Department of Labour Economics

Hochschule der Bundesagentur für Arbeit
University of Applied Labour Studies

HdBA Discussion Papers in Labour Economics

No. 23-02

Targeted Policies to Address Adverse Effects of Phasing Out Coal

Gerald Zunker

Andreas Löschel

Jörg Lingens

Marco de Pinto

Targeted policies to address adverse effects of phasing out coal*

Gerald Zunker† Andreas Löschel‡§¶ Jörg Lingens‖ Marco de Pinto**

July 25, 2023

Abstract

Reaching the temperature targets of the Paris Agreement requires a fast and drastic reduction in coal use. Yet, phasing out coal could lead to undesirable effects such as decreasing wages and rising electricity prices. Which policies are most efficient in counteracting these potential negative effects? To address this question, we introduce a general equilibrium model that combines firm heterogeneity and endogenous market entry with an electricity sector that, inter alia, uses clean and dirty (coal) resources. Within our model, we implement a coal phase-out as well as different complementary policy measures, which subsidize (1) market entry fixed costs, (2) production fixed cost, (3) wages, or (4) electricity prices. We solve our model numerically and show that targeted policies in the form of direct subsidies counteract falling wages and increasing electricity prices at lower welfare costs. With regard to wages, we find that a direct wage subsidy of 3.5 % allows to raise the wage to its initial level prior to the coal phase-out at a welfare loss of 0.02 %, which is 10 times less compared to a market entry subsidy and more than 15 times less compared to a production fixed cost subsidy. Hence, targeted policies are superior in addressing adverse effects of a coal phase-out.

Keywords: Coal Phase-out, Policy Choice, Welfare, Regulation, Structural Change, General Equilibrium Model

JEL Codes: Q38, Q48, Q52, Q58

---

*We are grateful to Monica Giulietti and Elmar Hillebrand for helpful comments and fruitful discussions. Declarations: This work was funded by the German Federal Ministry for Education and Research, grant no. 01LA1826B (PEGASOS project). We declare that there are no competing interests.

†University of Bochum, gerald.zunker@rub.de (Corresponding Author)

‡University of Bochum, andreas.loeschel@rub.de

§Leibniz Institute for Economic Research

¶Fraunhofer Center for International Management and Knowledge Economy

‖University of Münster, joerg.lingens@wwu.de

**University of Applied Labour Studies, marco.de-pinto@hdba.de

1 Introduction

Coal-based electricity production accounts for about one third of global CO_2-emissions and represents the single most important source of emissions in many countries (Oberschelp et al. 2019; IEA 2019). A prompt coal phase-out is essential if we are to limit climate change and reach the goals of the Paris Agreement (Rinscheid and Wüstenhagen 2019). Phasing out coal, though, will lead to challenging structural transformations as coal fired power plants are the reliable and cheap backbone of many countries' electricity system (Jakob et al. 2020; Kalkuhl et al. 2019). A phase-out of coal could lead to spiking electricity prices that give rise to undesirable distributional effects. Also, the coal industry is geographically located in particular regions, even within countries. Job and income losses would hence be highly concentrated, resulting in an uneven distribution of the potential burden. This implies that the political hurdles that must be overcome to abandon coal are immense.

Against this background, there exists a discussion on which policy measures can be taken to alleviate undesirable consequences and distributional effects of a coal phase-out. This may also be an important factor for its political feasibility as a just transition is more than a moral imperative (see OECD 2019, Jakob et al. 2020, Muttitt and Kartha 2020 or Bang et al. 2022). Offering an economic perspective to coal regions and new employment opportunities to workers are important parts of a successful phase-out (Rinscheid and Wüstenhagen 2019; Green and Gambhir 2020). New opportunities also help to prevent outward migration and economic hardship, which otherwise pose a threat to the affected regions (Oei, Hermann, et al. 2020; Oei, Brauers, et al. 2020). However, not only the economic situation of coal regions is of great concern, but also the burden of rising electricity prices. They affect production opportunities and pose a major challenge to poor households (Mayer et al. 2020; Cheon and Urpelainen 2013; Ohlendorf et al. 2022). Taking these concerns into account is necessary to achieve an equitable transition, and to ensure that the coal phase-out is politically feasible (Mayer et al. 2020; He et al. 2020).

Complementary policy measures are therefore part of a successful real-world phase-out. In the German case, for example, the federal government appointed the so-called Coal Commission in 2018, which comprised of representatives from academia, energy industry, environmental organizations, labor unions, and political parties. Its goal was to develop a time-line for the coal phase-out in

Germany and to identify complementary policy measures in order to support affected regions and to promote their economic development. The Coal Commission published its recommendations as a report in early 2019, and it is rather specific about what measures should be implemented. They range from support for local companies and transfer payments for affected workers all the way to subsidies for electricity consumers (BMWK 2019). The problem, however, is that these policies aim at a relatively complex and interdependent economic structure. As such, it is not straightforward how they translate into the desired outcomes.

In this paper, we address this issue by setting up a general equilibrium framework, which accounts for an electricity producing sector inspired by Acemoglu et al. (2012) and Löschel and Otto (2009) as well an endogenous market structure with heterogeneous consumption good firms in the spirit of Melitz (2003). Within this framework, we implement a stylized coal phase-out (refraining to use coal for electricity production) as well as additional policy interventions inspired by the German Coal Commission's proposal. This includes (1) a market entry fixed cost subsidy, (2) a production fixed cost subsidy, (3) a wage subsidy, and (4) an electricity price subsidy. We solve our model numerically, using parameters from related literature, and analyze the general equilibrium effects of the coal phase-out as well as the policies. Subsequently, we discuss these effects against the background of pursuing a just transition, as we want to assess how the impacts of a coal phase-out on households and industry can be alleviated. This provides the basis for a more informed discussion about which policies may be more helpful to mitigate adverse effects in order to achieve a high level of social acceptance and political feasibility for a coal phase-out.

Our results show that phasing out coal leads, ceteris paribus, to an increase in the electricity price by 28.5 % and a decrease in the wage by 2.5 % in our model. The market structure does not change with a coal phase-out. Both the number of firms in the market and their average productivity stay the same.[1] Firms are nevertheless affected by a coal phase-out as they sell lower quantities. The reason is that decreasing wages cause labor income and hence demand for consumption goods to decrease. Welfare decreases under the coal phase-out. This is not surprising

1. The intuition behind this result is that as wages fall, input costs for firms decline. This allows less productive firms to survive, such that the number of producing firms increases, while their average productivity decreases. This, however, also leads to rising expected profits such that more firms try to enter the market. Competition becomes more intense and the productivity required for survival increases (and so does the average productivity), while the number of producing firms decreases. As these effects perfectly offset each other, average productivity and the number of producing firms return to their initial levels. The effects of the rising electricity price are the exact opposite and therefore offset each other in an analogous way.

as we do not model negative externalities caused by burning coal explicitly. We deliberately refrain from modelling these externalities, because we take the coal phase-out for granted and do not take a stand on its overall welfare effects. We are more interested in the extent to which potential policy measures can address frequently communicated public worries, namely rising electricity prices and worse economic prospects in terms of wages and jobs in the affected regions (ILO 2015; Heinrichs et al. 2017).

Regarding the policy interventions, we find that in general each of them counteracts the negative effects of a coal phase-out on wages and electricity prices. But they also decrease welfare in all scenarios. This welfare result is in line with previous literature (Jung 2012, 2015) and arises from the fact that the only additional friction in our model is due to the monopolistic market structure, which in general equilibrium does not play a role because all relative prices are solely determined by marginal costs (see, Pearce 1952 for a similar argument).[2] The important point, however, is that the policies we consider are characterized by different degrees of welfare losses. We observe that direct subsidies counteract the effects of a coal phase-out at substantially lower welfare losses. A direct wage subsidy of 3.5 %, for example, allows to raise the wage to its initial level prior to the coal phase-out at a welfare loss of 0.02 %. For comparison, raising the wage to its initial level using a production fixed cost subsidy results in a welfare loss that is 15 times larger. Thus, the welfare cost of reaching a specific goal highly depends on the policy at hands.

Our paper adds to two strands of literature. On a conceptual level, we contribute to the literature on the consequences of phasing out coal and which measures can be taken to address them. This literature, on the one hand, examines the effects of past declines in coal mining. That includes the decline in Germany during the past 60 years (Oei, Brauers, et al. 2020; Morton and Müller 2016), but also the decline in other countries such as the US (Black et al. 2005) or the UK (Aragón et al. 2018). On the other hand, it takes a forward-looking position to assess the consequences of upcoming phase-outs of coal-based electricity production. In doing so, it most

2. This result could be different if we would complement our differentiated consumption good sector by a numeraire sector that produces a homogeneous good under constant returns to scale, like Pflüger and Südekum (2013) do. Including such numeraire sector induces a mark-up distortion because the numeraire good is priced at social marginal costs whereas the differentiated varieties are priced above social marginal costs (due to mark-up pricing). Consumers spend too little on the differentiated varieties and too much on the numeraire. This distortion can be reduced by policy measures such as a market entry subsidy, which in turn leads to positive welfare effects. However, we use a one-sector setup without a numeraire sector because we want to start from a first-best solution rather than a second-best solution in order to observe the pure effect of our policies without creating friction or interaction with any imperfections.

frequently considers the effects on carbon emissions as well as the labor and energy market (Gillich et al. 2020; Keles and Yilmaz 2020; Kittel et al. 2020; Heinisch et al. 2021; Oei, Hermann, et al. 2020). Some studies, however, also address local environmental and health benefits (Rauner et al. 2020) or the public attitudes towards a phase-out (Heinrichs et al. 2017; Rinscheid and Wüstenhagen 2019). What has not been taken into account so far is that the coal phase-out as well as the proposed policy interventions might also affect the market structure. In fact, some of the policy interventions even specifically aim to change the market structure by encouraging market entry through start up grants and innovation labs, or by supporting production of new firms via investment in public infrastructure. We pick up on this point by analyzing the coal phase-out and the additional policy interventions under firm heterogeneity and endogenous firm entry. This allows us to understand the selection and reallocation effects of policies in a rich general equilibrium framework.

On an operative level, we contribute to the literature that investigates the allocative effects of policies using the heterogeneous firm model by Melitz (2003). Within this framework, not only trade policies such as import tariffs (Demidova and Rodrıguez-Clare 2009), border carbon adjustment mechanisms (Böhringer et al. 2012; Balistreri and Rutherford 2012; Balistreri et al. 2018) or subsidies for foreign direct investment (Chor 2009) have been analysed, but also questions concerning the optimal market structure. See, for example, Jung (2012) or Pflüger and Südekum (2013), who analyze the welfare effects of fixed cost subsidies. We build upon these insights when analyzing policies that aim at alleviating the negative effects of a coal phase-out. However, we extend the Melitz model to account for an electricity sector, while at the same time keeping the model tractable. This offers a new perspective for applications of the standard heterogeneous firm framework.

The remainder of our paper is structured as follows. Chapter 2 outlines the basic setup of our model, how firms behave, as well as the aggregation over firms and consumers. In chapter 3, we derive the equilibrium conditions of our model, and show how they change if we allow for policy interventions by the government. Chapter 4 presents the numerical solution of our model. That includes our parameter choice, our main results, and multiple robustness checks against alternative parameterizations. Chapter 5 concludes and discusses limitations as well as potential extensions of our model.

2 The Model

2.1 Set-Up

We consider a closed economy which is endowed with labor $\bar{L}$, a dirty resource $\bar{R}$ and a clean resource $\bar{V}$. The former resource will be interpreted as fossil fuels (part of which is coal) and the latter as renewables. There is an energy sector, where the three inputs are used to produce electricity, and there is a consumption goods sector, where labor and electricity are used to produce differentiated varieties of a commodity. Workers are mobile across both sectors.[3] Since the labor market is perfectly competitive, there is no unemployment and each worker receives the same wage w.

Representative Consumer

A representative consumer decides upon the level of demand for any given variety. The utility U of the representative consumer is given by the CES-aggregate over all available varieties M, which reads

$$U = \left[\int_0^M x(\omega)^\rho d\omega\right]^{\frac{1}{\rho}} \qquad \rho \equiv \frac{\sigma - 1}{\sigma}, \tag{1}$$

where $x(\omega)$ denotes the consumed quantity of variety ω and σ (> 1) measures the elasticity of substitution between any two varieties. Maximizing (1) and taking into account that income I equals expenditures yields the demand function

$$x(\omega) = IP^{1-\sigma}p(\omega)^{-\sigma} = Ip(\omega)^{-\sigma}, \tag{2}$$

with $p(\omega)$ denoting the price of variety ω and $P = \left(\int_0^M p(\omega)^{1-\sigma} d\omega\right)^{\frac{1}{1-\sigma}} \equiv 1$ the associated CES price index (minimum expenditure for one unit of U), which is our numeraire.

Consumption Good Sector

The consumption good sector is characterized by monopolistic competition, endogenous entry and firm heterogeneity à la Melitz (2003). We, however, allow for two inputs, the primary input labor

3. Haywood et al. (2021) estimate a simple job search framework using data on employment biographies of former German coal workers. They show that former coal workers rarely become unemployed, because they are typically highly educated, which makes a career switch or a switch to other industries fairly easy.

l and the intermediate input electricity e. The production function is

$$x(\theta) = \theta l^{\alpha} e^{1-\alpha} \quad 0 < \alpha < 1. \tag{3}$$

We assume that firm productivity θ is Pareto distributed with density $g(\theta)$, shape parameter c ($> \sigma - 1$), and lower bound b (> 0). The distribution function reads $G(\theta) = 1 - (b/\theta)^c$. Operating profits are

$$\pi(\theta) = p(\theta)x(\theta) - wl(\theta) - P_E e(\theta), \tag{4}$$

where P_E denotes the (unit) price of electricity which is purchased from the energy sector. As in Melitz (2003), firms learn about their productivity after market entry, while they decide upon production afterwards. Both market entry and production require investments, which are expressed by fixed costs measured in labor units. Market entry costs are wF, which all firms have to bear in order to be endowed with some productivity. Production fixed costs wF_D are only incurred if firms decide to take up production. Because each firm produces one unique variety, M denotes the mass of firms operating in the market.

Energy Sector

In the energy sector, there is perfect competition with an exogenously given unit mass of competitors. The production function is

$$e = L_E^{\beta} \left(R^{\varphi} + V^{\varphi}\right)^{\frac{1-\beta}{\varphi}}, \tag{5}$$

where L_E is labor that is used for the production of electricity and R and V denote the clean and dirty resource, respectively, that is used in producing electricity.[4] The elasticity of substitution between the two types of resources in the composite is given by $\sigma_E \equiv 1/(1-\varphi)$. Profit is then given by[5]

$$\pi_E = P_E e - wL_E - p_R R - p_V V. \tag{6}$$

4. This modelling approach is inspired by papers like Acemoglu et al. (2012), Löschel and Otto (2009), Otto et al. (2008) as well as Otto et al. (2007), where clean and dirty inputs are used for production under constant elasticity of substitution. However, we explicitly add labor as an input to energy production, assuming a unit elasticity of substitution between labor and the resource composite to keep the analysis tractable.

5. In the setup we present here, electricity producing firms buy the resources from resource owners at fixed prices p_R and p_V. Alternatively, we could have assumed a setup in which energy firms are vertically integrated owners of the resources. In this case, the profit is just $\pi_E = P_E e - wL_E$, which is then also the resource rent.

2.2 Firm Behavior

Consumption Good Sector

In the consumption good sector, the sequence of events is as follows. First, firms decide upon market entry and whether to start producing. After this decision, they optimally choose how much to produce and thereby how many inputs to employ.

By backwards induction, we first solve the input and production choice of a firm with productivity θ producing variety ω. Cost minimization for producing x gives the demand functions for electricity and labor. The solution is

$$e(\theta, x) = \frac{x}{\theta} \left(\frac{\alpha}{1-\alpha} \frac{P_E}{w} \right)^{-\alpha}, \tag{7}$$

$$l(\theta, x) = \frac{x}{\theta} \left(\frac{\alpha}{1-\alpha} \frac{P_E}{w} \right)^{1-\alpha}. \tag{8}$$

The cost function of a firm endowed with productivity θ is then given by

$$C(x, \theta) = x \frac{\Psi P_E^{1-\alpha} w^{\alpha}}{\theta}, \tag{9}$$

with $\Psi \equiv \left(\frac{1}{1-\alpha}\right)\left(\frac{\alpha}{1-\alpha}\right)^{-\alpha}$. The firm sets the price such that operating profits are maximized, taking the demand function (2) into account. This yields

$$p(\theta) = \frac{1}{\rho} \frac{dC(x,\theta)}{dx} = \frac{1}{\rho} \frac{C(x,\theta)}{x}, \tag{10}$$

where the last step follows from linear homogeneity of production. Operating profit in equilibrium can hence be expressed as

$$\pi(\theta) = (1-\rho) p(\theta) x(\theta) = \tau(\theta)/\sigma, \tag{11}$$

where $\tau(\theta)$ denotes firm revenue in equilibrium. Using (10) and (2), revenue reads

$$\tau(\theta) \equiv p(\theta) x(\theta) = I p(\theta)^{-(\sigma-1)} = I \left(\frac{1}{\rho} \frac{\Psi P_E^{1-\alpha} w^{\alpha}}{\theta} \right)^{-(\sigma-1)}, \tag{12}$$

which implies that τ (and hence π) in equilibrium is decreasing in wage and electricity price and increasing in productivity and the overall market size measured by aggregate income in the economy.

