NICO PESTEL
IZA and Centre for European Economic Research (ZEW), Germany

I Z A
World of Labor
Evidence-based policy making

Employment effects of green energy policies

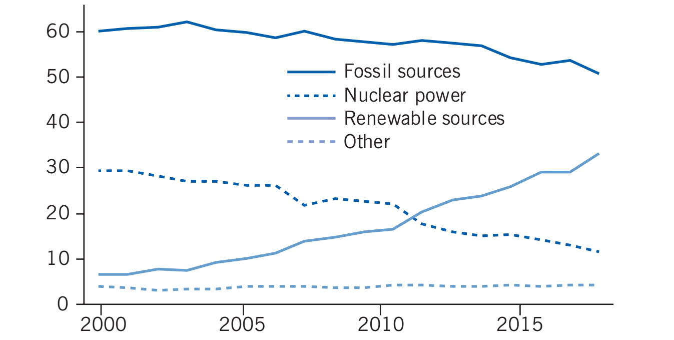
Does a switch in energy policy toward more renewable sources create or destroy jobs in an industrial country?

Keywords: employment, energy policy, renewable energy sources, energy turnaround

ELEVATOR PITCH

Many industrial countries are pursuing so-called green energy policies, which typically imply the replacement of conventional fossil fuel power plants with renewable sources. Such a policy shift may affect employment in different ways. On the one hand, it could create new and additional "green jobs" in the renewables sector; on the other hand, it could crowd out employment in other sectors. An additional consideration is the potential increase in energy prices, which has the potential to stifle labor demand in energy-intensive sectors and reduce the purchasing power of private households.

Electricity generation by type of energy source, Germany (%)



Note: Figures for 2017 are preliminary and partly estimated.
Source: AG Energiebilanzen e.V. Online at: http://www.ag-energiebilanzen.

KEY FINDINGS

Pros

- A green energy policy creates more "green jobs" in renewable energy sectors.
- A shift toward more renewable energy sources improves environmental quality by reducing emissions of ambient air pollutants, which is beneficial for health and labor productivity.

Cons

- Subsidizing renewable energies by feed-in tariffs increases energy prices for firms and private households.
- Rising energy prices put industrial jobs at risk when labor and energy are complementary inputs in industrial production.
- Estimates of net employment effects are, though positive, small at best.

AUTHOR'S MAIN MESSAGE

Empirical studies reveal both positive and negative employment effects related to green energy policies. These effects are, on the whole, quantitatively moderate. Job creation and destruction across sectors seem to cancel each other out, such that the overall net employment effect is rather limited. Neither the proponents nor the opponents of green energy policies should put forth job creation or destruction as an argument in the energy policy debate. Policymakers should ultimately evaluate green energy policies on whether they reduce air pollutant emissions and secure a steady supply of energy for industrial production at a reasonable cost.

doi: 10.15185/izawol.76.v2 | Nico Pestel © | December 2019 [Previous version July 2014] | wol.iza.org

MOTIVATION

Many industrialized countries have committed themselves to contribute more toward mitigating climate change by significantly reducing emissions of greenhouse gases and ambient air pollutants. To achieve these objectives, countries implement a variety of environmental policies including air quality standards. Moreover, many countries have decided to considerably reduce their reliance on conventional fossil fuel sources and expand their use of renewable sources. Such a political shift toward a low-carbon, green economy may create additional employment opportunities in research and development, in production, and in the installing and maintaining of green technologies. However, this shift may also crowd out investment-induced employment in non-green sectors.

The adoption of green energy policy usually entails subsidies for renewable energy sources, which leads to energy becoming more expensive for firms and private households. The extent to which this may stifle employment depends on the interrelationship of energy

