https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics and https://news.energysage.com/solar-tax-credit-explained/.

Figure 3. Solar Employment by Sector



Source: Solar Energy Industries Association (2021).

permanent job creation. I suggest an alternative hypothesis: the commuting zones that received ARRA green spending appropriations were also areas that were ideal for solar. As a result, households and businesses in those areas were more likely to take advantage of the solar tax incentives, which remained in place long after the ARRA green spending was spent. Thus, the apparent permanent job creation effects of the ARRA green spending are more likely to have been due to the tax incentives for rooftop solar interacting with the declining price of photovoltaic cells.

It would be interesting for future research to study the effects of rooftop solar for an additional reason: its use of labor and land. Installing rooftop solar requires more labor hours per energy unit installed. For example, according to the 2015 National Solar Jobs Census, residential installations required 40 labor hours per 5 kilowatt hours, commercial installations required 36, and utility-scale installations 25 (Solar Foundation 2016, 24). Many have argued that utility-scale installations, which involve large solar farms often situated in remote desert areas, are superior because they take advantage of economies of scale. However, this argument neglects two factors. First, rooftop solar reduces the need for transmission lines to carry the energy across long distances. Second, rooftop solar uses land more efficiently and does not disturb endangered habitat. A recent Brookings study highlights the fact that wind and solar energy require at least ten times more land per unit of power produced than fossil fuels do (Gross 2020). This

demand for additional land leads to numerous conflicts over land use. For example, in California climate change activists have clashed with conservationists over the construction of large solar farms in areas with endangered species (Roth 2021). In contrast, rooftop solar is installed on existing buildings, near the ultimate user.

THE IMPORTANCE OF COMMUNITY-PRESERVING POLICIES As I mentioned in the introduction to my comments, the major motivation for the authors' analysis is determining whether the workers displaced by the decline of fossil fuels can be reemployed in green industries. I have already raised questions about their finding of seemingly permanent job gains from temporary green spending. If the spending does not lead to permanent job gains, then there can be serious impacts on communities.

Consider the example of the mining communities of Asturias, Spain. The Spanish government phased out mining in the Asturias region of Spain, which had been mining coal for hundreds of years, and promised to bring in green jobs and retraining programs. According to numerous reports, the government has not fulfilled its promise. Instead, it started importing cheap coal from China. The older coal miners were pensioned off, preventing large income losses. However, because there are no jobs for the younger people, the towns in the mining areas are being depopulated, with mostly older people left behind (Benavides 2019).

The lesson to be learned from the example of Asturias, Spain, is that without the prospect of permanent, good-paying jobs for younger people, communities decline. The cycle can feed on itself since depopulation leads to reduced local tax revenue. The green transition is likely to face formidable opposition from some quarters if governments cannot develop credible, community-preserving policies.

CONCLUSIONS Popp and colleagues have written a very useful analysis of the possibilities of the green transition providing jobs to fossil fuel and other workers. In my discussion, I have raised questions primarily about the estimated permanent effects of the temporary green spending stimulus in the ARRA. Theory predicts that there should be no permanent employment effects of temporary spending at the aggregate level, but since the authors' estimates are at the local level, permanent employment shifts are possible. However, I have also raised the possibility that their estimates may be picking up the effects of another government green incentive, tax credits for rooftop solar. That incentive has been in place since the mid-2000s and, in conjunction with the declining price of photovoltaic panels, has likely led to an upward trend in green employment. If the ARRA green spending was more likely to be directed to communities that also had more

natural solar potential, then the upward trends in job creation found by the authors may be picking up these alternative effects.

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GENERAL DISCUSSION Jason Furman asked about the implications of the findings of the paper for welfare analysis. He noted that, generally, in educational settings students are taught to ignore jobs in cost-benefit analyses or even to treat jobs as a cost, given that the presence of jobs indicates a need to divert resources to that program (though this treatment depends on whether or not the economy is in a recession). He additionally asked if the implications for welfare or policy analysis change depending on whether the economy is in a recession or is closer to full employment.