A firm starts production only if operating profits (weakly) exceed production fixed costs. At the margin, we have

$$\pi(\underline{\theta}) = wF_D, \tag{13}$$

where $\underline{\theta}$ denotes the lowest productivity of all firms operating in the consumption good sector. This is the Zero-Profit-Cutoff Condition (ZPC). Moreover, a firm will enter the market, i.e., being endowed with a productivity, only if expected profits (weakly) exceed market entry costs. This free-entry condition (FE) is binding and can thus be written as

$$\int_b^\infty \left(\pi(\theta) - wF_D\right) g(\theta) d\theta = wF. \tag{14}$$

Energy Sector

Firms in the energy sector maximize profits π_E by choosing the employment L_E. Considering a situation in which the resources are supplied inelastically at $\bar{R}$ and $\bar{V}$, labor demand is given by[6]

$$L_E = \left(\beta \frac{P_E}{w}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}}. \tag{15}$$

Further, we can write down the electricity supply as[7]

$$E_S = \left(\beta \frac{P_E}{w}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}}. \tag{16}$$

2.3 Aggregation

In the consumption sector, total employment and electricity demand are defined by

$$L_X = M \int_{\underline{\theta}}^\infty l(\theta)\mu(\theta) d\theta, \tag{17}$$

$$E_X = M \int_{\underline{\theta}}^\infty e(\theta)\mu(\theta) d\theta, \tag{18}$$

6. In appendix C.1, we show that the general structure of the labor demand function in the energy sector remains by and large the same if we consider positively supplied resources R and V. The difference is, however, that the adjustment need in the labor market in case of a coal phase-out is larger under positively supplied resources. The case of a fixed resource base that we consider here in the main text hence represents the conservative case concerning the distributional effects and the needs for policy adjustment under a coal phase-out.

7. The same supply structure would apply in the vertically integrated energy firm.

respectively, where we used the truncated distribution of active firms

$$\mu(\theta) \equiv g(\theta \mid \theta \geq \underline{\theta}) = \frac{g(\theta)}{1 - G(\underline{\theta})}. \tag{19}$$

Similarly to Melitz (2003), we can calculate the average productivity of firms operating in the market as

$$\tilde{\theta} = \left[\int_{\underline{\theta}}^{\infty} \theta^{\sigma-1} \mu(\theta) d\theta \right]^{\frac{1}{\sigma-1}}. \tag{20}$$

Then, aggregate employment can be expressed as $L_X = Ml(\tilde{\theta})$ and aggregate electricity use is given by $E_X = Me(\tilde{\theta})$. Aggregate operating profits are given by $\Pi = M\pi(\tilde{\theta})$. This implies that the aggregate levels are identical to a scenario where M identical firms with productivity $\tilde{\theta}$ would produce in the consumption good sector.

Since we normalize the mass of firms in the energy sector at unity, aggregate employment L_E in this sector and aggregate electricity supply E_S are given by (15) and (16), respectively.

Income is defined by

$$I = w(L_X + MF_D + M_eF + L_E) + \Pi - w(MF_D + M_eF) + P_E E_S - wL_E, \tag{21}$$

where $M_e = M(1 - G(\underline{\theta}))^{-1}$ denotes the mass of firms entering the market. Aggregate income hence consists of labor income, profits in the consumption good sector, profits in the energy sector, and the resource rent. The resource rent, however, cancels out because it is not only a rent to the resource owners, but also a cost to the energy firms.

3 Equilibrium

When deriving the equilibrium, we consider two scenarios. In the baseline framework, the economy is described as in the previous section. Then, we allow for policy interventions by the government, which alter the equilibrium conditions and outcomes compared to the baseline setting.

3.1 Baseline Framework

3.1.1 Firm-Selection

Firm-selection is measured by productivity $\underline{\theta}$ of the least productive active firm. The higher this cutoff productivity, the more intense is the firm-selection and the higher is the average productivity $\tilde{\theta}$ of operating firms (see equation (20)).

To determine $\underline{\theta}$, note that

$$\frac{\pi(\tilde{\theta})}{\pi(\underline{\theta})} = \left(\frac{\tilde{\theta}}{\underline{\theta}}\right)^{\sigma-1}. \tag{22}$$

Plugging the ZPC (13) into (22) and applying the Pareto distribution, we obtain

$$\pi(\tilde{\theta}) = \left(\frac{\tilde{\theta}}{\underline{\theta}}\right)^{\sigma-1} wF_D = \frac{c}{c-(\sigma-1)} wF_D. \tag{23}$$

This shows that the average profits in the consumption good sector are solely determined by the production fixed costs, which are a function of the ensuing equilibrium wage in the economy. This is a well-known consequence of the assumed Pareto distribution (Egger and Kreickemeier 2009; de Pinto and Michaelis 2016).

In equilibrium, expected profit can be written as

$$\begin{aligned}\int_{\underline{\theta}}^{\infty} \pi(\theta)\mu(\theta)d\theta &= \left(\int_{\underline{\theta}}^{\infty} \theta^{\sigma-1}\mu(\theta)d\theta\right) P_E^{-(\sigma-1)(1-\alpha)} w^{-(\sigma-1)\alpha} \left(\frac{\Psi}{\rho}\right)^{-(\sigma-1)} I \\ &= \tilde{\theta}^{\sigma-1} P_E^{-(\sigma-1)(1-\alpha)} w^{-(\sigma-1)\alpha} \left(\frac{\Psi}{\rho}\right)^{-(\sigma-1)} I \\ &= \pi(\tilde{\theta}).\end{aligned} \tag{24}$$

Using this, the FE (14) in equilibrium reads

$$\begin{aligned}&\int_{\underline{\theta}}^{\infty} \pi(\theta)\mu(\theta)d\theta = \frac{wF}{1-G(\underline{\theta})} + wF_D \\ \Leftrightarrow &\pi(\tilde{\theta}) = b^{-c}\underline{\theta}^{c} wF + wF_D,\end{aligned} \tag{25}$$

where the last line results from using the Pareto distribution. Inserting (23) into (25) and using

(20) as well as the Pareto distribution yields

$$\underline{\theta}^{*} = b\left(\frac{\sigma-1}{c-(\sigma-1)}\frac{F_D}{F}\right)^{\frac{1}{c}}, \tag{26}$$

$$\tilde{\theta}^{*} = b\left(\frac{c}{c-(\sigma-1)}\right)^{\frac{1}{\sigma-1}}\underline{\theta}^{*}. \tag{27}$$

The superscript $*$ indicates equilibrium outcomes.

3.1.2 Income, Mass of Firms and Input Prices

In equilibrium, income (21) is a function of aggregate revenue only, i.e.,[8]

$$I = M\tau(\tilde{\theta}). \tag{28}$$

Using (11) and (23), we obtain

$$I = M\frac{\sigma c}{c-(\sigma-1)}wF_D. \tag{29}$$

The CES price index can be expressed as

$$P = M^{-\frac{1}{\sigma-1}}\left[\int_{\underline{\theta}}^{\infty} p(\theta)^{-(\sigma-1)}\mu(\theta)d\theta\right]^{-\frac{1}{\sigma-1}} = M^{-\frac{1}{\sigma-1}}p(\tilde{\theta}). \tag{30}$$

The mass of firms has to adjust in equilibrium such that P is identical to one, as the normalization requires. Moreover, the labor endowment must be equal to the aggregate labor demand of both sectors and the electricity supply of the energy sector must be identical to the electricity demand of the consumption good sector in the equilibrium. Using the labor market clearing condition $\bar{L} = L_E + L_X$ and the energy market clearing condition $E_X = E_S$ together with (28) and (30), we

8. See appendix A for a derivation of the equilibrium income.

can then formulate a system of four equations in four unknowns (w, P_E, M, I):

$$\bar{L} = \underbrace{Ml(\tilde{\theta}^*, w, P_E, I)}_{L_X} + MF_D + M(1-G(\underline{\theta}^*))^{-1}F + \underbrace{\left(\beta \frac{P_E}{w}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}}_{L_E}, \tag{31}$$

$$\underbrace{Me(\tilde{\theta}^*, w, P_E, I)}_{E_X} = \underbrace{\left(\beta \frac{P_E}{w}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}}_{E_S}, \tag{32}$$

$$I = M \frac{\sigma c}{c - (\sigma - 1)} w F_D, \tag{33}$$

$$M = p(\tilde{\theta}^*, w, P_E)^{\sigma - 1}. \tag{34}$$

This system of equations implicitly determines the equilibrium input prices w^* and P_E^*, the equilibrium mass of firms M^* and equilibrium income I^* as function of model parameters only, for instance of the amount of dirty resource $\bar{R}$. Note that equilibrium income measures welfare as well since we normalize the price index P.

3.2 Policy Interventions

We consider four different policy interventions based on the proposal of the German Coal Commission: a market entry subsidy, a production fixed cost subsidy, a wage subsidy and an electricity price subsidy. The real-world policy instruments to subsidize market entry include, for example, start up grants and establishing innovation labs, while investments in public infrastructure are a means to subsidize production fixed costs. In order to subsidize wages and electricity prices, the Coal Commission recommends to compensate workers for wage losses and to reduce grid charges (BMWK 2019).

We designed our model in a way that allows us to implement these measures in a stylized manner. We implement the market entry subsidy S_F as a reduction in market entry cost to $wF \times (1 - S_F)$. This directly affects firm-selection, implying that the cutoff productivity is altered by this policy. Analogously, a subsidy S_{F_D} on production fixed costs implies that firms' payments to start production decrease to $wF_D \times (1 - S_{F_D})$, which also affects firm-selection. The wage subsidy S_w lowers the wage that consumption good firms and energy firms have to pay in our model to $w \times (1 - S_w)$. Workers, however, earn the full wage w. Finally, the electricity price subsidy S_{P_E} reduces the (unit) price that firms in the consumption sector must pay for electricity to $P_E \times (1 - S_{P_E})$, while firms in the energy sector still receive P_E. All interventions we consider are financed by a lump-sum tax paid by the representative consumer.

The equilibrium conditions for our policy interventions are derived in appendices B.1 and B.2.

4 Numerical Solution

4.1 Parameterization

Due to the non-linearities in our model, we rely on a numerical rather than an analytical solution. Given that we want to better understand and quantify the allocative effects of our policies and also want to gain some understanding of which policy is more effective in alleviating the effects of a coal phase-out, we choose our parameter values carefully based on the relevant literature. For a summary of our parameter values, see table 1.

For the distribution of productivities and the production fixed costs, we use parameters from Balistreri et al. (2011), who structurally estimate a Melitz model. Specifically, they estimate the shape parameter c of the Pareto distribution and the production fixed costs F_D for a variety of countries and geographical regions, using data from the Global Trade Analysis Project. As such, the parameter values we adopt for c and F_D are estimated values for Europe. To obtain their estimates, the authors use parameters from previous studies by Bernard et al. (2003) and Bernard et al. (2007), which we adopt as well.

Bernard et al. (2003) estimate the elasticity of substitution σ between varieties. To obtain this parameter, they set up a theoretical model that reflects basic facts about manufacturing plants like firm heterogeneity or higher productivity among exporters. Afterwards, they fit their model to bilateral trade data on 47 countries and more than 1,000,000 different consumption goods. Bernard et al. (2007) estimate further key parameters of the Melitz model. Specifically, they estimate the minimum productivity b and the market entry fixed cost F using plant-level U.S. manufacturing data.

The output elasticities of labor, α and β, correspond to the cost share of labor in producing electricity and consumption goods, respectively. Data on the cost shares are taken from the Genesis data base of the German Federal Statistical Office.[9]

The elasticity of substitution σ_E between clean and dirty energy resources is taken from Papageorgiou et al. (2017), who estimate this parameter within the energy aggregate of macroeconomic production functions. To do so, they exploit cross-country data on energy use by fuel for 26 countries from the new World Input Output Database (WIOD). Their estimated elasticity parameter is 1.85 for the electricity sector, which implies that clean and dirty energy resources are (gross) substitutes.

The labor endowment $\overline{L} = 7,083$ is the sum of employees (in 1,000) working in the energy sector (250) as well as the manufacturing sector (6,833) in Germany, obtained from the German Federal Statistical Office.[10]

Finally, we need parameters for the clean energy resource endowment $\overline{V}$ and the dirty energy resource endowment $\overline{R}$. We calibrate the total resource endowment $(\overline{V} + \overline{R})$ such that the total electricity demand of the consumption good sector E_X reflects its true consumption of 245.8 TWh per year (see BMWK 2021). The total amount of resources following from this calibration is $\overline{V} + \overline{R} = 121.5$. The allocation of the total energy resource endowment between clean $\overline{V}$ and dirty $\overline{R}$ resources follows their respective shares in gross electricity production in Germany. According to the Federal Ministry for Economic Affairs and Climate Action (BMWK 2021), 51.65 % of Germany's gross electricity production in 2019 originated from dirty resources (hard coal, lignite, mineral oil, natural gas, nuclear power), while 48.35 % originated from clean resources (onshore and offshore wind, hydropower, biomass, photovoltaics). This results in $\overline{V} = 121.5 \times 0.4835 = 58.75$ and $\overline{R} = 121.5 \times 0.5165 = 62.75$.

To implement a coal phase-out, we reduce the dirty resource endowment from $\overline{R} = 121.5 \times 0.5165 = 62.75$ to $\underline{R} = 121.5 \times 0.2808 = 33.89$, because coal accounts for a share of around 23.57 % in gross electricity production in Germany (BMWK 2021).

4.2 Results

In this chapter, we present our main results. First, we analyze the effects of a coal phase-out on the electricity price, wages, consumption good prices, income, and market structure, which is described

9. Data on the cost shares are taken from Genesis data bases 43221 and 42251, respectively.
10. Sectoral employment data can be found in Genesis data base 13111.

Table 1: Parameter Values Used for Numerical Solution

Parameter	Description	Value	Source
σ	Elasticity of substitution	3.8	Bernard et al. 2003
c	Shape parameter	4.582	Balistreri et al. 2011
b	Minimum productivity	0.2	Bernard et al. 2007
$\overline{L}$	Labor endowment	7,083	Federal Statistical Office
F	Market entry fixed cost	2	Bernard et al. 2007
F_D	Production fixed cost	0.33	Balistreri et al. 2011
$\overline{R}$	Dirty resource endowment (pre phase-out)	62.75	BMWK 2021
$\underline{R}$	Dirty resource endowment (post phase-out)	33.89	BMWK 2021
$\overline{V}$	Clean resource endowment	58.75	BMWK 2021
α	Output elasticity of labor (X prod.)	0.9097	Federal Statistical Office
β	Output elasticity of labor (E prod.)	0.0427	Federal Statistical Office
$\sigma_E = \frac{1}{1-\phi}$	Resource elasticity of substitution (E prod.)	1.85	Papageorgiou et al. 2017

by the mass of firms operating in the market and their average productivity. The coal phase-out is modelled by reducing the amount of dirty energy resources used for electricity production (from $\overline{R}$ to $\underline{R}$). The corresponding figure 1 shows relative values compared to the initial level before a coal phase-out, where values smaller (larger) than one indicate decreases (increases).[11] Second, we investigate the impact of the aforementioned policy interventions. The starting point for this analysis is the new equilibrium we obtain after implementing a coal phase-out. We consider policies individually to focus on their generic effect on the above mentioned outcomes. For each policy, we gradually increase the strength of the subsidy starting at 0 and reaching to more than 50 % subsidization.[12] Third, we evaluate which of our policy interventions might be the most suitable to soften or even reverse potential negative effects of a coal phase-out in order to achieve high levels of acceptance by households and industry.

4.2.1 Coal Phase-Out

In the energy market, phasing out coal leads to lower supply of electricity, which causes the electricity price to rise (figure 1a). At the same time, energy firms demand less labor when they reduce their production, which leads to layoffs. Workers who lose their job in the energy sector reallocate to the consumption good sector because workers are perfectly mobile between sectors. This process

11. For the robustness checks, looking at relative values also makes it easier to compare results between different parameterizations.

12. We limit the plot range to only account for subsidies that seem to be politically feasible. In addition, we check that the government's budget constraint is met for all plotted values, that is, we ensure that total subsidy spending does not exceed income.

of reallocating workers to the consumption good sector leads to lower wages since labor demand in the energy sector decreases and labor supply in the consumption good sector increases (figure 1b). Although the wage and the electricity price change, marginal costs for any given productivity level remain constant, because the increase in electricity costs is perfectly offset by the decrease in wage costs. This reflects the linear-homogeneous production structure of our model where marginal costs do not vary with the size of the economy.

Figure 1: Coal Exit

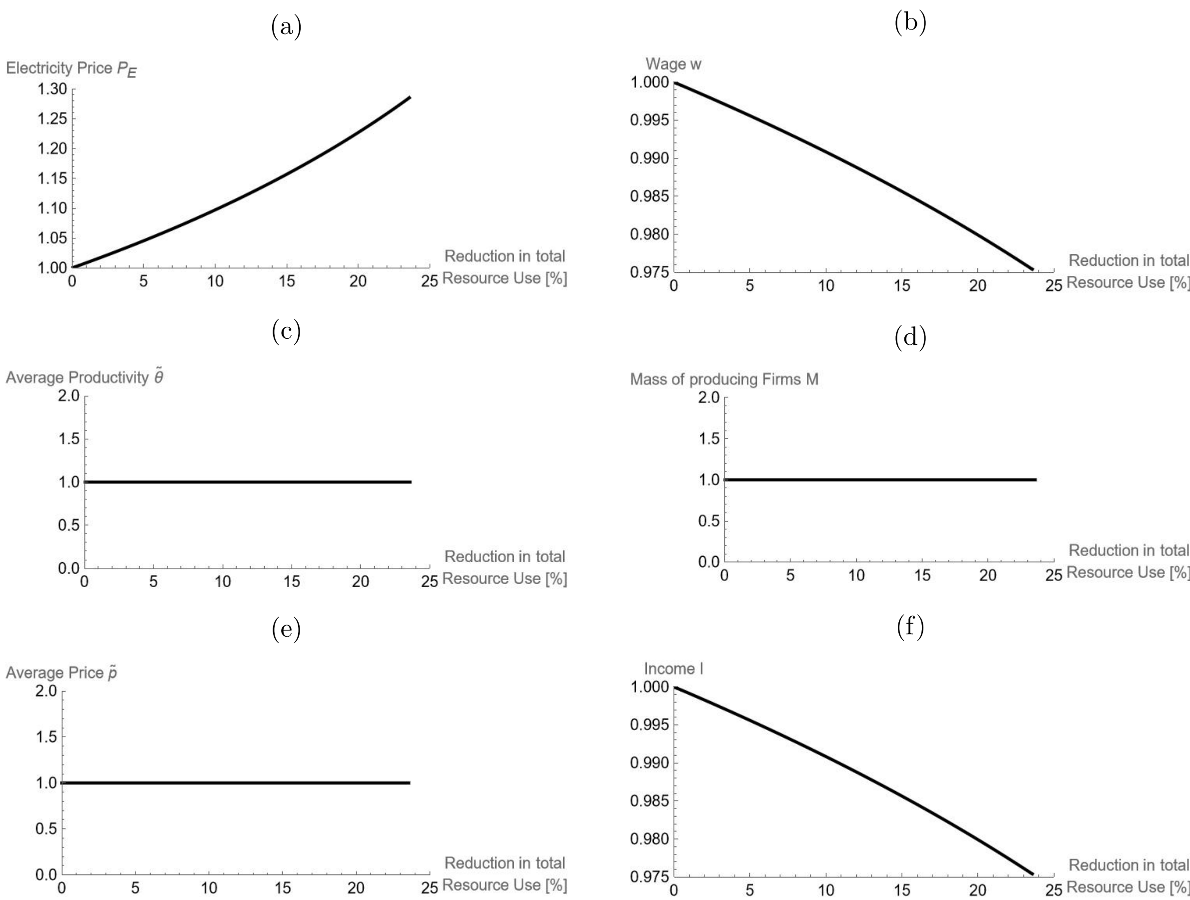

Figure 1 shows the effects of a coal phase-out on the different equilibrium variables in our model. All values are relative to the initial equilibrium levels before a coal phase-out.

