Government Size, Misallocation and the Resource Curse

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Structural transformation is a reallocation of labor across sectors. In this paper I investigate the impact of structural transformation in an open economy on sectoral and aggregate productivity with a particular focus on the role of government. While there are potentially many sources of structural transformation,[1] I focus on labor reallocation induced by a windfall of revenue. Furthermore, I only concentrate on windfall revenue arising from the export of natural resources (fuels, ores and metals); although, the entire analysis is applicable to other types of windfalls such as, for example, foreign aid, remittances, EU structural funds or war reparations.

The exact focus here is the size of public sector employment in resource-rich countries. Governments largely provide non-traded services such as law enforcement, defense, infrastructure, arbitration and, thus, we can expect the standard "Dutch-disease" mechanism to hold, pushing workers towards non-traded sectors in resource-rich countries. Higher windfalls of revenue should increase demand for both traded and non-traded goods, but since the supply of non-traded goods can only be provided locally, more workers need to shift to non-traded sectors (including the government sector) in order to satiate the higher demand for non-traded goods in resource-rich countries. As such, I am interested in how the size of public employment should optimally vary between resource-rich and resource-poor countries,

This paper has been prepared for the XVIII Central Bank of Chile Annual conference. Thanks to Antonio Mele and Kim Ruhl for useful discussion and comments. Previous versions of this work have been distributed as "Spend, Baby, Spend: Windfalls, Specialization and Misallocation." All errors are my own. Email: rls7@st-andrews.ac.uk.

1. Gollin, Parente, and Rogerson (2002), Duarte and Restuccia (2010), Rogerson (2008), Dekle and Vandenbroucke (2006) and Yi and Zhang (2010), for instance, focus on labor reallocation induced by non-homotheticities in agriculture.

Commodity Prices and Macroeconomic Policy, edited by Rodrigo Caputo and Roberto Chang. Santiago, Chile. © 2015. Central Bank of Chile.

whether the extent of government employment observed in resource-rich countries is efficient and, if not, what the productivity and welfare costs of this misallocation are.

I do two things in this paper: First, using a panel of macro cross-country data, I demonstrate that the share of public sector employment is greater in resource-rich countries than in resource-poor countries even controlling for the size of other non-traded sectors. Second, I construct and calibrate a small, open economy model with two production sectors and a government sector in which (optimally) higher government employment shares emerge as a consequence of windfall-induced labor reallocation. I then use a model to compare the optimal and observed size of government in order to obtain an estimate of the extent of government misallocation and the impact it has on welfare and productivity.

Importantly, the paper builds on earlier work by Kuralbayeva and Stefanski (2013). In that paper we did two things: First, we showed that resource-rich regions tend to have a) small but relatively productive manufacturing sectors and b) large but relatively unproductive non-manufacturing sectors. While this difference in sectoral size (or Dutch-disease effect) was well known and in line with theoretical predictions,[2] the productivity facts were novel and we showed that standard models were ill-equipped to replicate them. Second, we constructed and calibrated a small, open economy model with two sectors in which observed differences in sectoral productivity emerged endogenously as a consequence of windfall-induced labor reallocation and subsequent worker specialization. Since in the current paper I am interested in studying the impact of windfall-induced changes in government size on sectoral and aggregate productivity, it is crucial to correctly capture the windfall-induced changes in sectoral productivity that are not driven by changes in the size of the government sector. As such, in this paper, I adapt the framework of Kuralbayeva and Stefanski (2013) which does well in reproducing the pertinent facts relating to both sectoral size and sectoral productivity in resource-rich countries in the absence of government.

More specifically, in my model, I assume that manufacturing consumption goods are traded while non-manufacturing consumption goods are non-traded and that agents have heterogeneous skills

2. See for instance, Corden and Neary (1982), Matsuyama (1992) or Michaels (2011) for theoretical and empirical treatments of this so-called Dutch disease.