Germany's energy turnaround

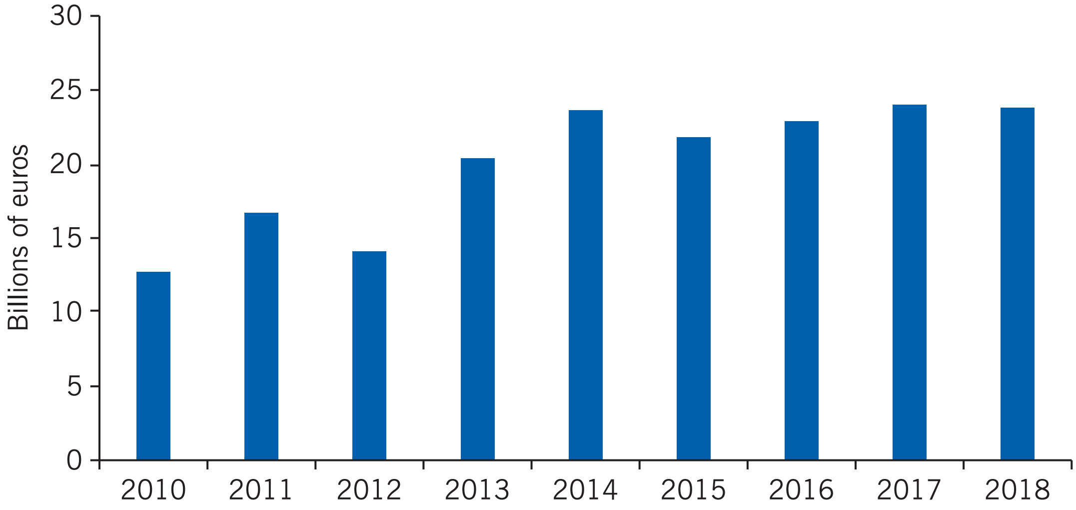
In Germany, the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, or EEG) is the most important legislative instrument steering the country's energy turnaround (*Energiewende*). This act guarantees the operators of renewable electricity sources the right to connect to public electricity grids and provides a fixed level of compensation per unit of electricity supplied over a period of 20 years. The subsidy is financed by electricity consumers through a surcharge on their electricity bills—a so-called "feed-in tariff"—known as the *EEG-Umlage*. Revenues from this surcharge are transferred to the operators of renewable energy facilities, thus subsidizing their investments in renewable energy infrastructure.

The feed-in tariff has triggered massive investments in solar panels, wind power stations, and power stations based on biomass. The share of renewable electricity in Germany rose from 6.6% in 2000 to 23.4% in 2013. The total remuneration for renewable electricity, increased from less than €1 billion in 2000 to more than €15 billion in 2012, as the EEG surcharge rose from 0.41 cents per kilowatt hour in 2003 to 6.24 cents in 2014, making electricity substantially more expensive for firms and private households. Only very energy-intensive production, which is exposed to fierce international competition, is exempt from the surcharge. The exemption clauses have been extended several times since 2013, a fact that has recently been scrutinized by the European Commission, since these exemptions could be interpreted as subsidies, which may not be in line with the EU's common market rules. The price increases, which lower the purchasing power of disposable income, especially for low-income households, have gained wide attention in the public debate on Germany's energy policy and pose a challenge to the public's acceptance of the *Energiewende*.

The German government and environmental associations highlight the positive effects of green job creation in renewable energy and energy-efficient technologies. But industrial business associations, on the other hand, stress that high energy prices constitute a threat to Germany's export-oriented manufacturing and may thus cost jobs in the long term. So, the potential employment effects, either positive or negative, have become important arguments both for and against the *Energiewende*.

and labor as inputs in production technologies. For this reason, empirical evidence on the potential magnitude of positive or negative employment effects related to an energy turnaround is required to inform decision makers about the labor market effects of a switch in energy policy (Figure 1).

Figure 1. Height of the feed-in tariff for electricity after the EEG in Germany in the years 2010–2018



Source: Information platform for German Transmission System Operators (TSOs). Online at: Netztransparenz.de

I Z A
World of Labor

DISCUSSION OF PROS AND CONS

Employment effects of green energy policies

Mitigating global climate change is now at the top of the policy agenda in many industrial countries. The EU member states have committed themselves to the "20–20–20" targets: a reduction in greenhouse gas emissions by 20% from the 1990 level, an increase to 20% in the share of EU energy consumption generated by renewable energy sources, and an energy-efficiency improvement of 20% by 2020.

Germany has played a pioneering role in key aspects of this agenda, particularly when it comes to the expansion of renewable energy sources. The energy turnaround in Europe's largest economy has included the replacement of conventional and nuclear power plants with renewable energy sources. The German government's long-term objective is to generate 60% of overall energy use from renewable sources by 2050. Obviously, such a politically motivated transition toward a low-carbon economy, which requires investments in green energy technologies, must be regulated in order to be implemented, since green technologies have not proven to be cost-competitive in their early years. For this reason, many countries subsidize the expansion of renewable energy sources by offering feed-in tariffs.