As shown in figures 1c and 1d, the market structure is unaffected by a coal phase-out. Intuitively, expected profits increase because the decline in wages implies a reduction of fixed costs. This reduces, ceteris paribus, the cutoff productivity. If more firms are sufficiently productive to earn positive operational profits, though, the mass of firms increases. This leads to fiercer competition and raises, ceteris paribus, the cutoff productivity. Due to our model specification, all firms are equally affected by these two effects, such that the effects equalize and the cutoff productivity remains constant.[13] Accordingly, the average productivity of active firms also remains constant. With respect to the mass of firms, there is also an offsetting mechanism. Since energy prices are higher, expected profits, ceteris paribus, decline, which reduces the mass of firms to its initial level. An implication of the constant average productivity, combined with the constant marginal costs discussed above, is that the average price of consumption goods remains constant (figure 1e).

Finally, income and hence welfare decline (figure 1f), which is due to the reduction in wage income.

4.2.2 Policy Interventions

Market Entry Subsidy

One of the major concerns associated with a coal phase-out is that it might deteriorate the economic production base of affected regions. This fear is deeply rooted among citizens living in coal areas, mainly because of negative experiences with structural change in the past (Johnstone and Kivimaa 2018; Brauers and Oei 2020; Campbell, Coenen, et al. 2017; UBA 2022). In order to stabilize the industry structure when regions face a coal phase-out, it is often considered to support market entry of new firms. This is also reflected in the suggestions of the German Coal Commission, which aim to facilitate market entry through multiple tools. This includes, for example, providing financial support through start up grants and establishing innovation labs, which encourage creative ideas and foster swift product development (BMWK 2019).

In our model, a market entry subsidy increases expected profits net of market entry costs, which raises the mass of firms entering the market. Competition hence becomes more severe, which leads to an increase in the cutoff productivity and a decrease in the mass of active firms (figure 2a). If the cutoff productivity increases, the average productivity of active firms increases as well (figure 2b). This yields, ceteris paribus, a reduction of the average price of consumption goods (figure 2c). Moreover, labor demand increases since the number of entering firms rises. This, in turn, causes the wage to increase (figure 2d).

13. This result is analogous to papers like Egger and Kreickemeier (2009) and de Pinto and Michaelis (2016), where the market structure is also independent of the input quantities.

Figure 2: Market Entry Subsidy

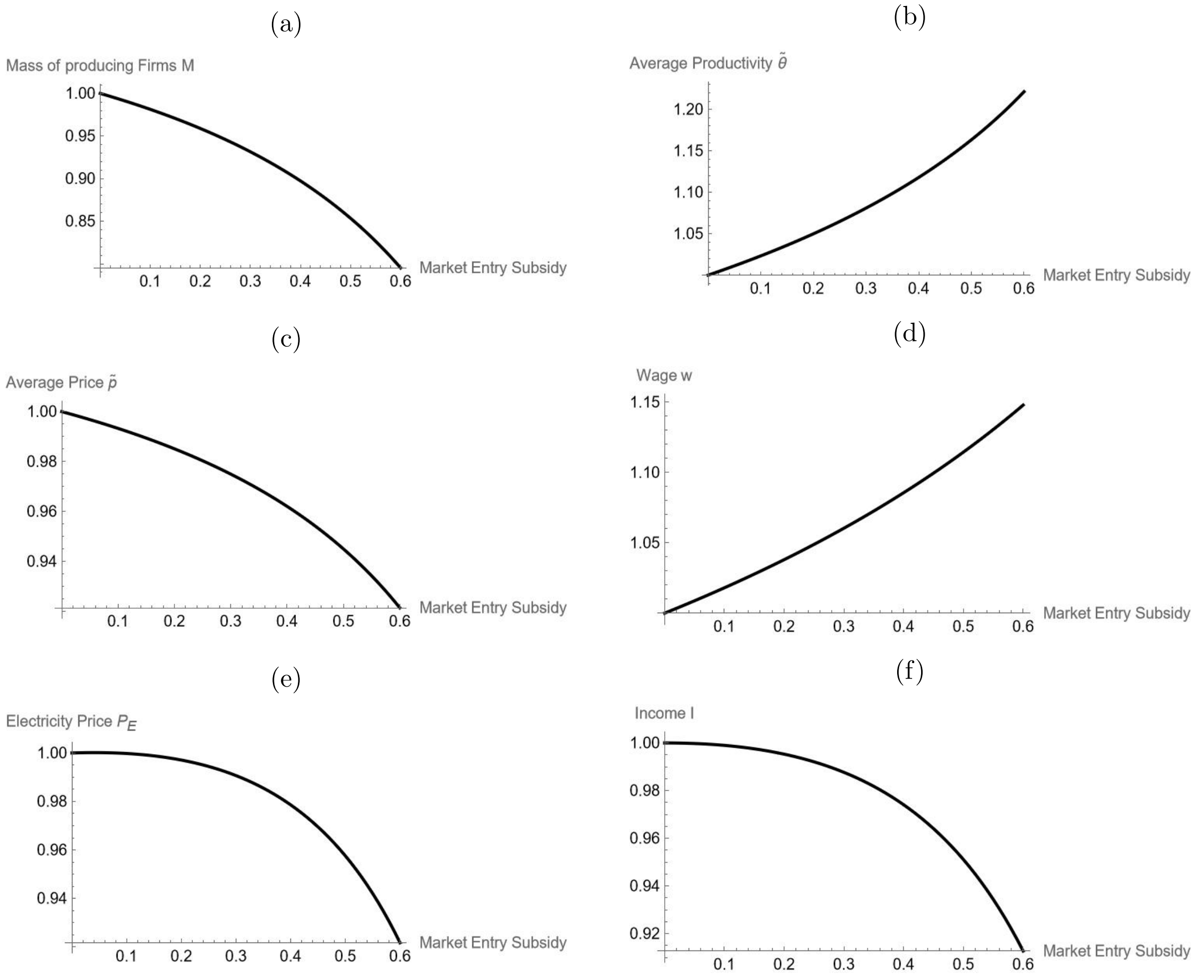

Figure 2 shows the effects of a market entry subsidy on the different equilibrium variables in our model. All values are relative to the equilibrium levels after a coal phase-out.

Regarding the electricity market, there are opposing effects. On the one hand, the reduction of active firms leads to a decrease in electricity demand. On the other hand, firms are on average larger and demand more electricity for production purposes. Additionally, the increase in wages leads to a substitution towards more energy intensive production, which further increases electricity demand. In case of a small subsidy, the latter effects outweigh the former, resulting in higher electricity demand and higher electricity price. For larger subsidies, the former effect dominates, such that electricity demand and electricity price decrease. Thus, the electricity price is a hump-shaped function of the subsidy (figure 2e).[14] Although the described opposing effects are relevant for the

14. The hump shape is difficult to see in figure 2e due to the scaling. We have chosen this scaling, however, in order to (1) show the full range of the effect and (2) to make the graphs uniform and hence comparable with each other.

labor market as well, the wage decreasing effect of having less active firms in the market never dominates. This is due to the fact that the increased demand for market entry workers puts comparatively stronger upward pressure on the wage.

Concerning welfare, the subsidy distorts the allocation of labor towards producing the fixed market entry resource, which leads to decreasing income (figure 2f). This is due to the aforementioned effect that we start from a first-best situation, since the implicit externality that results from coal-fired electricity generation has been internalized by limiting coal use via command and control.

Production Fixed Cost Subsidy

Subsidies towards production fixed costs aim at stabilizing the industry structure in a similar way as a market entry subsidy. Practical approaches to subsidizing production fixed costs include measures like innovation funds that provide financial support to growth-oriented, emerging companies (BMWK 2019). An alternative way to reduce production fixed costs, which is considered a priority by the German Coal Commission, is investment in public infrastructure (Egger and Falkinger 2006; Bougheas et al. 2000; BMWK 2019).

When production fixed cost are subsidized, the expected profit from entering the market increases. This creates an incentive for more firms to enter the market, which implies fiercer competition. However, starting production also becomes cheaper. This first-order effect dominates the change in competition intensity, such that the cutoff productivity and hence the average productivity decline (figure 3a). The average price for consumption goods therefore increases, ceteris paribus (figure 3b).

Figure 3: Production Fixed Costs Subsidy

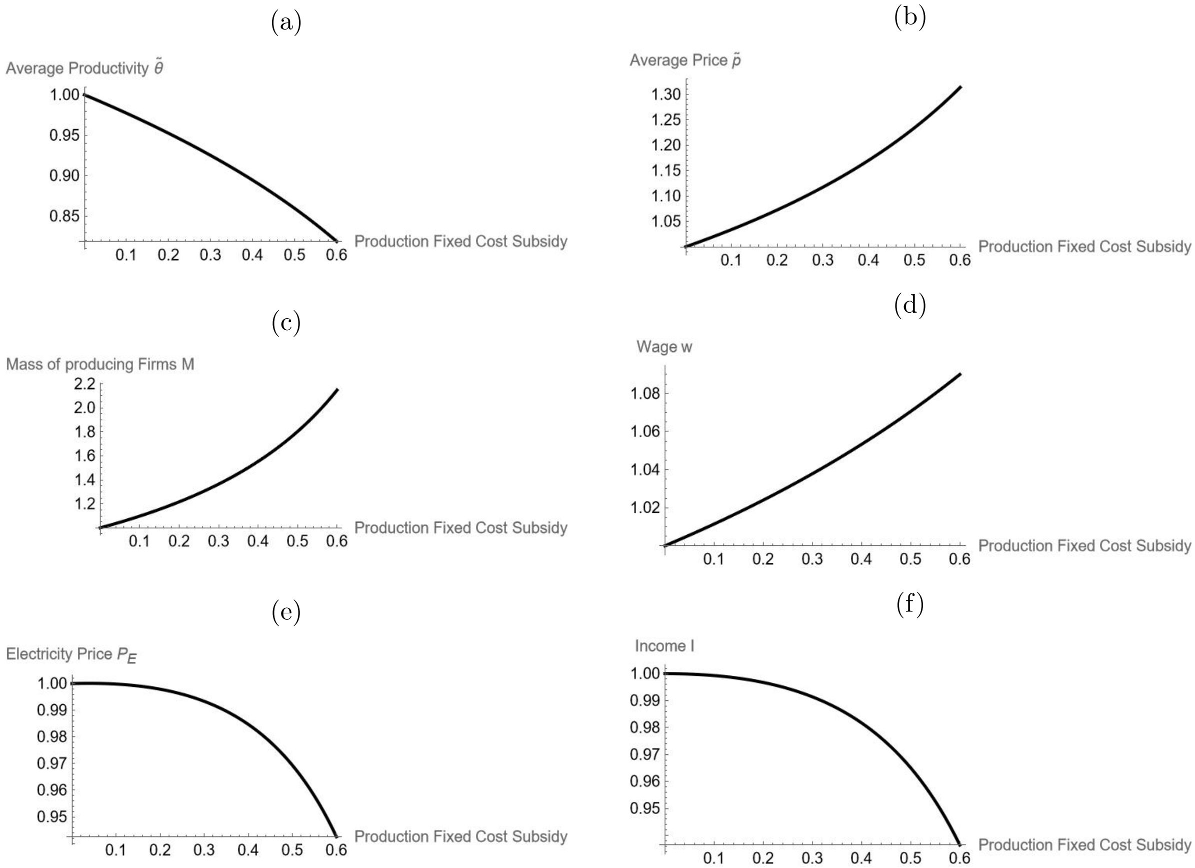

Figure 3 shows the effects of a production fixed cost subsidy on the different equilibrium variables in our model. All values are relative to the equilibrium levels after a coal phase-out.

Although firms are on average less productive and hence smaller, there will be more producing firms in the market (figure 3c), which has repercussions on the input markets. Aggregate labor demand (for production purposes but also for producing the fixed production resource) increases such that the wage increases (figure 3d). Regarding the electricity market, there are again opposing effects. First, increasing wages induce a substitution towards more energy-intense production. Second, there are more producing firms in the market. What opposes these effects is that firms are smaller and therefore demand less electricity on average. Analog to the market entry subsidy, the electricity demand increasing effects dominate in case of a small subsidy, while the demand decreasing effect dominates in case of a larger subsidy. As a result, the electricity price also responds in a hump-shaped way to the production fixed cost subsidy (figure 3e).

Welfare again decreases compared to the initial situation of a coal phase-out without any additional policy (figure 3f). The production fixed cost subsidy causes a misallocation of labor resulting in too many firms entering the market that are on average insufficiently productive. The important question, however, that we will discuss when evaluating the different policies, is which policy can stabilize declining wages and rising electricity prices caused by the coal phase-out at a lower welfare cost.

Wage Subsidy

Among the main arguments raised by opponents of a coal phase-out is that workers in the energy industry lose their jobs and hence face worse wage prospects (or employment prospects in a rigid wage setting). They frequently refer to threatened livelihoods and emphasize that workers in the energy industry would be disproportionately burdened (Leipprand and Flachsland 2018). The German Coal Commission therefore proposes to address these concerns directly by subsidizing wages. (BMWK 2019).

A wage subsidy decreases wage payments by firms without putting pressure on household wages (compare figures 4a and 4b). It thereby leads to higher labor demand in the consumption good sector as well as the energy sector. Since wages are subsidized, but electricity prices are not, firms in the consumption good sector adjust their production and substitute away from electricity to produce more labor intensive. This causes electricity demand and hence the electricity price to decrease (figure 4c).

The cutoff productivity is unaffected by the subsidy. There are two effects that offset each other. On the one hand, production costs decrease due to the wage subsidy, which raises expected profits. More firms enter the market, such that competition becomes more intense. On the other hand, starting production is easier for firms as production costs decline. The former effect raises the cutoff productivity, while the latter reduces it. On balance, the cutoff productivity remains constant, and so does the average productivity (figure 4d).

Figure 4: Wage Subsidy

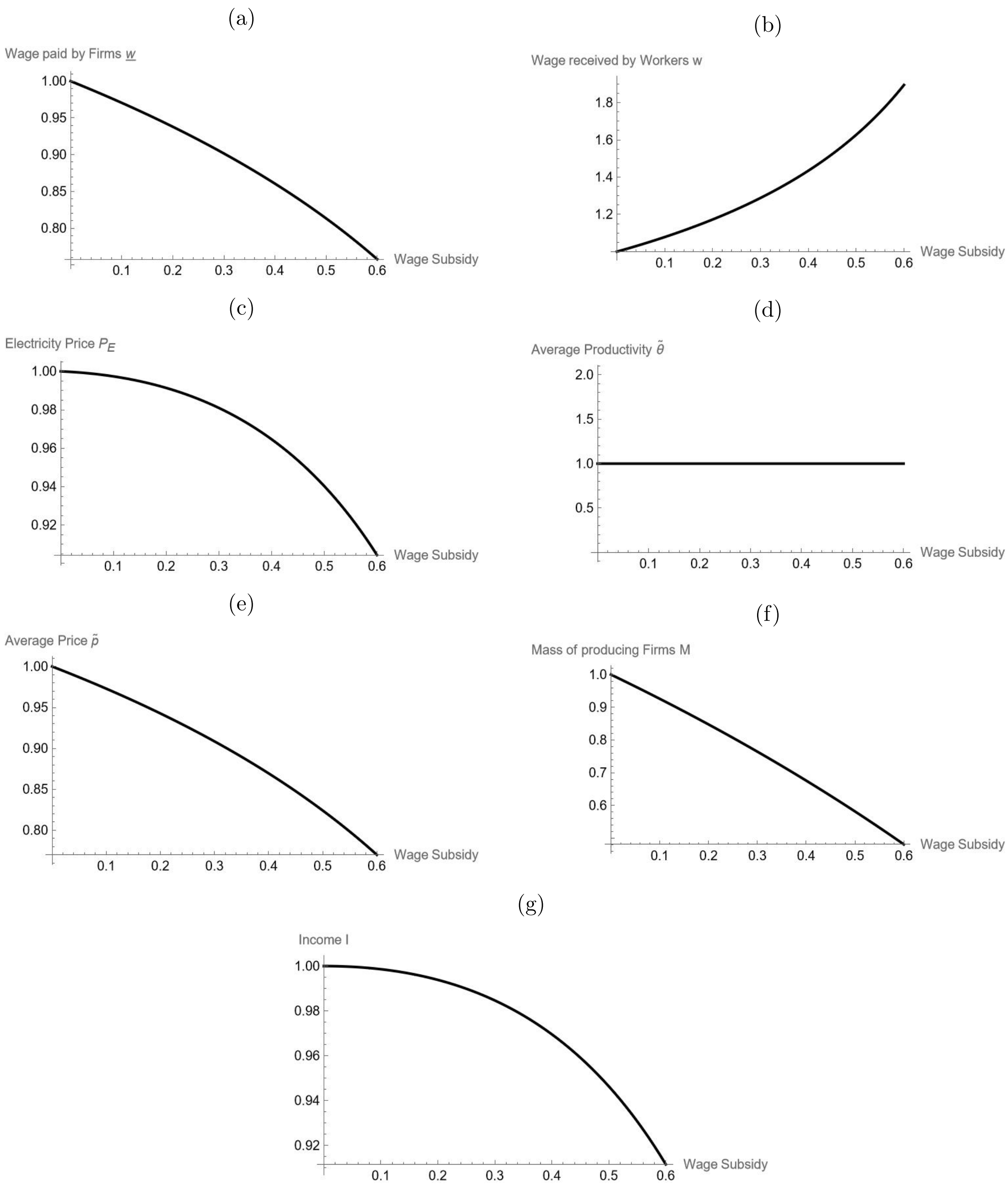

Figure 4 shows the effects of a wage subsidy on the different equilibrium variables in our model. All values are relative to the equilibrium levels after a coal phase-out.