at performing different tasks in both consumption-good sectors. In addition, I assume the existence of a government sector whose role it is to provide basic public services such as an institutional framework, law-enforcement, judiciary, defense, infrastructure etc. to the two consumption-good sectors. The government sector is modeled as having a positive (external) effect on the productivity of both consumption sectors; however, government employees will have to be paid through a tax levied on all workers. I will also assume that government services cannot be imported from abroad. A region with higher windfall revenues will demand more of both consumption goods and government services than a region without windfalls. While the region's higher demand for manufacturing consumption goods can be satiated by imports from abroad, more workers need to be employed in non-manufacturing sectors (including the government sector) to meet the higher demand for locally produced non-manufacturing consumption goods and government services. This generates a reallocation of labor from manufacturing to the non-manufacturing sectors and results in a process of self-selection. Workers who choose to remain in manufacturing despite a windfall are those who are most skilled at manufacturing sector tasks, which leads to a more specialized and, hence, more productive manufacturing sector. Workers who re-allocate to non-manufacturing do so only in response to the higher demand generated by the windfall and will be less skilled at non-manufacturing sector tasks than workers already employed in that sector. This can lead to a more de-specialized and, hence, less productive non-manufacturing sector.[3] Windfalls thus induce labor reallocation, which, in turn, can generate asymmetric changes in sectoral productivity and an increase in the size of government.

I calibrate the model and show that the exogenous variation in endowments of natural resources does remarkably well in explaining the differences in sectoral employment structure and the large, asymmetric differences in sectoral productivity observed across countries. The model also does well in explaining differences in non-manufacturing prices in the data. However, the optimal increase in government employment in resource-rich countries predicted by the model is significantly smaller than the employment

3. Although the extent of this de-specialization can be tempered by the higher productivity resulting from a bigger government, the exact pattern will depend on the particular calibration.

observed in the data. Resource-rich countries seem to employ far more workers in government than the above model would suggest is optimal. In order to calculate the cost of this apparent misallocation, I feed observed government employment levels into my model, and examine the subsequent changes in labor reallocation across manufacturing and non-manufacturing sectors and the resulting differences in productivity. I find that a ten percentage point increase in resource windfalls is associated with a 1.72% lower aggregate productivity and a 1.11% lower welfare arising from government misallocation. In short, resource-rich countries tend to have governments that are too big, and this can have a relatively large impact on both productivity and welfare.

The above idea of a negative relationship between natural resources and economic outcomes ties into the so-called “resource curse” literature (see for example Neary, 1978; van der Ploeg, 2010; Robinson, Torvik, and Verdier, 2006; Collier and Goderis, 2007; Collier and Hoeffler, 2005, etc.). While the conclusions of that literature are not definitive, there is strong evidence to suggest that resource windfalls can generate various negative economic effects especially in the presence of bad governance and poor institutions. In particular, in that literature, negative economic outcomes are often a consequence of a corrupt political process associated with higher resource wealth. In short, those papers tend to argue that resource-rich countries offer more opportunities for a graft which introduces a drag on the economy. The approach taken in this paper is different and intentionally complementary. In the model, I take the most charitable view of government possible. First, I assume that the government sector is a crucial input in production and that there is no corruption, no directly wasted resources, no electioneering, no graft and no costly power struggles. Second, governance in resource-rich countries is assumed to potentially be just as effective as in resource-poor countries. Finally, I assume that all tax revenues are raised via non-distortive lump-sum taxes. Thus, I do my best to give governments in resource-rich countries the benefit of the doubt and, as such, my model aims to generate the largest possible optimal increase of government employment in response to windfalls. In my setup, the only way that government can be inefficient is if it employs too many or too few workers relative to what is predicted as optimal by the model. Importantly, however, I do not take a stand on why governments are the size that they are and instead, in my baseline experiment, I simply take public sector employment from the data and analyze the implicit misallocation costs of governments that are too big or too small.

Like Kuralbayeva and Stefanski (2013), the self-selection aspect of this work is in the spirit of Lagakos and Waugh (2014), Roy (1951) and Lucas (1978), and is closely linked to a similar discussion in the development literature. Poorer countries tend to have a larger fraction of their labor force employed in agriculture due to subsistence requirements. Caselli (2005) and Restuccia and others (2008) also show that productivity differences in agriculture between rich and poor countries are significantly greater than aggregate productivity differences. Lagakos and Waugh (2014) argue that this fact stems from the specialization that takes place in the smaller agricultural sectors in rich countries. They formalize and test their idea in the framework of a Roy (1951) model of self-selection. The outcomes of the above models, however, are efficient and do not consider the impact of a misallocation stemming from suboptimal government size. Furthermore, Lagakos and Waugh (2014) rely on non-homothetic preferences and an exogenous variation in aggregate productivity to generate a shift of workers across sectors. The current model has homothetic preferences and, instead, emphasizes the role of exogenous resource windfalls and the existence of a non-traded sector as the channel driving labor reallocation. Thus, I avoid what Lagakos and Waugh (2014) call the "key challenge" of their setup, which is the requirement of large, exogenous productivity differences to drive workers across sectors.