The subsidies can be expected to boost aggregate demand for research and development, production, and the installation and maintenance of renewable energy technologies, which in turn create new jobs. But subsidies may also crowd out investments in conventional

Feed-in tariffs

Under a feed-in tariff, a supplier of renewable energy is guaranteed access to the electricity grid at a fixed selling price based on its costs. The intention is to induce investment by offering a long-term purchase agreement at known prices. The tariff, or surcharge, typically varies depending on the technology, the scale, and the region.

For example, the German version of a feed-in tariff, the *EEG-Umlage*, has proven to be a successful policy tool to attract investments in renewable energy sources. Interestingly, while consumer prices for electricity have *increased* owing to the *EEG-Umlage* (currently a surcharge of 6.24 cents per kilowatt hour added to consumers' bills), it has led to *decreasing* market prices for electricity at, for example, the European Power Exchange (EPEX). This is due to the so-called "merit-order effect" at the spot markets, where electricity produced at the lowest marginal cost is traded first.

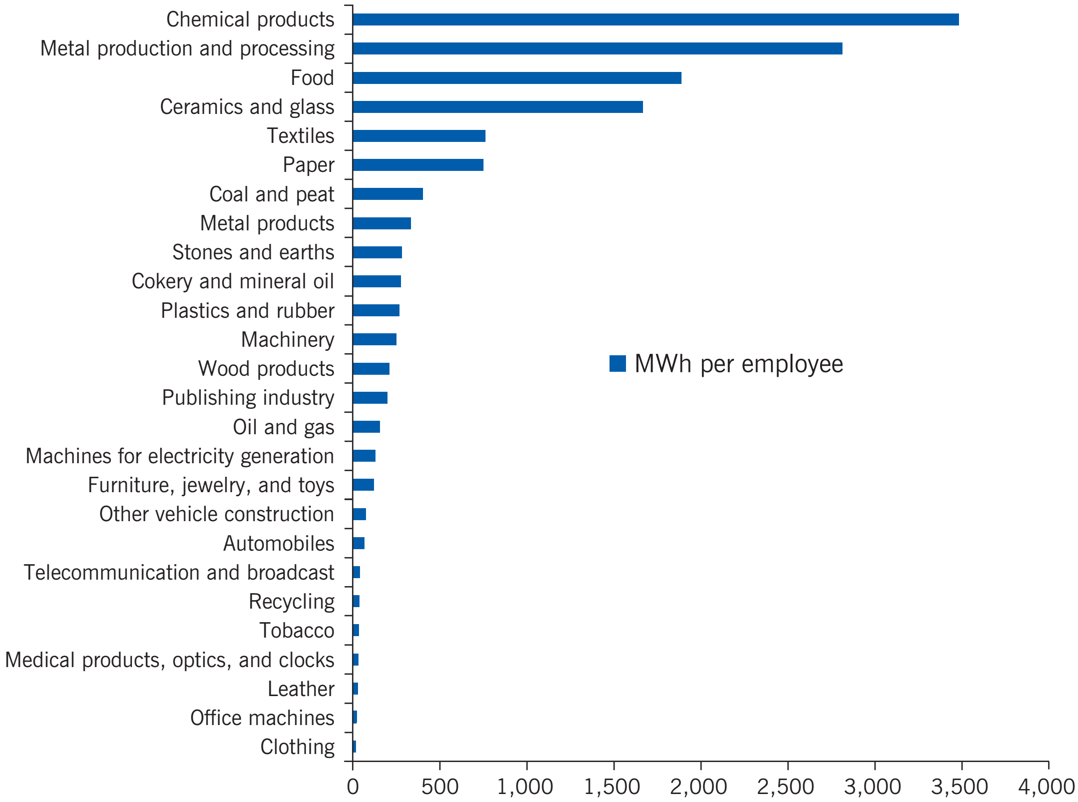
Since renewable technologies typically generate electricity at lower marginal costs, electricity generated from conventional power plants is crowded out, which lowers spot market prices. Mechanically, this widens the gap between guaranteed compensation of renewable electricity generation and the market prices, which in turn raises the total amount of EEG compensation. This situation has amplified renewable energy sources' impact on increasing consumer prices for electricity in Germany.

energy sources or other economic activities. While the expansion of green energy may be beneficial for environmental quality, health, and labor productivity, an energy turnaround financed by feed-in tariffs typically implies increasing energy prices for both firms and private households. As such, a common argument against renewable energy expansion is that it puts jobs in energy-intensive industrial and manufacturing sectors at risk, particularly when they are highly export-prone and their international competitors have significantly lower energy costs. For example, the German manufacturing industry's expenses for electricity account for a large portion of total production costs, but they vary substantially across sectors. Figure 2 shows the intensity of the power usage in megawatt hours per worker (mean values between 2003 and 2007) for aggregated sectors in Germany [1]. Clearly, the production of chemicals and metal requires most power relative to the number of workers in the sector. In contrast, the relative electricity consumption is very low in sectors like the manufacturing of textiles and clothes.