Since wages (from the firms' perspective) and electricity prices decline, marginal production costs decrease, which reduces the average price of consumption goods (figure 4e). This, in turn, leads to fiercer competition, which has a detrimental effect on consumption good firms as it forces part of them to exit the market. Consequently, the mass of producing firms declines (figure 4f).

With increasing wages for workers, one would expect that income also increases. The subsidy, however, is financed by a lump-sum tax. The effect of the tax outweighs the effect from rising wages, which leads to a decreasing income (figure 4g).

Electricity Price Subsidy

Low (or at least stable) electricity prices are being perceived as an important prerequisite for the acceptability of any reform or transformation in the energy sector. Firms need reliable and cheap electricity for production purposes and households consider cheap electricity as an important factor determining their subjective well-being (Welsch and Biermann 2014). A potential way to achieve this objective is a direct electricity price subsidy, which could be implemented, for example, through a reduction in grid charges (BMWK 2019).

An electricity price subsidy drives a wedge between the electricity price that energy producers receive and the price consumption good firms have to pay (compare figure 5a and 5b). In the consumption good sector, this results in a substitution away from labor, putting downward pressure on the wage. But since electricity producing firms expand and increase their labor demand, this is more than offset, causing the wage to increase (figure 5c).

Figure 5: Electricity Price Subsidy

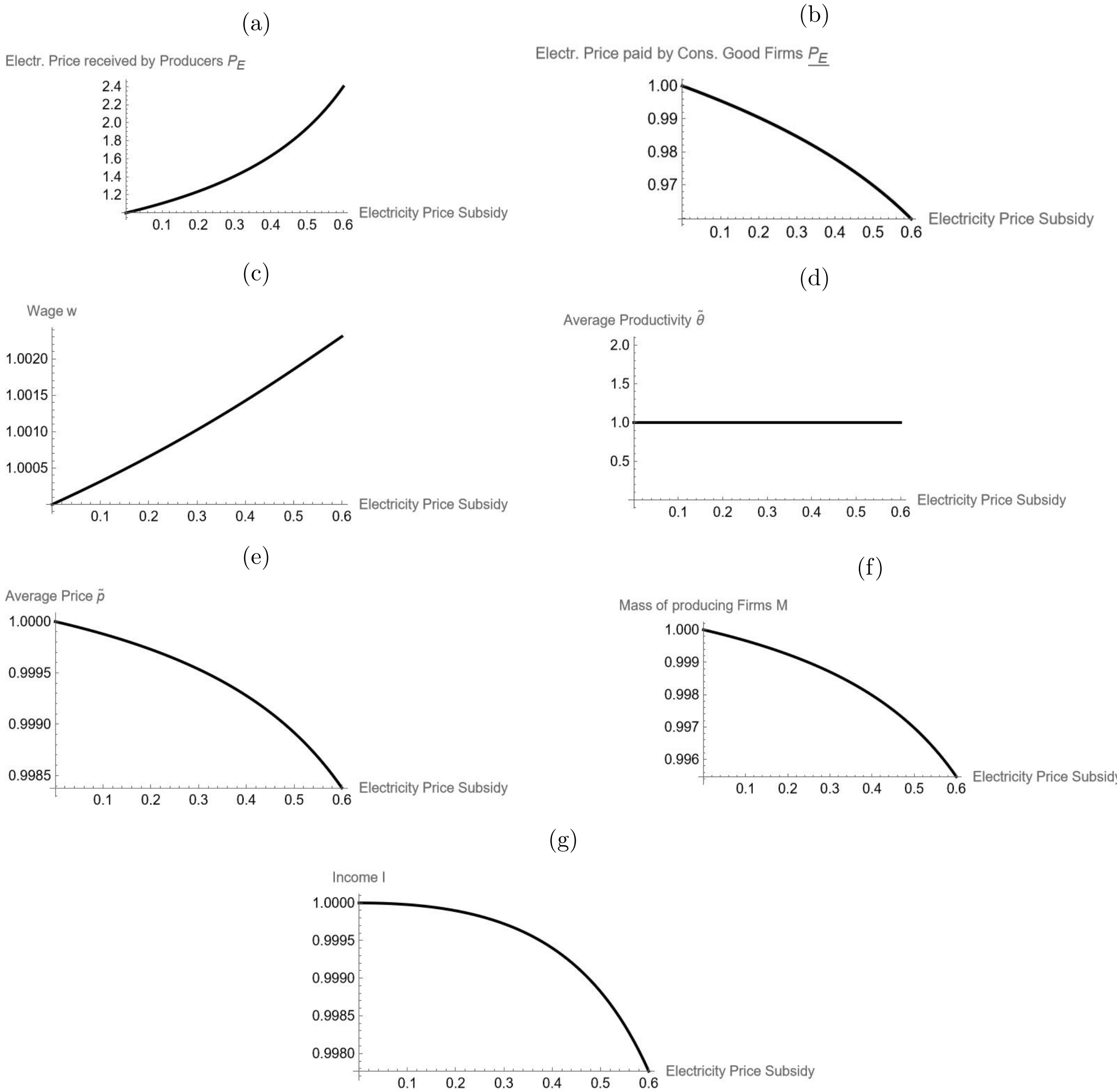

Figure 5 shows the effects of an electricity price subsidy on the different equilibrium variables in our model.
All values are relative to the equilibrium levels after a coal phase-out.

The decline in production costs for consumption good firms has very similar effects, compared to a wage subsidy. Due to the same offsetting mechanism (see above), average productivity remains constant (figure 5d). Marginal production costs in the consumption sector and the average price of consumption goods decline (figure 5e), because the decrease in the electricity price outweighs the increase in the wage. Therefore, the mass of firms operating in the market declines under an electricity price subsidy as well (figure 5f).

Income also decreases (figure 5g). This is due to the fact that rising wages and the resulting increase in labor income cannot compensate for the financing cost (lump-sum tax).

4.2.3 Policy Comparison

A coal phase-out leads to a decline in both electricity supply and labor demand. This inevitably causes consumption good firms to pay a higher price for electricity, while workers receive lower wages (or face worse employment prospects in a rigid wage setting).[15] Such shocks on the labor or the energy market tend to result in strong political opposition. They diminish voters' trust in political institutions as well as their support for political measures (Jensen et al. 2017; Im et al. 2019; Margalit 2019; Baccini and Weymouth 2021; Egli et al. 2022), while at the same time boosting efforts to prevent or soften policies via lobbying (Kim et al. 2016; Gullberg 2008; Markussen and Svendsen 2005; Li et al. 2019; Cadoret and Padovano 2016). Keeping energy prices stable and creating employment opportunities for workers are hence key elements of a politically feasible coal phase-out. Here, we therefore evaluate which of the policy measures at hand alleviates the impact of the coal phase-out on the wage or the electricity price at a lower welfare costs. In addition, we examine whether we can possibly even return the wage or the electricity price to their initial level prior to the coal phase-out, and what welfare losses would be associated with this.

Regarding the effect of the coal phase-out on the labor market, we find that the most efficient way to counteract deteriorating wages is a direct wage subsidy. It increases the wage at considerably lower welfare costs, compared to the other policy measures we consider. We illustrate the differences between the individual measures in figure 6. On the vertical axis, it shows the increase in wages under the different subsidies, and on the horizontal axis, it shows the associated welfare costs. Thereby, values above (below) one indicate increases (decreases) in the wage relative to the equilibrium level after a coal phase-out.

15. For comparable results regarding the effects of a coal phase-out on the labor market and the electricity market, see Heinisch et al. (2021) and Keles and Yilmaz (2020), respectively.

Figure 6: Policy Comparison: Effects on the Wage

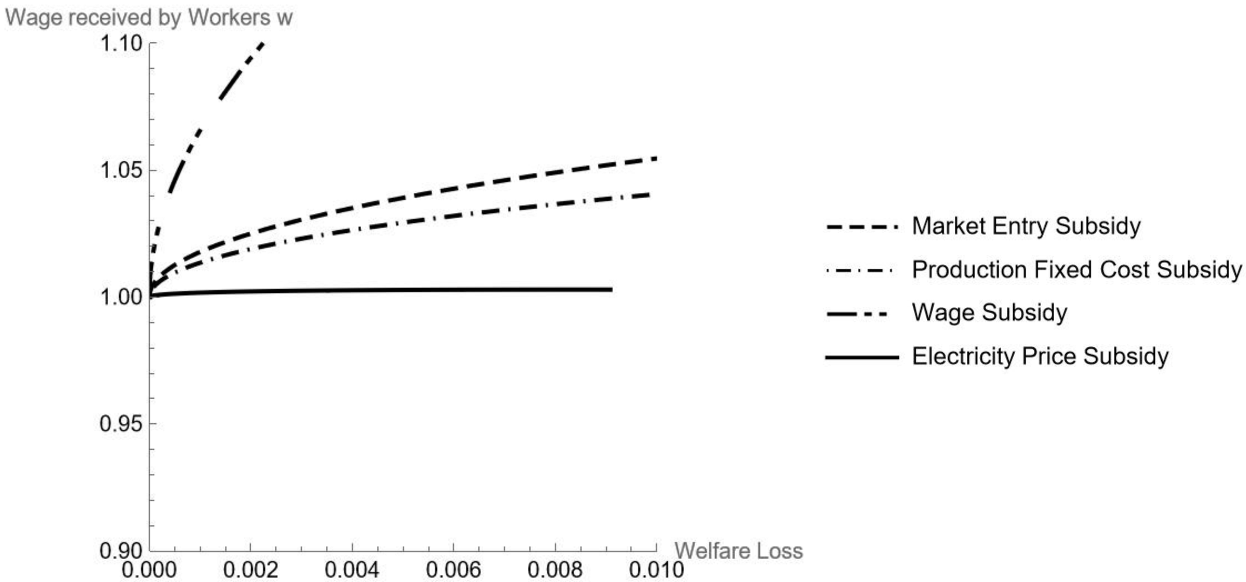

Figure 6 shows the effects of the proposed policies on the equilibrium wage in our model as well as the associated welfare losses. All values are relative to the equilibrium wage level after a coal phase-out.

If we set the specific goal to raise the wage to its initial level prior to the coal phase-out, a 3.5 % wage subsidy is sufficient, implying a welfare loss of only 0.02 % (compare table 2). If a market entry subsidy were used instead, a 14 % subsidy would be needed to restore wages. The associated welfare loss, though, would be 10 times larger compared to the direct wage subsidy. In case of a fixed production cost subsidy, a 21 % subsidy would be required, which would decrease welfare more than 15 times as much as the direct wage subsidy. Moreover, such a strong production fixed cost subsidy would reduce the average productivity of consumption good firms by about 5 % and thereby raise the average price of consumption goods by more than 7 %. An electricity price subsidy, though, does not allow to restore the wage. Its effect on wages is so small that the subsidy expenditure exceeds the economy's income before we reach the initial wage level prior to the coal phase-out (denoted as 'N/A' in table 2).

If we aim to keep the electricity price stable, the direct subsidy is the preferable option.[16] For any given welfare loss, it reduces the electricity price that consumption good firms pay to the largest extent among all policy interventions we consider (compare figure 7). In addition, it has

16. Our finding that we can stabilize the wage and the electricity price at lower welfare costs if we address them directly is consistent with previous studies. Fischer and Newell (2008), for example, assess different policy options (emissions tax, fossil fuels tax, direct renewables subsidy, renewables R&D subsidy) to increase renewable energy production, and evaluate their performance with respect to welfare. They find that the direct subsidy is the most efficient policy to boost renewables production.

Table 2: Effects of Restoring the Wage

	F Sub	F_D Sub	w Sub	P_E Sub
Required Subsidy	14%	21%	3.5%	N/A
Electricity price (received)	-0.09%	-0.24%	-0.06%	N/A
Electricity price (paid)	-0.09%	-0.24%	-0.06%	N/A
Wage (received)	2.53%	2.53%	2.53%	N/A
Wage (paid)	2.53%	2.53%	-0.99%	N/A
Average productivity	3.35%	-5.01%	0%	N/A
Average price	-0.98%	7.68%	-0.92%	N/A
Mass of firms	-2.72%	23.01%	-2.54%	N/A
Income/Welfare	-0.21%	-0.36%	-0.02%	N/A

almost no effect on other equilibrium variables. However, even though the direct subsidy offers the strongest decrease in the electricity price, it is not possible to drive the electricity price down to its initial level prior to the coal phase-out. Introducing an electricity price subsidy creates an incentive for energy companies to produce more electricity since they receive a higher price. At the same time, it creates an incentive for consumption good firms to use more electricity because electricity as an input becomes cheaper. As the equilibrium quantity increases, the marginal cost of producing electricity increase exponentially, whereas consumption good firms' marginal willingness to pay for electricity decreases less sharply. Electricity supply thereby becomes less price elastic, whereas electricity demand becomes more price elastic. The price increasing effect of the subsidy on producers' prices hence becomes relatively stronger compared to the price decreasing effect on consumption good firms' prices. Lowering prices for consumption good firms thus requires increasingly large subsidy expenditures and comes at increasingly large welfare losses (figure 7). As such, the budget needed for the subsidy exceeds the economy's income before we can reach the initial electricity price level.

Figure 7: Policy Comparison: Effects on the Electricity Price

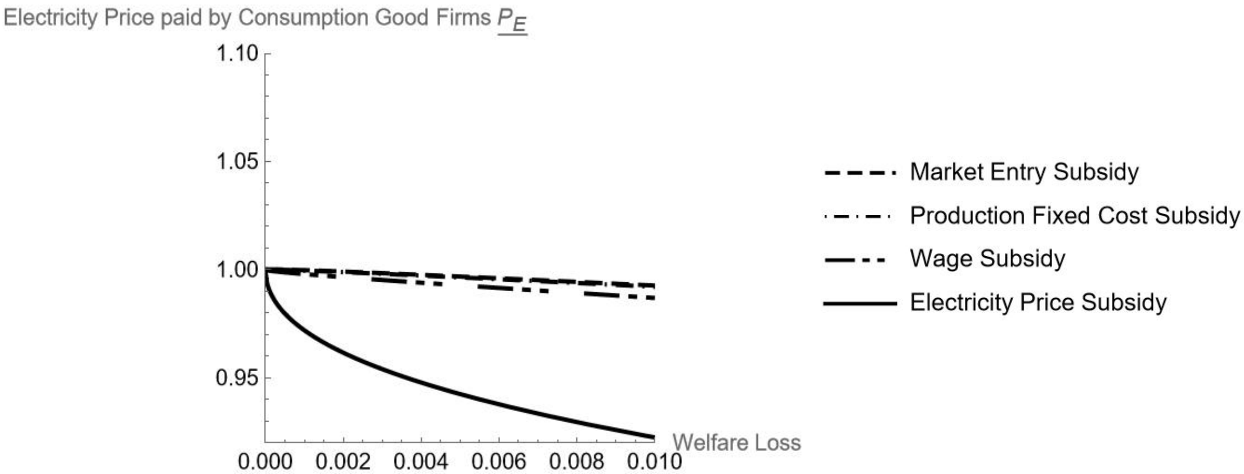

Figure 7 shows the effects of the proposed policies on the equilibrium electricity price in our model as well as the associated welfare losses. All values are relative to the equilibrium electricity price after a coal phase-out.

4.3 Robustness

To test whether our results are robust, we solve our model with several alternative parameterizations and investigate whether they lead to qualitatively and quantitatively similar results. In this section, we describe which alternative parameterizations we use for the robustness checks and what results they generate.

4.3.1 Alternative Parameterizations

We first check the robustness of our results against alternative parameterizations from the related literature (parameterizations 2 to 7 in table 3). This includes Pflüger and Südekum (2013), Chor (2009), de Pinto and Lingens (2019), Felbermayr and Prat (2011), Cui (2017) and Bernard et al. (2007). Their parameterizations differ in terms of the elasticity of substitution, distribution of productivities (shape & minimum productivity), labor endowment as well as fixed costs for market entry and production.[17]

For the robustness against alternative resource endowments, we consider both a parameterization, where the energy resource endowment is 10 times larger (parameterization 8), as well as a

17. While testing these parameterizations, we avoid any further changes in the parameter values. We always maintain 1) the same ratio between labor endowment and energy resource endowment as in the main parameterization, 2) the same ratio of dirty to clean resources (51.65 % dirty & 48.35 % clean), and 3) reduce the use of dirty resources by the same proportion when phasing out coal.

parameterization, where the energy resource endowment is 10 times smaller (parameterization 9), compared to our main parameterization.

Regarding the output elasticities in the consumption good sector, there is a debate on whether they actually correspond to their cost shares or not. Kümmel et al. (2015), Kümmel and Lindenberger (2014), Kümmel et al. (2010), Ayres et al. (2013), and Lindenberger and Kümmel (2011) argue that the output elasticity must be smaller for labor and larger for electricity to reflect historical economic growth in Germany, Japan, or the US. To account for this possibility, we test for the robustness of our results against a lower output elasticity of labor, which comes hand-in-hand with a higher output elasticity of electricity (parameterization 10). The parameter value that we use for this parameterization is an estimate from Lindenberger and Kümmel (2011). To the best of our knowledge, their estimate is the lowest value in the literature and hence the one that differs most from our main parameterization.