Section 1 introduces the data used in this study and establishes the productivity and employment facts. Section 2 introduces a general version of the model while section 3 considers the role of heterogeneity and government in a simple version of the model. Sections 4 and 5 present the solution and calibration of the general model, section 6 presents the results and section 7 delves into the scope of the government misallocation and its impact on productivity and welfare. Section 8 examines the role of weights and section 9 concludes.

1. Data and Facts

In this section, I briefly review the data and facts pertaining to manufacturing and (non-resource) non-manufacturing employment shares and productivity constructed in Kuralbayeva and Stefanski

(2013). I also examine the data and facts pertaining to employment in the government sector. In particular, I show that resource-rich regions have a) small and relatively productive manufacturing sectors, b) large and relatively unproductive non-manufacturing sectors and c) a greater proportion of workers employed in the government sector.

Throughout, I follow aforesaid paper and divide economies into mining and utilities (*MU*), manufacturing (*M*) and non-resource non-manufacturing (*NM*) sectors:[4]

$$\text{Total Economy} = \overbrace{\underbrace{A + C + S + G}_{\text{NonRes.Non-Mfg.}} + \underbrace{M}_{\text{Mfg.}}}^{\text{Non-Resource Economy}} + \underbrace{MU}_{\text{Mining and Utilities}} \quad (1)$$

As in Kuralbayeva and Stefanski (2013), I focus only on the productivity and employment structure of the non-resource economy.[5] Diverging from it, however, I will also consider the proportion of non-manufacturing workers employed in the public sector. Notice, however, that I will not say anything about productivity in the government sector. Constructing sectoral productivity measures is challenging and the assumptions needed to calculate government-specific productivity would be heroic to say the least. In what follows, I give a brief overview of the data.

1.1 Data

In Kuralbayeva and Stefanski (2013), we considered three different measures of productivity for the manufacturing and non-manufacturing sector. We begin with labor productivity, then add sectoral physical capital and finally include sectoral human capital. In principle, each subsequent measure of TFP is better than the last, since it controls for a greater variety of factor inputs. In practice, each measure requires additional data that is often hard to come by and, as such, has to be estimated. Considering all three measures gives a better overall picture of sectoral productivity. However,

4. The lowest level of aggregation available for all data is the one sector ISIC classification. NM here is defined as the sum of agriculture (A), construction (C), (private) services (S) and Government (G).

5. Thus, when we refer to aggregate productivity or sectoral employment share, we always mean aggregate productivity of the *non-resource* economy, or sectoral employment relative to *non-resource* employment.

when we examine the results and compare the changes of sectoral productivity with respect to resource wealth, we find quantitatively and qualitatively very similar results across all three measures. As such, in this paper, to save space, and since that was the baseline measure chosen in the original paper, I will only consider the most comprehensive measure of productivity from that paper, D_s, obtained as a residual from the following production function

$$Y_s = D_s(K_s)^{\alpha_s}(h_sL_s)^{1-\alpha_s} \quad (2)$$

Where Y_s is sector s's value-added, L_s is sectoral employment, K_s is sectoral physical capital, and h_s is average sectoral human capital, so that h_sL_s is the "quality adjusted" workforce.[6] Constant price sectoral value-added data comes from the UN (2009) and is adjusted to control for cross-country sectoral price level differences using the World Bank's 2005 International Comparison Program (ICP) price data. Employment data comes from the ILO (2003) and physical capital is constructed using the perpetual inventory method from the PWT. I follow Caselli (2005) in constructing aggregate human capital from the Barro and Lee (2010) education data set, and in constructing sectoral physical capital. Finally, due to lack of data, I assume the ratio of human capital between any two sectors is constant across countries and time, equal to the corresponding ratio in the U.S., and that labor shares in the last two measures of productivity, $1 - \alpha_s$, are identical across countries, constant over time, and equal to OECD averages. For construction details, see the appendix of Kuralbayeva and Stefanski (2013).