A green energy policy in an industrial country could thus have both direct positive and indirect negative effects on total employment. A conclusive estimate of the overall net employment effect of an energy turnaround must, therefore, take into account both direct and indirect effects. In addition, the assessment should distinguish between potential short-term and long-term effects on the labor market. For example, investment-induced effects on creating jobs in the production and installation of renewable energy facilities in the short term may disappear in the longer term when infrastructure expansion has reached its saturation point. After this point, only the maintenance and replacement of renewable energy plants will require some labor input.

Firms could mitigate the negative effects of energy price increases by introducing more energy-efficient production technologies. However, if these savings are insufficient, then energy-intensive firms in, say, the manufacturing sector may ultimately decide to move their production sites abroad. Firms leaving the country or closing down altogether could reasonably be expected to have negative long-term effects on labor demand.

Figure 2. Relative electricity consumption



Source: Cox, M., A. Peichl, N. Pestel, and S. Siegloch. "*Labor demand effects of rising electricity prices: Evidence for Germany.*" Energy Policy 75 (2014) 266–277 [1].

I Z A
World of Labor

Investment-induced employment effects and crowding-out

The direct gross employment effect of investments in renewable energy sources should always be positive: expansions in the infrastructure of renewable technologies induce additional demand for goods and services in the respective sectors, as well as along their supply chains. This creates additional demand for labor related to research and development, production, and the installation and maintenance of green power plants.

The size of the gross employment effect is typically estimated using macroeconomic input–output models, capturing the flow of goods and services across sectors of an economy. The main advantage of this methodology is that it allows researchers to estimate the total (net) effects of increasing investments in renewables by relying on detailed supply chain linkages. However, a main drawback is that production technologies are assumed to be fixed, which could be very restrictive when considering rapidly changing technologies such as renewable energy generation.

Studies on Germany build upon a standard input–output model to capture the interdependencies of the renewable energy sector in relation to other sectors [2]. Estimates show positive gross employment effects related to renewable energy sector expansion, ranging between 23,000 and 258,000 additional jobs through 2030 [2], depending on some key assumptions (e.g. projections of global energy prices and German firms' global market share in the industry).

Similar studies have been conducted for other countries. In Tunisia, government legislation to support renewable energy is expected to create 10,000 jobs, for the Czech Republic, additional jobs are estimated to exceed 14,000. A study from China uses a slightly different approach, finding positive gross employment effects from investment in the photovoltaic industry in the country, though this impact is expected to decline as the sector becomes more automatized [3]. Similarly, the number of jobs in low carbon environmental goods and services in Scotland is estimated to be sizable, with more than 75,000 jobs added in each year between 2004 and 2012, though employment in this area has been more volatile than aggregate employment [4].

A dynamic macroeconometric model examining Germany, based on marginal effects rather than average reactions, was used to estimate investment-induced employment effects from the expansion of renewable energy [5]. The cumulative gross impact is about 100,000 additional jobs from 2004 to 2010; the effect is strongest in earlier years and declines over time due to a diminishing production effect.

While the above studies examine the gross impact of renewable energy investments on labor, a general equilibrium framework allows consideration of how and to what degree the additional demand for renewable energy sectors may have offsetting effects on other sectors. Consider, for instance, effects on imports and exports, lower consumption, and investments due to crowding-out in non-green sectors, and the additional production costs of the German EEG [2]. As shown above, the net employment effect is relatively small and positive. Based on a similar set of assumptions, a 2006 study estimates the accumulated negative employment effect to be about 50,000 over the same period, owing to additional costs of renewable energy, which increased from 2004 to 2010 [5]. The conclusion from this study is that net employment effects are positive in the short term and turn negative in the longer term.