In our main parameterization, we assume a value of 1.85 for the elasticity of resource substitution σ_E. For our robustness checks, we consider a higher elasticity of substitution (parameterization 12), which implies that energy resources substitute more easily for each other. Specifically, we assume a value of $\sigma_E = 3$, which is taken from Acemoglu et al. (2012). We do not consider the case of complementary energy resources ($\sigma_E < 1$), because the case of substitutes ($\sigma_E > 1$) seems to be the empirically more relevant benchmark (Stern 2012).[18]

Finally, we also check the robustness against alternative output elasticities in the energy sector for the sake of completeness. We consider a higher output elasticity for labor and hence a lower output elasticity of resources (parameterization 11).

Table 3 provides an overview of all alternative parameterizations we consider. Parameter values that differ from our main parameterization are highlighted in bold letters.

18. In a meta-analysis, Stern (2012) summarizes the results of 47 studies on the elasticity of substitution between different energy resources and none of them reports complementary energy resources.

Table 3: Alternative Parameterizations for Robustness Check

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		Main Parameterization	Pflüger & Südekum 2013	Chor 2009	de Pinto & Lingens 2019	Felbermayr & Prat 2011	Cui 2017	Bernard et al. 2007	High Resource End.	Low Resource End.	Low Output Elast. (X)	High Output Elast. (E)	High Elast. of Res. Sub.
Parameter	Description	Values											
σ	Elasticity of subst.	3.8	3.8	3.8	3.8	**8.6**	**4.0**	3.8	3.8	3.8	3.8	3.8	3.8
c	Shape parameter	4.582	**3.4**	**3.4**	4.582	**9.23**	**4.25**	**3.4**	4.582	4.582	4.582	4.582	4.582
m	Minimum prod.	0.2	**0.1**	**0.04**	0.2	**0.62**	**0**	0.2	0.2	0.2	0.2	0.2	0.2
$\overline{L}$	Labor endowment	7,083	**100**	**100,000**	**2**	**1**	**1,362**	**1,000**	7,083	7,083	7,083	7,083	7,083
F	Market entry fixed cost	2	2	**100**	2	**0.6**	**1**	2	2	2	2	2	2
F_D	Production fixed cost	0.33	**1**	**10**	**0.251**	**0.01**	**1**	**0.1**	0.33	0.33	0.33	0.33	0.33
$\overline{R}$	Dirty res. end. (ex ante)	62.75	0.8860	886.0	0.0177	0.0089	12.067	8.860	**627.5**	**6.275**	62.75	62.75	62.75
$\underline{R}$	Dirty res. end. (ex post)	33.89	0.4817	481.7	0.0096	0.0048	6.560	4.817	**338.9**	**3.389**	33.89	33.89	33.89
$\overline{V}$	Clean resource end.	58.75	0.8294	829.4	0.0166	0.0083	11.296	8.294	**587.5**	**5.875**	58.75	58.75	58.75
α	Outp. elast. labor (X)	0.9097	0.9097	0.9097	0.9097	0.9097	0.9097	0.9097	0.9097	0.9097	**0.53**	0.9097	0.9097
β	Outp. elast. labor (E)	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	0.0427	**0.10**	0.0427
$\sigma_E = \frac{1}{1-\phi}$	Resource elast. of subst.	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	**3.00**

4.3.2 Results

Our robustness checks show that none of the alternative parameterizations qualitatively changes our results. The effects of the coal phase-out and the individual policy interventions are qualitatively identical under all parameterizations. With regard to our policy comparison, we find that direct subsidies always counteract falling wages and increasing electricity prices at lower welfare costs. We further observe that we can never drive the electricity price down to its initial level prior to the coal phase-out, but that we can always restore the wage. We hence argue that our results are qualitatively robust.

In terms of quantitative robustness, we find that our results for the coal phase-out are quantitatively identical under most alternative parameterizations, indicating that they are independent of most parameter values. There are only three exceptions.

First, under a higher elasticity of resource substitution (parameterization 12), the electricity supply of the energy sector decreases less in case of a coal phase-out, since the reduction in dirty resource use is more easily substituted by clean resources. If the initial effect on the energy sector is smaller, this also softens all subsequent effects in our model. We therefore observe a smaller increase in the electricity price, a smaller decrease in the wage, as well as a smaller decrease in income. Compared to our main parameterization, though, the quantitative differences are very small, since the elasticity of resource substitution is already high under the main parameterization.

Second, if one assumes a higher output elasticity for labor and hence a lower output elasticity for resources in the energy sector (parameterization 11), the electricity supply decreases less sharply under a coal phase-out. The initial effect in the energy sector is therefore smaller such that all subsequent effects are smaller as well (similar to the case of a higher elasticity of resource substitution).

Third, if we consider a lower output elasticity for labor and hence a higher output elasticity for electricity in the consumption good sector (parameterization 10), the reduction in electricity supply caused by a coal phase-out forces consumption good firms to scale down production to a larger extent. They hence reduce both their labor demand and their electricity demand more sharply. In comparison to the main parameterization, this leads to a stronger decrease in the wage, but a smaller increase in the electricity price.

Next, we consider the quantitative robustness of our individual policy measures and our policy comparison. For the effects of the individual policy measures, we find that our results only differ in the percentage range under the alternative parameterizations, and in most cases even in the per thousand range. We further observe that a direct wage subsidy between 3.0 % and 3.5 % is sufficient to raise the wage to its initial level prior to the coal phase-out under almost every alternative parameterization. This is on par with or even below the required subsidy level of our main parameterization. The same applies to the associated welfare losses. Ranging between 0.01 % and 0.02 %, they are just as large or even smaller than under our main parameterization.

The only exception where a substantially larger subsidy is required to restore the wage level is under a lower output elasticity for labor in the consumption good sector (parameterization 10). If the output elasticity is lower, wages decrease more strongly in case of a coal phase-out (as explained above). Thus, bringing wages up to their initial level before the coal phase-out requires a stronger wage subsidy (19 %) and causes a larger welfare loss (0.5 %). However, restoring wages would, due to the larger decline, also require a stronger market entry subsidy or a stronger production fixed cost subsidy. The market entry subsidy would need to be at 41 % and the production fixed cost subsidy as high as 55.5 %. Such high subsidies, in turn, not only seem to be hardly feasible from a political perspective, but they would also cause even greater welfare losses. Specifically, they would be 5 times larger (2.5 %) under a market entry and 9 times larger (4.5 %) under a production fixed, compared to the direct wage subsidy. We hence argue that even for this parameterization the key message of our paper, that falling wages can be compensated at substantially lower welfare costs if they are subsidized directly, is quantitatively robust.

Detailed results of our robustness checks, including output tables for all parameterizations, can be found in Appendix C.

5 Conclusion

In this paper, we set up a general equilibrium model with heterogeneous firms and endogenous market entry à la Melitz (2003). Inspired by Acemoglu et al. (2012) and Löschel and Otto (2009), we extend the standard framework by including an energy sector that produces electricity using labor as well as clean and dirty resources. Within our model, we implement a coal phase-out by reducing the amount of dirty resources used to generate electricity. Starting from post phase-out equilibrium, we introduce a set of policy interventions financed by a lump-sum tax. We solve our model numerically using parameters from the related literature, and analyze the general equilibrium effects of a coal phase-out as well as the policy measures.

Our results show that a coal phase-out leads to rising electricity prices, falling wages as well as declining income, whereas the market structure (measured by the number of producing firms in the consumption good sector and their average productivity) remains unaffected in our model. For the policy measures, we find that all of them help to counteract the negative effects of the coal phase-out on wages and the electricity price. They differ substantially, however, in what welfare loss they imply. A comparison indicates that falling wages and rising electricity prices can be counteracted with lower welfare losses if they are subsidized directly.

In particular, a direct wage subsidy allows to raise the wage to its initial level prior to the coal phase-out at a minor welfare loss of 0.02 %, which is 15 times less compared to raising the wage with a production fixed cost subsidy. The wage subsidy thereby relieves workers, who would otherwise bear the main burden of a coal phase-out.

When we think about the validity of our policy analysis, though, we need to be aware of potential limitations of our approach. A first limitation is that we consider an economy under autarky rather than an open economy. This simplification allows us to keep the effects of the coal phase-out and the policy interventions tractable. It also implies, however, that we neglect potential additional effects (and potential strategic interaction by choosing optimal policies) that could arise through trade channels. In an open economy model without an energy sector, Pflüger and Südekum (2013) show that it becomes more difficult for foreign firms to enter the export market, if domestic firms receive a market entry subsidy. Domestic firms become more productive, charge lower prices, and hence become more competitive on average. This lowers the expected export profits and hence the export incentives of foreign companies, and strengthens the market position of domestic firms. A similar argument applies to the wage subsidy and the electricity price subsidy. As inputs get cheaper, firms face lower marginal costs and charge lower prices. This creates a competitive advantage for domestic firms and allows to gain market share. In contrast, a production fixed cost subsidy may weaken the market position of domestic firms, as they become less productive, charge higher prices, and hence become less competitive.

A second limitation is that we consider a static model with exogenous technology. Under endogenous technological change, investment in more efficient technology is typically affected by the relative prices of inputs, with higher investment being directed towards technologies that substitute more expensive inputs (Acemoglu 2002; Acemoglu et al. 2012; Otto et al. 2007; Otto et al. 2008; Löschel and Otto 2009; Linn 2008; Newell et al. 1999). An electricity price subsidy could hence diminish the incentive to invest in renewable clean resources or energy-efficient technology as is makes electricity relatively cheaper (Fouquet 2016; Ley et al. 2016). The same applies to the market entry subsidy and the production fixed cost subsidy.[19] Discouraging or delaying technological change might be costly, as it could result in an extended transition period with slow growth in the future (Acemoglu et al. 2012; Löschel and Otto 2009). The only policy measure we consider that makes electricity relatively more expensive, and thus might encourage investment in energy-efficient technology and accelerate the transition process, is a wage subsidy.

Our study is only a first attempt to better understand which policy interventions might be helpful to counteract negative effects of a coal phase-out. For our analysis, however, we set up a rich and tractable general equilibrium framework. This provides us not only with a detailed picture of the allocative effects of the phase-out and potential additional policies, but also with a better understanding of the underlying mechanisms. It moreover allows us to obtain a rough estimate of the welfare costs associated with each policy. Our analysis hence provides the basis for a more informed discussion about which policies may be helpful to mitigate adverse effects of the coal phase-out on consumers and industry in order to achieve a high level of social acceptance and political feasibility.

Our paper, however, might also offer political guidance beyond the coal phase-out. A recent example is that Germany and other European countries face a decline in Russian energy supplies, which are difficult to substitute in the short and medium run (Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, et al. 2022; Bachmann, Baqaee, Bayer, Kuhn, Löschel, McWilliams, et al. 2022; IEA 2022; Hausmann et al. 2022). In response to that, the German Federal Government implemented (among other measures) a temporary tax cut on fuels (BMF 2022). The interesting point here is that the effects of both the initial reduction in resource supply and the tax cut are consistent with

19. For large subsidies, a market entry subsidy and a production fixed cost subsidy lead to rising wages and falling electricity prices. And for small subsidies, the increase in the wage outweighs the increase in the electricity price. Thus, in either case, electricity becomes relatively cheaper under these subsidies.

the results of our model. The former caused rising energy prices (Hausmann et al. 2022; Halser and Paraschiv 2022) as well as decreasing wages and employment (Kagerl et al. 2022; Weyerstrass et al. 2022), while the latter has been widely criticized for raising the prices suppliers receive rather than lowering the prices consumers have to pay (Bach 2022; Duso 2022). This emphasizes that energy price subsidies might not be the preferable political measure to address energy resource scarcity, and highlights that our model might have important implications for how to deal with energy resource shortages more generally.

References

Acemoglu, Daron. 2002. "Directed technical change." *The Review of Economic Studies* 69 (4): 781–809.

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. 2012. "The environment and directed technical change." *American Economic Review* 102 (1): 131–66.

Aragón, Fernando M, Juan Pablo Rud, and Gerhard Toews. 2018. "Resource shocks, employment, and gender: evidence from the collapse of the UK coal industry." *Labour Economics* 52: 54–67.

Ayres, Robert U, Jeroen CJM Van den Bergh, Dietmar Lindenberger, and Benjamin Warr. 2013. "The underestimated contribution of energy to economic growth." *Structural Change and Economic Dynamics* 27: 79–88.

Baccini, Leonardo, and Stephen Weymouth. 2021. "Gone for good: Deindustrialization, white voter backlash, and US presidential voting." *American Political Science Review* 115 (2): 550–567.

Bach, Stefan. 2022. "Übergewinnbesteuerung bei Öl und Gas sinnvoll, aber in Deutschland nicht zu machen." *DIW Wochenbericht* 89 (24): 354–354.

Bachmann, Rüdiger, David Baqaee, Christian Bayer, Moritz Kuhn, Andreas Löschel, Ben McWilliams, Benjamin Moll, et al. 2022. "How it can be done." *ECONtribute Policy Brief* 34.

Bachmann, Rüdiger, David Baqaee, Christian Bayer, Moritz Kuhn, Andreas Löschel, Benjamin Moll, Andreas Peichl, Karen Pittel, and Moritz Schularick. 2022. "What if? The economic effects for Germany of a stop of energy imports from Russia." *ECONtribute Policy Brief* 28.

Balistreri, Edward J, Christoph Böhringer, and Thomas F Rutherford. 2018. "Carbon policy and the structure of global trade." *The World Economy* 41 (1): 194–221.

Balistreri, Edward J, Russell H Hillberry, and Thomas F Rutherford. 2011. "Structural estimation and solution of international trade models with heterogeneous firms." *Journal of International Economics* 83 (2): 95–108.

Balistreri, Edward J, and Thomas F Rutherford. 2012. "Subglobal carbon policy and the competitive selection of heterogeneous firms." *Energy Economics* 34: S190–S197.

Bang, Guri, Knut Einar Rosendahl, and Christoph Böhringer. 2022. "Balancing cost and justice concerns in the energy transition: comparing coal phase-out policies in Germany and the UK." *Climate Policy,* 1–16.

Bernard, Andrew B, Jonathan Eaton, J Bradford Jensen, and Samuel Kortum. 2003. "Plants and productivity in international trade." *American Economic Review* 93 (4): 1268–1290.

Bernard, Andrew B, Stephen J Redding, and Peter K Schott. 2007. "Comparative advantage and heterogeneous firms." *The Review of Economic Studies* 74 (1): 31–66.

Black, Dan, Terra McKinnish, and Seth Sanders. 2005. "The economic impact of the coal boom and bust." *The Economic Journal* 115 (503): 449–476.

Böhringer, Christoph, Edward J Balistreri, and Thomas F Rutherford. 2012. "The role of border carbon adjustment in unilateral climate policy: Overview of an Energy Modeling Forum study (EMF 29)." *Energy Economics* 34:S97–S110.

Bougheas, Spiros, Panicos O Demetriades, and Theofanis P Mamuneas. 2000. "Infrastructure, specialization, and economic growth." *Canadian Journal of Economics* 33 (2): 506–522.

Brauers, Hanna, and Pao-Yu Oei. 2020. "The political economy of coal in Poland: Drivers and barriers for a shift away from fossil fuels." *Energy Policy* 144: 111621.

Cadoret, Isabelle, and Fabio Padovano. 2016. "The political drivers of renewable energies policies." *Energy Economics* 56: 261–269.

Campbell, Stephanie, Lars Coenen, et al. 2017. "Transitioning beyond coal: Lessons from the structural renewal of Europe's old industrial regions." *CCEP Working Paper* 1709.

Cheon, Andrew, and Johannes Urpelainen. 2013. "How do competing interest groups influence environmental policy? The case of renewable electricity in industrialized democracies, 1989–2007." *Political Studies* 61 (4): 874–897.

Chor, Davin. 2009. "Subsidies for FDI: Implications from a model with heterogeneous firms." *Journal of International Economics* 78 (1): 113–125.

Cui, Jingbo. 2017. "Induced clean technology adoption and international trade with heterogeneous firms." *The Journal of International Trade & Economic Development* 26 (8): 924–954.

de Pinto, Marco, and Jörg Lingens. 2019. "The impact of unionization costs when firm-selection matters." *Labour Economics* 60: 50–63.

de Pinto, Marco, and Jochen Michaelis. 2016. "The labor market effects of trade unions in an open economy: Layard meets Melitz." *International Economics and Economic Policy* 13 (2): 223–232.

Demidova, Svetlana, and Andrés Rodrıguez-Clare. 2009. "Trade policy under firm-level heterogeneity in a small economy." *Journal of International Economics* 78 (1): 100–112.

Duso, Tomaso. 2022. "Der Tankrabatt ist der einfachste und schnellste, aber nicht der beste Weg." *DIW Wochenbericht* 89 (23): 342–342.

Egger, Hartmut, and Josef Falkinger. 2006. "The role of public infrastructure and subsidies for firm location and international outsourcing." *European Economic Review* 50 (8): 1993–2015.

Egger, Hartmut, and Udo Kreickemeier. 2009. "Firm heterogeneity and the labor market effects of trade liberalization." *International Economic Review* 50 (1): 187–216.

Egli, Florian, Nicolas Schmid, and Tobias S Schmidt. 2022. "Backlash to fossil fuel phase-outs: the case of coal mining in US presidential elections." *Environmental Research Letters* 17 (9): 094002.

Felbermayr, Gabriel, and Julien Prat. 2011. "Product market regulation, firm selection, and unemployment." *Journal of the European Economic Association* 9 (2): 278–317.

Fischer, Carolyn, and Richard G Newell. 2008. "Environmental and technology policies for climate mitigation." *Journal of Environmental Economics and Management* 55 (2): 142–162.

Fouquet, Roger. 2016. "Historical energy transitions: Speed, prices and system transformation." *Energy Research & Social Science* 22: 7–12.

German Environmental Agency. 2022. "Structural change in coal regions as a process of economic and social-ecological transition: lessons learnt from structural change processes in Germany." *Climate Change Publication Series* 33. https://www.umweltbundesamt.de/publikationen/structural-change-in-coal-regions-as-a-process-of.

German Federal Ministry for Economic Affairs and Climate Action. 2019. "Abschlussbericht der Kommission 'Wachstum, Strukturwandel und Beschäftigung'," https://www.bmwk.de/Redaktion/DE/Downloads/A/abschlussbericht-kommission-wachstum-strukturwandel-und-beschaeftigung.html.

———. 2021. "Energy data," https://www.bmwi.de/Redaktion/DE/Binaer/Energiedaten/energiedaten-gesamt-xls.html.

German Federal Ministry of Finance. 2022. "Schnelle und spürbare Entlastungen - Fast and significant reliefs," https://www.bundesregierung.de/breg-en/news/relief-package-2027038.

Gillich, Annika, Kai Hufendiek, and Nikolai Klempp. 2020. "Extended policy mix in the power sector: How a coal phase-out redistributes costs and profits among power plants." *Energy Policy* 147: 111690.

Green, Fergus, and Ajay Gambhir. 2020. "Transitional assistance policies for just, equitable and smooth low-carbon transitions: who, what and how?" *Climate Policy* 20 (8): 902–921.

Gullberg, Anne Therese. 2008. "Lobbying friends and foes in climate policy: The case of business and environmental interest groups in the European Union." *Energy Policy* 36 (8): 2964–2972.

Halser, Christoph, and Florentina Paraschiv. 2022. "Pathways to overcoming natural gas dependency on Russia — The German case." *Energies* 15 (14): 4939.

Hausmann, Ricardo, Agata Łoskot-Strachota, Axel Ockenfels, Ulrich Schetter, Simone Tagliapietra, Guntram Wolff, and Georg Zachmann. 2022. "Cutting Putin's energy rent: Smart sanctioning Russian oil and gas." *CID Faculty Working Paper Series* 412.

Haywood, Luke, Markus Janser, and Nicolas Koch. 2021. "The welfare costs of job loss and decarbonization–Evidence from Germany's coal phase out." *IZA Discussion Papers* 14464.

He, Gang, Jiang Lin, Ying Zhang, Wenhua Zhang, Guilherme Larangeira, Chao Zhang, Wei Peng, Manzhi Liu, and Fuqiang Yang. 2020. "Enabling a rapid and just transition away from coal in China." *One Earth* 3 (2): 187–194.

Heinisch, Katja, Oliver Holtemöller, and Christoph Schult. 2021. "Power generation and structural change: Quantifying economic effects of the coal phase-out in Germany." *Energy Economics* 95: 105008.

Heinrichs, Heidi Ursula, Diana Schumann, Stefan Vögele, Klaus Hendrik Biß, Hawal Shamon, Peter Markewitz, Johannes Többen, Bastian Gillessen, Fabian Gotzens, and Anna Ernst. 2017. "Integrated assessment of a phase-out of coal-fired power plants in Germany." *Energy* 126: 285–305.

Im, Zhen Jie, Nonna Mayer, Bruno Palier, and Jan Rovny. 2019. "The "losers of automation": A reservoir of votes for the radical right?" *Research & Politics* 6 (1): 2053168018822395.

International Energy Agency. 2019. "Global energy & CO_2 status report," https://www.iea.org/reports/global-energy-co2-status-report-2019.

———. 2022. "A 10-Point plan to reduce the European Union's reliance on Russian natural gas," https://www.iea.org/reports/a-10-point-plan-to-reduce-the-european-unions-reliance-on-russian-natural-gas.

International Labor Organization. 2015. "Guidelines for a just transition towards environmentally sustainable economies and societies for all," https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_432859.pdf.

Jakob, Michael, Jan Christoph Steckel, Frank Jotzo, Benjamin K Sovacool, Laura Cornelsen, Rohit Chandra, Ottmar Edenhofer, Chris Holden, Andreas Löschel, and Ted Nace. 2020. "The future of coal in a carbon-constrained climate." *Nature Climate Change* 10 (8): 704–707.

Jensen, J Bradford, Dennis P Quinn, and Stephen Weymouth. 2017. "Winners and losers in international trade: The effects on US presidential voting." *International Organization* 71 (3): 423–457.

Johnstone, Phil, and Paula Kivimaa. 2018. "Multiple dimensions of disruption, energy transitions and industrial policy." *Energy Research & Social Science* 37: 260–265.

Jung, Benjamin. 2012. "Optimal fixed cost subsidies in Melitz-type models." *Empirica* 39 (1): 87–108.

———. 2015. "Allocational efficiency with heterogeneous firms: Disentangling love of variety and market power." *Economics Letters* 134: 141–143.

Kagerl, Christian, Michael Moritz, Duncan Roth, Jens Stegmaier, Ignat Stepanok, and Enzo Weber. 2022. "Energiekrise und Lieferstopp für Gas: Auswirkungen auf die Betriebe in Deutschland." *Wirtschaftsdienst* 102 (6): 486–491.

Kalkuhl, Matthias, Jan Christoph Steckel, Lorenzo Montrone, Michael Jakob, Jörg Peters, and Ottmar Edenhofer. 2019. "Successful coal phase-out requires new models of development." *Nature Energy* 4 (11): 897–900.

Keles, Dogan, and Hasan Ümitcan Yilmaz. 2020. "Decarbonisation through coal phase-out in Germany and Europe—Impact on Emissions, electricity prices and power production." *Energy Policy* 141: 111472.

Kim, Sung Eun, Johannes Urpelainen, and Joonseok Yang. 2016. "Electric utilities and American climate policy: lobbying by expected winners and losers." *Journal of Public Policy* 36 (2): 251–275.

Kittel, Martin, Leonard Goeke, Claudia Kemfert, Pao-Yu Oei, and Christian von Hirschhausen. 2020. "Scenarios for coal-exit in Germany—A model-based analysis and implications in the European context." *Energies* 13 (8): 2041.

Kümmel, Reiner, Robert U Ayres, and Dietmar Lindenberger. 2010. "Thermodynamic laws, economic methods and the productive power of energy." *Journal of Non-Equilibrium Thermodynamics* 35: 145–179.

Kümmel, Reiner, and Dietmar Lindenberger. 2014. "How energy conversion drives economic growth far from the equilibrium of neoclassical economics." *New Journal of Physics* 16 (12): 125008.

Kümmel, Reiner, Dietmar Lindenberger, and Florian Weiser. 2015. "The economic power of energy and the need to integrate it with energy policy." *Energy Policy* 86: 833–843.

Leipprand, Anna, and Christian Flachsland. 2018. "Regime destabilization in energy transitions: The German debate on the future of coal." *Energy Research & Social Science* 40: 190–204.

Ley, Marius, Tobias Stucki, and Martin Woerter. 2016. "The impact of energy prices on green innovation." *The Energy Journal* 37 (1).

Li, Aitong, Yuan Xu, and Hideaki Shiroyama. 2019. "Solar lobby and energy transition in Japan." *Energy Policy* 134: 110950.

Lindenberger, Dietmar, and Reiner Kümmel. 2011. “Energy and the state of nations.” *Energy* 36 (10): 6010–6018.

Linn, Joshua. 2008. “Energy prices and the adoption of energy-saving technology.” *The Economic Journal* 118 (533): 1986–2012.

Löschel, Andreas, and Vincent M Otto. 2009. “Technological uncertainty and cost effectiveness of CO2 emission reduction.” *Energy Economics* 31:S4–S17.

Margalit, Yotam. 2019. “Political responses to economic shocks.” *Annual Review of Political Science* 22: 277–295.

Markussen, Peter, and Gert Tinggaard Svendsen. 2005. “Industry lobbying and the political economy of GHG trade in the European Union.” *Energy Policy* 33 (2): 245–255.

Mayer, Adam, E Keith Smith, and Jeff Rodriguez. 2020. “Concerned about coal: security, dependence, and vulnerability among coal dependent communities in western Colorado.” *Energy Research & Social Science* 70: 101680.

Melitz, Marc J. 2003. “The impact of trade on intra-industry reallocations and aggregate industry productivity.” *Econometrica* 71 (6): 1695–1725.

Morton, Tom, and Katja Müller. 2016. “Lusatia and the coal conundrum: The lived experience of the German Energiewende.” *Energy Policy* 99: 277–287.

Muttitt, Greg, and Sivan Kartha. 2020. “Equity, climate justice and fossil fuel extraction: principles for a managed phase out.” *Climate Policy* 20 (8): 1024–1042.

Newell, Richard G, Adam B Jaffe, and Robert N Stavins. 1999. “The induced innovation hypothesis and energy-saving technological change.” *The Quarterly Journal of Economics* 114 (3): 941–975.

Oberschelp, Christopher, Stephan Pfister, CE Raptis, and Stefanie Hellweg. 2019. “Global emission hotspots of coal power generation.” *Nature Sustainability* 2 (2): 113–121.

OECD. 2019. "Accelerating climate action: Refocusing policies through a well-being lens," https://www.oecd.org/env/accelerating-climate-action-2f4c8c9a-en.htm.

Oei, Pao-Yu, Hanna Brauers, and Philipp Herpich. 2020. "Lessons from Germany's hard coal mining phase-out: policies and transition from 1950 to 2018." *Climate Policy* 20 (8): 963–979.

Oei, Pao-Yu, Hauke Hermann, Philipp Herpich, Oliver Holtemöller, Benjamin Lünenbürger, and Christoph Schult. 2020. "Coal phase-out in Germany–Implications and policies for affected regions." *Energy* 196: 117004.

Ohlendorf, Nils, Michael Jakob, and Jan Christoph Steckel. 2022. "The political economy of coal phase-out: Exploring the actors, objectives, and contextual factors shaping policies in eight major coal countries." *Energy Research & Social Science* 90: 102590.

Otto, Vincent M, Andreas Löschel, and Rob Dellink. 2007. "Energy biased technical change: A CGE analysis." *Resource and Energy Economics* 29 (2): 137–158.

Otto, Vincent M, Andreas Löschel, and John Reilly. 2008. "Directed technical change and differentiation of climate policy." *Energy Economics* 30 (6): 2855–2878.

Papageorgiou, Chris, Marianne Saam, and Patrick Schulte. 2017. "Substitution between clean and dirty energy inputs: A macroeconomic perspective." *Review of Economics and Statistics* 99 (2): 281–290.

Pearce, IF. 1952. "Total demand curves and general equilibrium." *The Review of Economic Studies* 20 (3): 216–227.

Pflüger, Michael, and Jens Südekum. 2013. "Subsidizing firm entry in open economies." *Journal of Public Economics* 97: 258–271.

Rauner, Sebastian, Nico Bauer, Alois Dirnaichner, Rita Van Dingenen, Chris Mutel, and Gunnar Luderer. 2020. "Coal-exit health and environmental damage reductions outweigh economic impacts." *Nature Climate Change* 10 (4): 308–312.

Rinscheid, Adrian, and Rolf Wüstenhagen. 2019. "Germany's decision to phase out coal by 2038 lags behind citizens' timing preferences." *Nature Energy* 4 (10): 856–863.

Stern, David I. 2012. "Interfuel substitution: A meta-analysis." *Journal of Economic Surveys* 26 (2): 307–331.

Welsch, Heinz, and Philipp Biermann. 2014. "Electricity supply preferences in Europe: Evidence from subjective well-being data." *Resource and Energy Economics* 38: 38–60.

Weyerstrass, Klaus, Ines Fortin, Daniela Grozea-Helmenstein, Sebastian P Koch, and Projektgruppe Gemeinschaftsdiagnose. 2022. "Von der Pandemie zur Energiekrise–Wirtschaft und Politik im Dauerstress Kurzfassung der Gemeinschaftsdiagnose Frühjahr 2022." *ifo Schnelldienst* 75 (05): 58–63.

A Appendix: Equilibrium Income

Income is defined by (21), which we can simplify as

$$I = wL_X + \Pi + P_E E_S. \tag{35}$$

Given that aggregate operational profits are

$$\Pi = M \int_{\underline{\theta}}^{\infty} \tau(\theta)\mu(\theta)d\theta - wL_X - P_E E_X, \tag{36}$$

we get

$$I = M \int_{\underline{\theta}}^{\infty} \tau(\theta)\mu(\theta)d\theta + P_E E_S - P_E E_X. \tag{37}$$

In equilibrium, the energy market clearing condition $E_X = E_S$ then implies

$$I = M \int_{\underline{\theta}}^{\infty} \tau(\theta)\mu(\theta)d\theta. \tag{38}$$

Inserting (12) and taking into account the average productivity of firms operating in the market (20), equilibrium income in our model can be written as

$$I = M\tau(\tilde{\theta}). \tag{39}$$

B Appendix: Policy Interventions

B.1 Subsidy on Market Entry or Production Fixed Costs

In case of the market entry subsidy, the cutoff productivity (26) must be transformed to

$$\underline{\theta}(w) = m \left(\frac{\sigma - 1}{c - (\sigma - 1)} \frac{wF_D}{wF * (1 - S_F)} \right)^{\frac{1}{c}}, \tag{40}$$

which also implies $\tilde{\theta}(w)$. The equilibrium conditions then read

$$\begin{aligned} \bar{L} = Ml(\tilde{\theta}(w), w, P_E, I) + MF_D + M\left[1 - G(\underline{\theta}(w))\right]^{-1} F \\ + \left(\beta \frac{P_E}{w}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}, \end{aligned} \tag{41}$$

$$Me(\tilde{\theta}(w), w, P_E, I) = \left(\beta \frac{P_E}{w}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}, \tag{42}$$

$$I = M \frac{\sigma c}{c - (\sigma - 1)} w F_D, \tag{43}$$

$$M = p(\tilde{\theta}(w), w, P_E)^{\sigma - 1}, \tag{44}$$

$$T = wF * S_F * \underbrace{\frac{M}{1 - G(\underline{\theta}(w))}}_{=M_e}, \tag{45}$$

with T denoting the lump-sum tax. The equation system (40) - (45) implicitly determines the equilibrium levels of $\underline{\theta}^*_F$, w^*_F, $P^*_{E_F}$, M^*_F, I^*_F and T^*_F, where the subscript F is used to indicate the subsidy on market entry costs.

In a similar vein, the modified cutoff productivity in a situation where the government implements a subsidy on production fixed costs is given by

$$\underline{\theta}(w) = m \left(\frac{\sigma - 1}{c - (\sigma - 1)} \frac{wF_D * (1 - S_{F_D})}{wF} \right)^{\frac{1}{c}}. \tag{46}$$

The equilibrium conditions are

$$\begin{aligned} \bar{L} = Ml(\tilde{\theta}(w), w, P_E, I) + MF_D + M\left[1 - G(\underline{\theta}(w))\right]^{-1} F \\ + \left(\beta \frac{P_E}{w}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}, \end{aligned} \tag{47}$$

$$Me(\tilde{\theta}(w), w, P_E, I) = \left(\beta \frac{P_E}{w}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^{\varphi} + \bar{V}^{\varphi}\right)^{\frac{1}{\varphi}}, \tag{48}$$

$$I = M \frac{\sigma c}{c - (\sigma - 1)} w F_D * (1 - S_{F_D}), \tag{49}$$

$$M = p(\tilde{\theta}(w), w, P_E)^{\sigma - 1}, \tag{50}$$

$$T = w * F_D * S_{F_D} * M. \tag{51}$$

The equation system (46) - (51) implicitly determines the equilibrium levels of $\underline{\theta}^*_{F_D}$, $w^*_{F_D}$, $P^*_{E_{F_D}}$,

$M^*_{F_D}$, $I^*_{F_D}$ and $T^*_{F_D}$, where the subscript F_D is used to indicate the subsidy on production fixed costs.

B.2 Subsidy on Wages or Electricity Prices

If a subsidy is paid on wages, firm-selection is not affected. The equilibrium conditions are

$$\begin{aligned}\bar{L} &= Ml(\tilde{\theta}^*, w(1-S_w), P_E, I) + MF_D + M(1-G(\underline{\theta}^*))^{-1}F \\ &+ \left(\beta \frac{P_E}{w(1-S_w)}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}},\end{aligned} \tag{52}$$

$$Me(\tilde{\theta}^*, w(1-S_w), P_E, I) = \left(\beta \frac{P_E}{w(1-S_w)}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}}, \tag{53}$$

$$I = M\frac{\sigma c}{c-(\sigma-1)} wF_D(1-S_w), \tag{54}$$

$$M = p(\tilde{\theta}^*, w(1-S_w), P_E)^{\sigma-1}, \tag{55}$$

$$T = w * S_w * (L_X(\tilde{\theta}^*, w(1-S_w), P_E, I, M) + L_E(w(1-S_w), P_E)). \tag{56}$$

The equation system (52) - (56) implicitly determines the equilibrium levels of w^*_w, $P^*_{E_w}$, M^*_w, I^*_w and T^*_w, where the subscript w is used to indicate the subsidy on wages.

The electricity price subsidy has no effect on firm-selection as well. Thus, we get

$$\begin{aligned}\bar{L} &= Ml(\tilde{\theta}^*, w, P_E(1-S_{P_E}), I) + MF_D + M(1-G(\underline{\theta}^*))^{-1}F \\ &+ \left(\beta \frac{P_E}{w}\right)^{\frac{1}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}},\end{aligned} \tag{57}$$

$$Me(\tilde{\theta}^*, w, P_E(1-S_{P_E}), I) = \left(\beta \frac{P_E}{w}\right)^{\frac{\beta}{1-\beta}} \left(\bar{R}^\varphi + \bar{V}^\varphi\right)^{\frac{1}{\varphi}}, \tag{58}$$

$$I = M\frac{\sigma c}{c-(\sigma-1)} wF_D, \tag{59}$$

$$M = p(\tilde{\theta}^*, w, P_E(1-S_{P_E}))^{\sigma-1}, \tag{60}$$

$$T = P_E * S_{P_E} * E_X(\tilde{\theta}^*, w, P_E(1-S_{P_E}), I, M). \tag{61}$$

The equation system (57) - (61) implicitly determines the equilibrium levels of $w^*_{P_E}$, $P^*_{E_{P_E}}$, $M^*_{P_E}$, $I^*_{P_E}$ and $T^*_{P_E}$, where the subscript P_E is used to indicate the subsidy on electricity.