More recent studies, however, paint a slightly different picture for Germany. Several of these estimate the net economic effects in Germany over the same period taking into account general equilibrium factors such as the costs of deployment, trade, and interactions with other sectors. They find overall positive effects on employment, also in the long term. The result is robust to sensitivity analyses based on different assumptions for fossil fuel prices, domestic installations, and international trade [6]. However, the macroeconomic success of the transition to renewable energy is vulnerable to abrupt policy changes, as seen in the German photovoltaic industry [7]. The introduction of green energy policies in Germany and other European countries has led to the adoption of such policies by the EU which are aimed at the transformation of the entire European energy market. One study finds an overall net employment effect of 530,000 jobs from this transformation process while considering spill over effects between countries (e.g. employment generated in one country due to a change in another) [8]. Research which focuses on countries outside the EU also finds positive net employment effects: in the Brazilian wind energy sector [9] as well as in the overall renewable energy sector in the US [10], more jobs are estimated to be created than lost due to offsetting factors such as job losses in the fossil fuel industry.

Despite these recent findings, it is possible that increasing energy prices may have a negative indirect effect on employment through another channel. When energy expenses account for an increasing share of private households' consumer spending, the purchasing power of disposable income falls, potentially reducing demand for other consumer goods and thereby employment in those respective sectors. Private households may, however, adjust their consumption after price increases and shift expenditures toward more energy-efficient goods and appliances in the long term. It is not clear how this might affect aggregate demand.

Interrelationship of energy prices and labor demand

The transition toward a green economy is typically associated with feed-in tariffs subsidizing investments in renewable energy sources, which usually trigger energy price increases for firms and private households. Any economic costs, such as negative effects on industrial activity or labor market outcomes, depend on the interrelationship between labor and energy as inputs in production technologies. However, knowledge about these economic costs is limited, especially as regards any potential employment effects.

The interaction of inputs in production technologies is typically gauged by assessing whether inputs are substitutes or complements in the production process. Empirically, this is usually determined by estimating cross-price elasticities, which quantify the degree to which the demand for an input changes when the price of another input increases marginally.

A variety of empirical studies estimate predominantly positive but small cross-price elasticities for labor demand with respect to energy prices [11]. The conclusion is that labor and energy are rather weak substitutes. This means that firms producing a fixed quantity of output can substitute manual labor for energy only to a limited extent. This characterization of the interrelationship of energy and labor seems plausible, given modern production technologies, where mechanical energy used in complex production processes cannot be easily transferred to workers. In addition, the energy required to generate process heat in production can be substituted only to a limited extent by other energy sources, such as switching from electricity to natural gas, and not at all by labor.

Cross-price elasticities

Demand elasticities are easily accessible measures characterizing the responsiveness of the demand for a particular (input or consumer) good to changes in prices. While own-price elasticities measure the responsiveness of the demand for a good to changes in prices for the good itself, cross-price elasticities quantify the percentage change in demand for an input good relative to a 1% price increase for another input. For example, cross-price elasticities greater than zero imply substitutability: when the price of input *A* increases, the demand for this input decreases (negative own-price elasticity), while demand for input *B* increases. Hence, input *A* can at least to some extent be replaced by input *B*. On the contrary, negative cross-price elasticities imply complementarity: when input *A*'s price increases, not only its own demand falls, but so does demand for input *B*, since both inputs are needed in a particular proportion. The absolute size of cross-price elasticities, either positive or negative, indicates how strongly demand reacts to price changes. Elasticities close to zero imply very limited reactions and vice versa. Both the sign as well as the size of cross-price elasticities depend on how different input goods interact in the production process, which is in the end a matter of production technology.

The findings on the substitutability or complementarity of labor and energy conditional on outputs are informative only about their characteristics as input factors and their interactions in production processes. Policymakers are more interested in the overall labor demand effect of increasing energy prices, in cases when output is not held constant. When firms can adjust their production levels, they reduce their output because of higher overall production costs induced by higher energy prices. This reduces demand for all input factors. Again, it is not clear whether this negative scale effect dominates the small but positive substitution effect of increasing energy prices on labor demand. Only a few studies address this empirical question.

Cross-price elasticities between labor demand and electricity use for the US have been estimated for a sample covering 12 sectors, exploiting electricity price variations within states over the period 1976–2007 [12]. The main finding is that employment is weakly related to electricity prices: an increase of 1% reduces full-time equivalent employment by 0.10−0.16%. Another study using US data broken down by county, industry, and year between 1998 and 2009 reports responses of the same order of magnitude for non-manufacturing industries [13]. For electricity-intensive manufacturing firms, the response in employment is much stronger, implying a greater than 1% employment decline for a 1% price increase. It should be noted that these results refer to labor as a homogeneous input factor and do not account for different skill levels.