C Appendix: Robustness Results

C.1 Robustness Results – Positively Supplied Resources

In the main text of the paper, we have argued that the clean and dirty energy resource are supplied inelastically, which made the labour demand function of the energy sector straightforward. In this section of the appendix, we argue that the general structure of this demand function remains by and large the same if we consider positively supplied resources R and V.

Given the production structure from before

$$e = L_E^{\beta} \left(R^{\varphi} + V^{\varphi}\right)^{\frac{1-\beta}{\varphi}} \tag{62}$$

and the price taking behavior of energy firms, we can write down the demand system for the three inputs as

$$\beta L_E^{\beta-1} \left(R^{\varphi} + V^{\varphi}\right)^{\frac{1-\beta}{\varphi}} = w \tag{63}$$

$$L_E^{\beta}(1-\beta) \left(R^{\varphi} + V^{\varphi}\right)^{\frac{1-\beta}{\varphi}-1} R^{\varphi-1} = P_R \tag{64}$$

$$L_E^{\beta}(1-\beta) \left(R^{\varphi} + V^{\varphi}\right)^{\frac{1-\beta}{\varphi}-1} V^{\varphi-1} = P_V. \tag{65}$$

Suppose that instead of assuming a fixed supply $\bar{R}$ and $\bar{V}$, we assume that the (inverse) supply functions for the two inputs are given by

$$P_R = \theta_R R^{\gamma} \tag{66}$$

$$P_V = \theta_V V^{\gamma}, \tag{67}$$

where we assume the general functional form to be identical and we only consider differences in (absolute) marginal costs.

Using the demand relation fixes the 'dirtyness' of the energy input in equilibrium as a function of relative prices

$$\frac{P_R}{P_V} = \left(\frac{R}{V}\right)^{1/(\varphi-1)}. \tag{68}$$

Combining this with the supply functions fixes the expansion path such that we have

$$\frac{\theta_R}{\theta_V}\left(\frac{R}{V}\right)^{\gamma}=\left(\frac{R}{V}\right)^{1/(\varphi-1)}, \tag{69}$$

which results in

$$\left(\frac{\theta_R}{\theta_V}\right)^{\frac{\varphi-1}{1-\gamma\varphi-\gamma}}V=R. \tag{70}$$

Plugging this into the demand relation for the clean resource gives

$$\begin{aligned} L_E^{\beta}(1-\beta)\left(\left(\frac{\theta_R}{\theta_V}\right)^{\frac{\varphi^2-\varphi}{1-\gamma\varphi-\gamma}}+\right)^{\frac{1-\beta}{\varphi}-1}V^{1-\beta-\varphi}V^{\varphi-1}=P_V \\ \Leftrightarrow L_E^{\beta}(1-\beta)\Theta V^{-\beta}=P_V \\ \Leftrightarrow L_E\left(\frac{1-\beta}{P_V}\Theta\right)=V, \end{aligned} \tag{71}$$

where $\Theta := \left(\left(\frac{\theta_R}{\theta_V}\right)^{\frac{\varphi^2-\varphi}{1-\gamma\varphi-\gamma}}+\right)^{\frac{1-\beta}{\varphi}-1}$. As a final step, plugging this into the labor demand function gives

$$\begin{aligned} \beta L_E^{\beta-1}\left(R^{\varphi}+V^{\varphi}\right)^{\frac{1-\beta}{\varphi}}=w \\ \Leftrightarrow \beta L_E^{\beta-1}V^{1-\beta}\Theta^{(1-\beta)/(1-\beta-\varphi)}=w \\ \Leftrightarrow \left(\frac{1-\beta}{P_V}\Theta\right)^{1-\beta}\Theta^{(1-\beta)/(1-\beta-\varphi)}=w. \end{aligned} \tag{72}$$

This shows that the labor demand of the energy sector becomes horizontal if energy firms have an adjustment margin along the energy inputs, which due to the assumed linear homogeneity of production. In this case, policies that reduce the use of the dirty (coal) resource imply an increase in θ_R, which results in a downward shift of the labor demand curve. This is similar to the case of a fixed resource base where $\bar{R}$ is reduced. The difference here is that the adjustment need in the labor market, i.e. the wage decrease that is needed to absorb labor in the consumption good sector from the energy sector, is now larger. As such, the adjustments are qualitative identical, but they are quantitatively larger. The case with a fixed resource base that we consider in the main text hence represents the conservative case concerning the distributional effects and the needs for policy adjustment.

C.2 Robustness Results – Coal Phase-Out

The subsequent tables show what results we obtain for the coal phase-out, using the alternative parameterizations. The column on the far right of each table shows the ratio of the equilibrium results before and after the phase-out. Ratios above (below) one indicate that the equilibrium value increases (decreases) as a result of the coal phase-out.

Table 4: (1) Main Parameterization - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	3.4786	4.47042	1.28512
Wage	1.70178	1.65993	0.975407
Average productivity	0.208719	0.208719	1.
Average price	15.9845	15.9845	1.
Mass of firms	2,346.15	2,346.15	1.
Income/Welfare	12,873.7	12,557.1	0.975407

Table 5: (2) Pflüger & Südekum 2013 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.440354	0.565907	1.28512
Wage	0.215428	0.21013	0.975407
Average productivity	0.238382	0.238382	1.
Average price	1.77167	1.77167	1.
Mass of firms	4.95989	4.95989	1.
Income/Welfare	23.0083	22.4424	0.975407

Table 6: (3) Chor 2009 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.568288	0.730317	1.28512
Wage	0.278015	0.271177	0.975407
Average productivity	0.059396	0.059396	1.
Average price	9.17632	9.17632	1.
Mass of firms	495.989	495.989	1.
Income/Welfare	29,692.8	28,962.5	0.975407

Table 7: (4) de Pinto & Lingens 2019 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.195139	0.250777	1.28512
Wage	0.095465	0.093117	0.975407
Average productivity	0.196619	0.196619	1.
Average price	0.951863	0.951863	1.
Mass of firms	0.87098	0.87098	1.
Income/Welfare	0.203919	0.198904	0.975407

Table 8: (5) Felbermayr & Prat 2011 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.972562	1.24986	1.28512
Wage	0.394612	0.384908	0.975407
Average productivity	0.59056	0.59056	1.
Average price	1.11086	1.11086	1.
Mass of firms	2.22331	2.22331	1.
Income/Welfare	0.427251	0.416744	0.975407

Table 9: (6) Cui 2017 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.094665	0.121656	1.28512
Wage	0.045481	0.044362	0.975407
Average productivity	0.018477	0.018477	1.
Average price	4.74879	4.74879	1.
Mass of firms	107.09	107.09	1.
Income/Welfare	66.2389	64.6099	0.975407

Table 10: (7) Bernard et al. 2007 - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	2.3174	2.97813	1.28512
Wage	1.1337	1.10582	0.975407
Average productivity	0.242207	0.242207	1.
Average price	9.17632	9.17632	1.
Mass of firms	495.989	495.989	1.
Income/Welfare	1,210.83	1,181.05	0.975407

Table 11: (8) High Resource Endowment - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	0.468327	0.601856	1.28512
Wage	2.07658	2.02551	0.975407
Average productivity	0.208719	0.208719	1.
Average price	15.9845	15.9845	1.
Mass of firms	2,346.15	2,346.15	1.
Income/Welfare	15,709.	15,322.7	0.975407

Table 12: (9) Low Resource Endowment - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	25.8381	33.205	1.28512
Wage	1.39463	1.36034	0.975407
Average productivity	0.208719	0.208719	1.
Average price	15.9845	15.9845	1.
Mass of firms	2,346.15	2,346.15	1.
Income/Welfare	10,550.2	10,290.7	0.975407

Table 13: (10) Low Output Elasticity (X) - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	5.55832	6.43302	1.15737
Wage	0.406011	0.356658	0.878444
Average productivity	0.208719	0.208719	1.
Average price	18.0285	18.0285	1.
Mass of firms	3,286.16	3,286.16	1.
Income/Welfare	4,302.02	3,779.08	0.878444

Table 14: (11) High Output Elasticity (E) - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	3.65912	4.63233	1.26597
Wage	1.69056	1.65144	0.976862
Average productivity	0.208719	0.208719	1.
Average price	15.9613	15.9613	1.
Mass of firms	2,336.63	2,336.63	1.
Income/Welfare	12,737.	12,442.3	0.976862

Table 15: (12) High Elasticity of Resource Substitution - Effects of the Coal Phase-Out

	Before Exit	After Exit	Ratio (after/before)
Electricity price	5.23241	6.6808	1.27681
Wage	1.6342	1.59504	0.976035
Average productivity	0.208719	0.208719	1.
Average price	15.9845	15.9845	1.
Mass of firms	2,346.15	2,346.15	1.
Income/Welfare	12,362.5	12,066.2	0.976035

C.3 Robustness Results – Policy Interventions

The tables below show what results we obtain for the policy interventions, using the alternative parameterizations. The upper part of each table reports absolute values, whereas the lower part reports ratios. Ratios above (below) one indicate that the equilibrium value increases (decreases).

All robustness results we present in the tables are for a 20 % subsidy, that is, they show results for a 20 % market entry subsidy, a 20 % production fixed cost subsidy, a 20 % wage subsidy, and a 20 % energy price subsidy.

Table 16: (1) Main Parameterization - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	4.47042	4.45735	4.46098	4.43192	5.53464
Electricity price (paid)	4.47042	4.45735	4.46098	4.43192	4.42771
Wage (received)	1.65993	1.72305	1.69974	1.94622	1.66102
Wage (paid)	1.65993	1.72305	1.69974	1.55697	1.66102
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	15.9845	15.7463	17.1446	15.0682	15.9801
Mass of firms	2,346.15	2,249.56	2,854.67	1,988.71	2,344.37
Income/Welfare	12,557.1	12,498.	12,516.2	12,479.8	12,555.8
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.997077	0.997889	0.991388	1.23806
Electricity price (paid)	1.	0.997077	0.997889	0.991388	0.990447
Wage (received)	1.	1.03802	1.02398	1.17247	1.00066
Wage (paid)	1.	1.03802	1.02398	0.937974	1.00066
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985097	1.07258	0.942677	0.999729
Mass of firms	1.	0.95883	1.21675	0.847648	0.999242
Income/Welfare	1.	0.995289	0.996741	0.99384	0.999897

Table 17: (2) Pflüger & Südekum 2013 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	0.565907	0.563959	0.565302	0.561033	0.700626
Electricity price (paid)	0.565907	0.563959	0.565302	0.561033	0.560501
Wage (received)	0.21013	0.220992	0.212396	0.24637	0.210267
Wage (paid)	0.21013	0.220992	0.212396	0.197096	0.210267
Average productivity	0.238382	0.254552	0.22324	0.238382	0.238382
Average price	1.77167	1.73643	1.91021	1.67011	1.77119
Mass of firms	4.95989	4.68858	6.12392	4.20424	4.95613
Income/Welfare	22.4424	22.3115	22.4067	22.3042	22.4401
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.996558	0.998931	0.991388	1.23806
Electricity price (paid)	1.	0.996558	0.998931	0.991388	0.990447
Wage (received)	1.	1.0517	1.01079	1.17247	1.00066
Wage (paid)	1.	1.0517	1.01079	0.937974	1.00066
Average productivity	1.	1.06783	0.936477	1.	1.
Average price	1.	0.98011	1.0782	0.942677	0.999729
Mass of firms	1.	0.9453	1.23469	0.847648	0.999242
Income/Welfare	1.	0.994167	0.998406	0.99384	0.999897

Table 18: (3) Chor 2009 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	0.730317	0.727803	0.729536	0.724027	0.904175
Electricity price (paid)	0.730317	0.727803	0.729536	0.724027	0.72334
Wage (received)	0.271177	0.285196	0.274102	0.317947	0.271355
Wage (paid)	0.271177	0.285196	0.274102	0.254357	0.271355
Average productivity	0.059396	0.063425	0.055623	0.059396	0.059396
Average price	9.17632	8.9938	9.89391	8.6503	9.17383
Mass of firms	495.989	468.858	612.392	420.424	495.613
Income/Welfare	28,962.5	28,793.6	28,916.4	28,784.1	28,959.5
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.996558	0.998931	0.991388	1.23806
Electricity price (paid)	1.	0.996558	0.998931	0.991388	0.990447
Wage (received)	1.	1.0517	1.01079	1.17247	1.00066
Wage (paid)	1.	1.0517	1.01079	0.937974	1.00066
Average productivity	1.	1.06783	0.936477	1.	1.
Average price	1.	0.98011	1.0782	0.942677	0.999729
Mass of firms	1.	0.9453	1.23469	0.847648	0.999242
Income/Welfare	1.	0.994167	0.998406	0.99384	0.999897

Table 19: (4) de Pinto & Lingens 2019 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	0.250777	0.250044	0.250248	0.248617	0.310477
Electricity price (paid)	0.250777	0.250044	0.250248	0.248617	0.248381
Wage (received)	0.093117	0.096658	0.09535	0.109177	0.093178
Wage (paid)	0.093117	0.096658	0.09535	0.087342	0.093178
Average productivity	0.196619	0.206431	0.187273	0.196619	0.196619
Average price	0.951863	0.937677	1.02095	0.897299	0.951605
Mass of firms	0.87098	0.835122	1.05977	0.738285	0.87032
Income/Welfare	0.198904	0.197967	0.198256	0.197678	0.198883
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.997077	0.997889	0.991388	1.23806
Electricity price (paid)	1.	0.997077	0.997889	0.991388	0.990447
Wage (received)	1.	1.03802	1.02398	1.17247	1.00066
Wage (paid)	1.	1.03802	1.02398	0.937974	1.00066
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985097	1.07258	0.942677	0.999729
Mass of firms	1.	0.95883	1.21675	0.847648	0.999242
Income/Welfare	1.	0.995289	0.996741	0.99384	0.999897

Table 20: (5) Felbermayr & Prat 2011 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.24986	1.24802	1.24939	1.24512	1.54741
Electricity price (paid)	1.24986	1.24802	1.24939	1.24512	1.23793
Wage (received)	0.384908	0.393871	0.386812	0.467751	0.385223
Wage (paid)	0.384908	0.393871	0.386812	0.374201	0.385223
Average productivity	0.59056	0.605011	0.576454	0.59056	0.59056
Average price	1.11086	1.10712	1.14312	1.08234	1.11072
Mass of firms	2.22331	2.16715	2.76378	1.82459	2.22126
Income/Welfare	0.416744	0.415676	0.41649	0.415617	0.416701
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.998529	0.999629	0.99621	1.23807
Electricity price (paid)	1.	0.998529	0.999629	0.99621	0.990454
Wage (received)	1.	1.02329	1.00495	1.21523	1.00082
Wage (paid)	1.	1.02329	1.00495	0.972184	1.00082
Average productivity	1.	1.02447	0.976114	1.	1.
Average price	1.	0.996639	1.02905	0.97433	0.999879
Mass of firms	1.	0.974739	1.24309	0.820664	0.999079
Income/Welfare	1.	0.997439	0.999392	0.997295	0.999897

Table 21: (6) Cui 2017 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	0.121656	0.121291	0.121466	0.120661	0.150617
Electricity price (paid)	0.121656	0.121291	0.121466	0.120661	0.120494
Wage (received)	0.044362	0.046224	0.045126	0.052181	0.044392
Wage (paid)	0.044362	0.046224	0.045126	0.041745	0.044392
Average productivity	0.018477	0.019473	0.017531	0.018477	0.018477
Average price	4.74879	4.67638	5.08239	4.48988	4.74757
Mass of firms	107.09	102.266	131.282	90.5113	107.007
Income/Welfare	64.6099	64.2894	64.4554	64.232	64.6033
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.996999	0.998437	0.991821	1.23806
Electricity price (paid)	1.	0.996999	0.998437	0.991821	0.990448
Wage (received)	1.	1.04198	1.01722	1.17625	1.00067
Wage (paid)	1.	1.04198	1.01722	0.940997	1.00067
Average productivity	1.	1.05391	0.94885	1.	1.
Average price	1.	0.984752	1.07025	0.945478	0.999742
Mass of firms	1.	0.954949	1.2259	0.845189	0.999228
Income/Welfare	1.	0.995039	0.997608	0.994151	0.999897

Table 22: (7) Bernard et al. 2007 - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	2.97813	2.96788	2.97494	2.95248	3.6871
Electricity price (paid)	2.97813	2.96788	2.97494	2.95248	2.94968
Wage (received)	1.10582	1.16299	1.11775	1.29654	1.10655
Wage (paid)	1.10582	1.16299	1.11775	1.03723	1.10655
Average productivity	0.242207	0.258636	0.226821	0.242207	0.242207
Average price	9.17632	8.9938	9.89391	8.6503	9.17383
Mass of firms	495.989	468.858	612.392	420.424	495.613
Income/Welfare	1,181.05	1,174.16	1,179.17	1,173.77	1,180.93
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.996558	0.998931	0.991388	1.23806
Electricity price (paid)	1.	0.996558	0.998931	0.991388	0.990447
Wage (received)	1.	1.0517	1.01079	1.17247	1.00066
Wage (paid)	1.	1.0517	1.01079	0.937974	1.00066
Average productivity	1.	1.06783	0.936477	1.	1.
Average price	1.	0.98011	1.0782	0.942677	0.999729
Mass of firms	1.	0.9453	1.23469	0.847648	0.999242
Income/Welfare	1.	0.994167	0.998406	0.99384	0.999897