Two other studies suggest moderate gross complementarity, implying negative unconditional cross-elasticities. This means that higher energy or electricity prices have a negative effect on employment. Taking different qualifications into account, labor demand seems to be affected differently across skill levels, with low- and high-skilled workers affected more than the medium-skilled [1].

LIMITATIONS AND GAPS

Despite the fact that employment effects have become an important argument both for and against a transition toward a green economy, only a limited number of studies assess the labor market effects of shifting energy generation to renewable sources in industrial countries. Evidence of the employment effects of an expanding renewable energy sector is dominated by macroeconomic modeling (input–output analysis). The advantage of this approach is that it not only accounts for direct employment effects, but can also take into account indirect (employment) effects on other sectors by explicitly modeling flows of goods and services between different sectors of the economy, as well as the interdependence of an economy with the rest of the world. But macro-modeling requires a wide range of assumptions and parameters that are very difficult to make explicit and thus to make transparent in determining what drives different results.

Previous research at the macro level has been mainly in the energy economics literature, which might explain why the labor market outcomes under consideration refer mainly to aggregate employment by sector only. Evidence on other outcomes of interest in labor economics, such as wages and hours worked, as well as skill formation, is limited. In addition, very little is known about worker characteristics in renewable energy sectors. In this context, previous research has not paid much attention to effects on the employment structure, especially regarding the skill composition of employment in the energy sector. This is partly due to the limited availability of detailed microdata on workers in this industry. Given that there is some descriptive evidence that workers in green energy technologies are disproportionally more highly skilled, a transition from conventional energy generation to renewable energy technologies will imply a higher demand for employees with tertiary education, in particular in engineering. If the supply of labor does not adjust accordingly, this can be expected to trigger shortages of skilled labor in fast-growing green technology sectors. Policy coordination might be important in promoting skill development and training activities.

With respect to research on the interrelationship between labor demand and energy prices, one limitation is that previous studies differ substantially in the countries, periods, and types of energy under consideration. This makes comparing different findings on cross-price elasticities difficult. A range of studies, especially those on the interesting case of Germany, are based on data from the 1970s to the early 1990s, which is perhaps a problem due to changes in production technologies.

In addition, due to the limited data available, more recent research papers typically use highly aggregated industrial sector data, which could miss substantial variation between regions and firms within sectors. To fill this gap, additional high-quality microdata are required, especially on firms and individual workers. Ideally, linked employer–employee data would be merged with detailed survey information on energy usage and prices, production technologies, and capital stocks. This would allow a comprehensive and detailed assessment of the relationship between firms' labor demand and energy prices, as well as the impact of energy policies on labor markets.

Future research should pay more attention to the extreme extensive margin of firms' potential reaction to rising energy prices, such as relocating abroad or even closing down production sites [13]. If a large-scale drain on energy-intensive production is very likely when energy prices remain high, then this margin is indeed a serious concern for policymakers. Another relevant outcome would be the investment decisions of multinational companies in energy-intensive industries and how they are affected by cross-country differences in policies affecting energy prices.

Focusing on employment as the only margin of adjustment is too narrow, particularly in the long term. There is evidence that environmental regulation also affects employment growth in regulated industries in the US [14]. Moreover, the costs of sectoral reallocation borne by individual workers may emerge not only in unemployment, but also in earnings losses after job changes [15]. In Europe, where labor markets are more regulated and layoffs more difficult, adjustment could also occur on the intensive margin of hours worked. Future research should therefore take into account the European variation in the regulatory scope of labor market institutions.

SUMMARY AND POLICY ADVICE

The shift to a low-carbon green economy in many industrial countries is intended to meet political objectives for the mitigation of climate change. Both supporters and opponents of green energy policies put forward the potential employment effects as arguments.

A change in energy policy may have a positive gross employment effect, creating additional green jobs, but it could also crowd out investment-induced employment in non-green sectors. This policy shift usually entails subsidies for renewable energy sources, making energy more expensive for firms and private households. The extent to which this may reduce employment depends on the interrelationship of energy and labor as inputs in production technologies. For this reason, empirical evidence on the potential magnitude of positive as well as negative employment effects is required in order to inform decision makers about the overall net effects of a switch in energy policy on labor markets.