Table 23: (8) High Resource Endowment - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	0.601856	0.600096	0.600585	0.596672	0.745132
Electricity price (paid)	0.601856	0.600096	0.600585	0.596672	0.596106
Wage (received)	2.02551	2.10253	2.07408	2.37484	2.02684
Wage (paid)	2.02551	2.10253	2.07408	1.89988	2.02684
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	15.9845	15.7463	17.1446	15.0682	15.9801
Mass of firms	2,346.15	2,249.56	2,854.67	1,988.71	2,344.37
Income/Welfare	15,322.7	15,250.5	15,272.7	15,228.3	15,321.1
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.997077	0.997889	0.991388	1.23806
Electricity price (paid)	1.	0.997077	0.997889	0.991388	0.990447
Wage (received)	1.	1.03802	1.02398	1.17247	1.00066
Wage (paid)	1.	1.03802	1.02398	0.937974	1.00066
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985097	1.07258	0.942677	0.999729
Mass of firms	1.	0.95883	1.21675	0.847648	0.999242
Income/Welfare	1.	0.995289	0.996741	0.99384	0.999897

Table 24: (9) Low Resource Endowment - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	33.205	33.108	33.1349	32.9191	41.1098
Electricity price (paid)	33.205	33.108	33.1349	32.9191	32.8878
Wage (received)	1.36034	1.41206	1.39296	1.59495	1.36123
Wage (paid)	1.36034	1.41206	1.39296	1.27596	1.36123
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	15.9845	15.7463	17.1446	15.0682	15.9801
Mass of firms	2,346.15	2,249.56	2,854.67	1,988.71	2,344.37
Income/Welfare	10,290.7	10,242.2	10,257.2	10,227.3	10,289.7
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.997077	0.997889	0.991388	1.23806
Electricity price (paid)	1.	0.997077	0.997889	0.991388	0.990447
Wage (received)	1.	1.03802	1.02398	1.17247	1.00066
Wage (paid)	1.	1.03802	1.02398	0.937974	1.00066
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985097	1.07258	0.942677	0.999729
Mass of firms	1.	0.95883	1.21675	0.847648	0.999242
Income/Welfare	1.	0.995289	0.996741	0.99384	0.999897

Table 25: (10) Low Output Elasticity (X) - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	6.43302	6.42151	6.42351	6.37667	7.96271
Electricity price (paid)	6.43302	6.42151	6.42351	6.37667	6.37017
Wage (received)	0.356658	0.376492	0.36917	0.408551	0.358442
Wage (paid)	0.356658	0.376492	0.36917	0.326841	0.358442
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	18.0285	17.6564	19.2639	17.1423	17.9931
Mass of firms	3,286.16	3,099.74	3,956.27	2,853.61	3,268.09
Income/Welfare	3,779.08	3,762.93	3,767.45	3,759.12	3,777.1
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.998212	0.998523	0.99124	1.23779
Electricity price (paid)	1.	0.998212	0.998523	0.99124	0.99023
Wage (received)	1.	1.05561	1.03508	1.1455	1.005
Wage (paid)	1.	1.05561	1.03508	0.916399	1.005
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.979358	1.06853	0.950843	0.998032
Mass of firms	1.	0.94327	1.20392	0.86837	0.9945
Income/Welfare	1.	0.995726	0.996923	0.994717	0.999475

Table 26: (11) High Output Elasticity (E) - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	4.63233	4.62983	4.62964	4.5773	5.66227
Electricity price (paid)	4.63233	4.62983	4.62964	4.5773	4.52982
Wage (received)	1.65144	1.71394	1.69086	1.93671	1.65397
Wage (paid)	1.65144	1.71394	1.69086	1.54937	1.65397
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	15.9613	15.7244	17.1204	15.045	15.9512
Mass of firms	2,336.63	2,240.81	2,843.4	1,980.16	2,332.51
Income/Welfare	12,442.3	12,383.6	12,401.7	12,365.5	12,439.3
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.999461	0.999419	0.988122	1.22234
Electricity price (paid)	1.	0.999461	0.999419	0.988122	0.97787
Wage (received)	1.	1.03785	1.02387	1.17274	1.00153
Wage (paid)	1.	1.03785	1.02387	0.938192	1.00153
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985156	1.07262	0.942595	0.999369
Mass of firms	1.	0.95899	1.21688	0.847443	0.998234
Income/Welfare	1.	0.995284	0.996739	0.993831	0.99976

Table 27: (12) High Elasticity of Resource Substitution - Effects of Policy Interventions

Absolute values					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	6.6808	6.66127	6.6667	6.62326	8.27122
Electricity price (paid)	6.6808	6.66127	6.6667	6.62326	6.61698
Wage (received)	1.59504	1.65569	1.63328	1.87013	1.59608
Wage (paid)	1.59504	1.65569	1.63328	1.4961	1.59608
Average productivity	0.208719	0.219135	0.198798	0.208719	0.208719
Average price	15.9845	15.7463	17.1446	15.0682	15.9801
Mass of firms	2,346.15	2,249.56	2,854.67	1,988.71	2,344.37
Income/Welfare	12,066.2	12,009.4	12,026.9	11,991.9	12,065.
Relative values (ratios)					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Electricity price (received)	1.	0.997077	0.997889	0.991388	1.23806
Electricity price (paid)	1.	0.997077	0.997889	0.991388	0.990447
Wage (received)	1.	1.03802	1.02398	1.17247	1.00066
Wage (paid)	1.	1.03802	1.02398	0.937974	1.00066
Average productivity	1.	1.04991	0.952467	1.	1.
Average price	1.	0.985097	1.07258	0.942677	0.999729
Mass of firms	1.	0.95883	1.21675	0.847648	0.999242
Income/Welfare	1.	0.995289	0.996741	0.99384	0.999897

C.4 Robustness Results – Policy Comparison

The subsequent tables show what results we obtain for our policy comparison, using the alternative parameterizations. The upper part of each table reports (1) how strong the respective subsidy needs to be in order to restore the initial wage level prior to the coal phase-out, and (2) what effects this has on the equilibrium variables in our model. The lower part of each table reports (1) how strong the respective subsidy needs to be in order to achieve a 1 % decrease in the electricity price paid by consumption good firms, and (2) what effects this has on the equilibrium variables in our model. Both the upper and the lower part report the effects on the equilibrium variables as ratios. Ratios above (below) one indicate that the equilibrium value increases (decreases).

'N/A' indicates that we can not restore the wage with the respective subsidy (upper part), or that we we can not reach a 1 % decrease in the electricity price paid by consumption good firms (lower part), because the budget required for the subsidy exceeds the economy's income before we can reach the respective target.

Table 28: (1) Main Parameterization - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.140	0.210	0.035	N/A
Electricity price (received)	1	0.999054	0.997571	0.999416	N/A
Electricity price (paid)	1	0.999054	0.997571	0.999416	N/A
Wage (received)	1	1.02578	1.0253	1.02591	N/A
Wage (paid)	1	1.02578	1.0253	0.990002	N/A
Average productivity	1	1.03346	0.949856	1.	N/A
Average price	1	0.9902	1.07676	0.990849	N/A
Mass of firms	1	0.972801	1.23008	0.974587	N/A
Income/Welfare	1	0.997878	0.996352	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891

Table 29: (2) Pflüger & Südekum 2013 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.105	0.415	0.035	N/A
Electricity price (received)	1	0.999726	0.991363	0.999416	N/A
Electricity price (paid)	1	0.999726	0.991363	0.999416	N/A
Wage (received)	1	1.0257	1.02473	1.02591	N/A
Wage (paid)	1	1.0257	1.02473	0.990002	N/A
Average productivity	1	1.03317	0.854115	1.	N/A
Average price	1	0.990477	1.19618	0.990849	N/A
Mass of firms	1	0.973563	1.6513	0.974587	N/A
Income/Welfare	1	0.998583	0.9899	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891

Table 30: (3) Chor 2009 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.105	0.415	0.035	N/A
Electricity price (received)	1	0.999726	0.991363	0.999416	N/A
Electricity price (paid)	1	0.999726	0.991363	0.999416	N/A
Wage (received)	1	1.0257	1.02473	1.02591	N/A
Wage (paid)	1	1.0257	1.02473	0.990002	N/A
Average productivity	1	1.03317	0.854115	1.	N/A
Average price	1	0.990477	1.19618	0.990849	N/A
Mass of firms	1	0.973563	1.6513	0.974587	N/A
Income/Welfare	1	0.998583	0.9899	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.285	0.43	0.215	0.205
Electricity price (received)	1	0.990345	0.990365	0.990137	1.24551
Electricity price (paid)	1	0.990345	0.990365	0.990137	0.990177
Wage (received)	1	1.07765	1.02581	1.18826	1.00067
Wage (paid)	1	1.07765	1.02581	0.932784	1.00067
Average productivity	1	1.1037	0.847615	1.	1.
Average price	1	0.968974	1.2064	0.937824	0.999721
Mass of firms	1	0.915532	1.69111	0.835487	0.999218
Income/Welfare	1	0.98662	0.988813	0.992776	0.999891

Table 31: (4) de Pinto & Lingens 2019 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.140	0.210	0.035	N/A
Electricity price (received)	1	0.999054	0.997571	0.999416	N/A
Electricity price (paid)	1	0.999054	0.997571	0.999416	N/A
Wage (received)	1	1.02578	1.0253	1.02591	N/A
Wage (paid)	1	1.02578	1.0253	0.990002	N/A
Average productivity	1	1.03346	0.949856	1.	N/A
Average price	1	0.9902	1.07676	0.990849	N/A
Mass of firms	1	0.972801	1.23008	0.974587	N/A
Income/Welfare	1	0.997878	0.996352	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891

Table 32: (5) Felbermayr & Pratt 2011 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.215	0.685	0.03	N/A
Electricity price (received)	1	0.998164	0.97972	0.999785	N/A
Electricity price (paid)	1	0.998164	0.97972	0.999785	N/A
Wage (received)	1	1.02528	1.02502	1.02698	N/A
Wage (paid)	1	1.02528	1.02502	0.99617	N/A
Average productivity	1	1.02657	0.88236	1.	N/A
Average price	1	0.996323	1.15695	0.996496	N/A
Mass of firms	1	0.972392	3.0282	0.973677	N/A
Income/Welfare	1	0.996971	0.977747	0.999947	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.375	0.575	0.325	0.205
Electricity price (received)	1	0.99048	0.990222	0.990211	1.24551
Electricity price (paid)	1	0.99048	0.990222	0.990211	0.990184
Wage (received)	1	1.04938	1.01872	1.40947	1.00084
Wage (paid)	1	1.04938	1.01872	0.951391	1.00084
Average productivity	1	1.05224	0.911462	1.	1.
Average price	1	0.992092	1.11481	0.954833	0.999875
Mass of firms	1	0.941444	2.28423	0.703797	0.99905
Income/Welfare	1	0.987931	0.98897	0.991979	0.999891

Table 33: (6) Cui 2017 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.125	0.295	0.035	N/A
Electricity price (received)	1	0.999387	0.995301	0.999445	N/A
Electricity price (paid)	1	0.999387	0.995301	0.999445	N/A
Wage (received)	1	1.02516	1.02663	1.02642	N/A
Wage (paid)	1	1.02516	1.02663	0.990491	N/A
Average productivity	1	1.03192	0.921043	1.	N/A
Average price	1	0.991172	1.11152	0.991296	N/A
Mass of firms	1	0.97375	1.37326	0.974114	N/A
Income/Welfare	1	0.998252	0.993926	0.999846	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.3	0.375	0.215	0.205
Electricity price (received)	1	0.990321	0.990613	0.990635	1.24551
Electricity price (paid)	1	0.990321	0.990613	0.990635	0.990177
Wage (received)	1	1.06686	1.03531	1.19243	1.00069
Wage (paid)	1	1.06686	1.03531	0.93606	1.00069
Average productivity	1	1.08755	0.895307	1.	1.
Average price	1	0.97441	1.15177	0.940862	0.999734
Mass of firms	1	0.925178	1.52792	0.83287	0.999203
Income/Welfare	1	0.987038	0.988665	0.993142	0.999891

Table 34: (7) Bernard et al. 2007 - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.105	0.415	0.035	N/A
Electricity price (received)	1	0.999726	0.991363	0.999416	N/A
Electricity price (paid)	1	0.999726	0.991363	0.999416	N/A
Wage (received)	1	1.0257	1.02473	1.02591	N/A
Wage (paid)	1	1.0257	1.02473	0.990002	N/A
Average productivity	1	1.03317	0.854115	1.	N/A
Average price	1	0.990477	1.19618	0.990849	N/A
Mass of firms	1	0.973563	1.6513	0.974587	N/A
Income/Welfare	1	0.998583	0.9899	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.285	0.43	0.215	0.205
Electricity price (received)	1	0.990345	0.990365	0.990137	1.24551
Electricity price (paid)	1	0.990345	0.990365	0.990137	0.990177
Wage (received)	1	1.07765	1.02581	1.18826	1.00067
Wage (paid)	1	1.07765	1.02581	0.932784	1.00067
Average productivity	1	1.1037	0.847615	1.	1.
Average price	1	0.968974	1.2064	0.937824	0.999721
Mass of firms	1	0.915532	1.69111	0.835487	0.999218
Income/Welfare	1	0.98662	0.988813	0.992776	0.999891

Table 35: (8) High Resource Endowment - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.140	0.210	0.035	N/A
Electricity price (received)	1	0.999054	0.997571	0.999416	N/A
Electricity price (paid)	1	0.999054	0.997571	0.999416	N/A
Wage (received)	1	1.02578	1.0253	1.02591	N/A
Wage (paid)	1	1.02578	1.0253	0.990002	N/A
Average productivity	1	1.03346	0.949856	1.	N/A
Average price	1	0.9902	1.07676	0.990849	N/A
Mass of firms	1	0.972801	1.23008	0.974587	N/A
Income/Welfare	1	0.997878	0.996352	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891

Table 36: (9) Low Resource Endowment - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.140	0.210	0.035	N/A
Electricity price (received)	1	0.999054	0.997571	0.999416	N/A
Electricity price (paid)	1	0.999054	0.997571	0.999416	N/A
Wage (received)	1	1.02578	1.0253	1.02591	N/A
Wage (paid)	1	1.02578	1.0253	0.990002	N/A
Average productivity	1	1.03346	0.949856	1.	N/A
Average price	1	0.9902	1.07676	0.990849	N/A
Mass of firms	1	0.972801	1.23008	0.974587	N/A
Income/Welfare	1	0.997878	0.996352	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891

Table 37: (10) Low Output Elasticity (X) - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.41	0.555	0.19	N/A
Electricity price (received)	1	0.981682	0.962124	0.991984	N/A
Electricity price (paid)	1	0.981682	0.962124	0.991984	N/A
Wage (received)	1	1.13826	1.13732	1.13684	N/A
Wage (paid)	1	1.13826	1.13732	0.920838	N/A
Average productivity	1	1.12205	0.838024	1.	N/A
Average price	1	0.946287	1.25453	0.953618	N/A
Mass of firms	1	0.85677	1.88689	0.875484	N/A
Income/Welfare	1	0.975224	0.954972	0.995283	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.335	0.365	0.215	0.2
Electricity price (received)	1	0.990195	0.990208	0.990051	1.23779
Electricity price (paid)	1	0.990195	0.990208	0.990051	0.99023
Wage (received)	1	1.10479	1.07348	1.15883	1.005
Wage (paid)	1	1.10479	1.07348	0.909682	1.005
Average productivity	1	1.09312	0.905641	1.	1.
Average price	1	0.95997	1.14118	0.946609	0.998032
Mass of firms	1	0.891911	1.44742	0.857585	0.9945
Income/Welfare	1	0.98537	0.986648	0.993796	0.999475

Table 38: (11) High Output Elasticity (E) - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.13	0.2	0.03	N/A
Electricity price (received)	1	1.00072	0.999419	0.999038	N/A
Electricity price (paid)	1	1.00072	0.999419	0.999038	N/A
Wage (received)	1	1.02371	1.02387	1.02215	N/A
Wage (paid)	1	1.02371	1.02387	0.991485	N/A
Average productivity	1	1.03086	0.952467	1.	N/A
Average price	1	0.991027	1.07262	0.992164	N/A
Mass of firms	1	0.975077	1.21688	0.978215	N/A
Income/Welfare	1	0.998193	0.996739	0.999881	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.345	0.375	0.175	0.1
Electricity price (received)	1	0.990945	0.990921	0.990402	1.0995
Electricity price (paid)	1	0.990945	0.990921	0.990402	0.989546
Wage (received)	1	1.07095	1.04899	1.14743	1.00073
Wage (paid)	1	1.07095	1.04899	0.946629	1.00073
Average productivity	1	1.09674	0.902509	1.	1.
Average price	1	0.96966	1.15634	0.950501	0.999719
Mass of firms	1	0.917349	1.5019	0.867495	0.999214
Income/Welfare	1	0.982434	0.984671	0.995389	0.999948

Table 39: (12) High Elasticity of Resource Substitution - Policy Comparison

Restoring the wage					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.14	0.21	0.035	N/A
Electricity price (received)	1	0.999054	0.997571	0.999416	N/A
Electricity price (paid)	1	0.999054	0.997571	0.999416	N/A
Wage (received)	1	1.02578	1.0253	1.02591	N/A
Wage (paid)	1	1.02578	1.0253	0.990002	N/A
Average productivity	1	1.03346	0.949856	1.	N/A
Average price	1	0.9902	1.07676	0.990849	N/A
Mass of firms	1	0.972801	1.23008	0.974587	N/A
Income/Welfare	1	0.997878	0.996352	0.999838	N/A
1 % decrease in electricity price					
	After Exit	F Sub	F_D Sub	w Sub	P_E Sub
Subsidy	/	0.305	0.345	0.215	0.205
Electricity price (received)	1	0.990219	0.990079	0.990137	1.24551
Electricity price (paid)	1	0.990219	0.990079	0.990137	0.990177
Wage (received)	1	1.06156	1.04458	1.18826	1.00067
Wage (paid)	1	1.06156	1.04458	0.932784	1.00067
Average productivity	1	1.08265	0.911791	1.	1.
Average price	1	0.974381	1.14011	0.937824	0.999721
Mass of firms	1	0.92991	1.4436	0.835487	0.999218
Income/Welfare	1	0.987151	0.987715	0.992776	0.999891