Existing empirical studies, especially on the German case, reveal both positive and negative employment effects from a green energy policy. But the effects are quantitatively moderate, so the overall net employment effect is rather limited. Therefore, neither job creation nor job destruction are adequate arguments to put forward in the energy policy debate, neither in Germany nor in other industrial countries. At the end of the day, green energy policies should be judged on whether they are able to reduce the emission of ambient air pollutants while securing a reliable supply of energy for industrial production at a reasonable cost.

Acknowledgments

The author thanks an anonymous referee, the IZA World of Labor editors, and Michael Cox for many helpful suggestions on earlier drafts. Version 2 of the article updates the “Graphical abstract” and Figure 1, adds additional evidence on investment-induced employment effects of green energy policies, and fully revises the “Key references” and “Additional references.”

Competing interests

The IZA World of Labor project is committed to the IZA Code of Conduct. The author declares to have observed the principles outlined in the code.

REFERENCES

Further reading

Couture, T. D., K. Cory, C. Kreycik, and E. Williams. *A Policymaker's Guide to Feed-in Tariff Policy Design*. National Renewable Energy Laboratory Technical Report No. NREL/TP-6A2-44849, 2010.

Frondel, M., N. Ritter, C. M. Schmidt, and C. Vance. "Economic impacts from the promotion of renewable energy technologies: The German experience." *Energy Policy* 38:8 (2010): 4048–4056.

Key references

[1] Cox, M., A. Peichl, N. Pestel, and S. Siegloch. "Labor demand effects of rising electricity prices: Evidence for Germany." *Energy Policy* 75 (2014) 266–277.

[2] Lehr, U., J. Nitsch, M. Kratzat, C. Lutz, and D. Edler. "Renewable energy and employment in Germany." *Energy Policy* 36:1 (2008): 108–117.

[3] Zhang, S., Y. Chen, X. Liu, M. Yangs, and L. Xu. "Employment effects of solar PV industry in China. A spreadsheet-based analytical model." *Energy Policy* 109 (2017): 59–65.

[4] Connolly, K., G. Allan, and S. G. McIntyre. "The evolution of green jobs in Scotland. A hybrid approach." *Energy Policy* 88 (2016): 355–360.

[5] Hillebrand, B., H. G. Buttermann, J. M. Behringer, and M. Bleuel. "The expansion of renewable energies and employment effects in Germany." *Energy Policy* 34:18 (2006): 3484–3494.

[6] Blazecjzak, J., F. Braun, D. Edler, and W.-P. Schill. "Economic effects of renewable energy expansion. A model-based analysis for Germany." *Renewable and Sustainable Energy Reviews* 40 (2014): 1070–1080.

[7] Lehr U., and P. Ulrich. "Economic impacts of renewable energy increase in Germany." In: Uyar T. (eds). *Towards 100% Renewable Energy*. Springer Proceedings in Energy. Cham: Springer, 2017.

[8] Markandya, A., A. Inaki, M. González-Eguino, and M. V.Róman. "Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union." *Applied Energy* 179 (2016): 1342–1350.

[9] Simas, M., and S. Pacca. "Assessing employment in renewable energy technologies. A case study for wind power in Brazil." *Renewable and Sustainable Energy Reviews* 31 (2014): 83–90.

[10] Garrett-Peltier, H. "Green versus brown. Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model." *Economic Modelling* 61 (2017): 439–447.

[11] Hamermesh, D. *Labor Demand*. Princeton, NJ: Princeton University Press, 1993.

[12] Deschenes, O. "Climate policy and labor markets." In: Fullerton, D., and C. Wolfram (eds). *The Design and Implementation of US Climate Policy*. Chicago, IL: University of Chicago Press, 2012.

[13] Kahn, M. E., and E. T. Mansur. "Do local energy prices and regulation affect the geographic concentration of employment?" *Journal of Public Economics* 101 (2013): 105–114.

[14] Walker, W. R. "Environmental regulation and labor reallocation." *American Economic Review: Papers and Proceedings* 101:3 (2011): 442–447.

[15] Walker, W. R. "The transitional costs of sectoral reallocation: Evidence from the Clean Air Act and the workforce." *Quarterly Journal of Economics* 128:4 (2013): 1787–1835.

Online extras

The **full reference list** for this article is available from:

https://wol.iza.org/articles/employment-effects-of-green-energy-policies

View the **evidence map** for this article:

https://wol.iza.org/articles/employment-effects-of-green-energy-policies/map