Next, I obtain public sector employment data from the ILO which "covers all employment of [the] general government sector as defined in the System of National Accounts 1993 plus employment of publicly owned enterprises and companies, resident and operating at central, state (or regional) and local levels of government. It covers all persons employed directly by those institutions, without regard for the particular type of employment contract."[7]

6. I also refer to D as the corresponding measure of aggregate (non-resource) productivity.

7. A limited subset of the public employment data is provided at the ISIC one sector level and, in that (very limited) subset, public employment is overwhelmingly in the non-manufacturing sector. As such, in the baseline experiment of this paper, in order to maintain as large a sample of data as possible, I shall assume that all government employment belongs entirely to the non-manufacturing sector.

I follow Sachs and Warner (2001) and Kuralbayeva and Stefanski (2013) in defining natural resource "wealth" as the ratio of exports of natural resources (fuels, ores and metals) to GDP using WDI (2007) data.

In my baseline sample, like in my paper with Kuralbayeva, I consider a panel of the 120 richest countries for the 1980-2007 period.[8] I keep all country-date points for which I have all necessary data and those that do not deviate significantly across different data sources. This leaves me with a total of 33 countries in my sample. On average, there are 10 observations for each country, 22 observations for each year and a total of 340 data points. Notice that, until 1995, the data for public employment is only available once every five years and there are very few observations from 1980 and 1985.

1.2 Summary of Facts

Table 1 shows summary results by comparing the largest 10 percent of natural resource exporters with the smallest 10 percent. The table reproduces the results (pertaining to sectoral size and productivity) found in Kuralbayeva and Stefanski (2013) for the current sample of data and adds the new finding pertaining to the size of government employment in resource-rich countries. The table shows the decomposition of employment according to manufacturing/non-manufacturing and public/non-public sectors. Furthermore it also shows the sectoral productivity (in manufacturing and non-manufacturing) normalized by aggregate productivity of each group. From the table observe that resource-rich countries: a) employ, proportionally, 27% less workers in manufacturing (column 4) and 6% more workers in (non-resource) non-manufacturing (column 3) than resource-poor countries; b) are 24% more productive in manufacturing (column 8) and 4% less productive in non-manufacturing (column 7) relative to aggregate productivity than resource-poor countries and; c) employ 48% more workers in the public sector (column 5) and 10% less workers in the non-public sector (column 6) than resource-poor countries.

8. I focus on richer countries for three reasons: First, I am examining more disaggregate data than is standard so data quality in poorer countries is a serious concern. Second, the mechanism of specialization described later may play a more prominent role in richer countries. Finally, focusing on richer countries may avoid the worst of unobserved cross-country heterogeneity. Since this procedure may in principle result in unobserved selection bias, I have also experimented with a complete sample and the results are independent from this cutoff.

Table 1. Characteristics of Top and Bottom Deciles of Natural Resource Exporters

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E Res./ GDP	*Output/ worker*	*Emp. NM*	*Share M*	*Emp. G*	*Share NG*	*TFP NM*	(D_s) *M*
10^{th} percentile	0.17	30,716	0.86	0.14	0.25	0.75	0.94	1.37
90^{th} percentile	0.00	17,756	0.81	0.19	0.17	0.83	0.98	1.11
10^{th} /90^{th}			1.06	0.73	1.48	0.90	0.96	1.24

Source: See section 1.1.
(1) Resource Export Share (2) Output per Worker (3-6) Composition of Employment (Manufacturing vs Non-manufacturing and Public vs. Non-public) (7-8) Sectoral Productivity (Relative to Aggregate Productivity). Data for 33 countries from 1980 to 2007.

As in that paper, I stress that the productivity results refer to relative and not absolute productivity. So, for example, looking at the column labeled D_m (column 8) in table 1, the average productivity of manufacturing in the top 10% of resource exporters is 37% higher than the average aggregate productivity of those same countries; whereas, in the bottom 10% of exporters, the average manufacturing productivity is only 11% higher than the average aggregate productivity in that group of countries. Countries that have low aggregate (or sector neutral) levels of productivity will have low absolute levels of productivity in all sectors irrespective of the size of their resource endowments but may still have high productivity in manufacturing relative to their aggregate productivity.

1.3 Earlier Results

In this section, in table 2, I briefly reproduce the baseline regressions of Kuralbayeva and Stefanski (2013) for the current sample of data. For robustness, with respect to these regressions and further discussion, see that paper. Column (1) shows the regression of manufacturing employment share on the log of the windfall measure controlling for changes in output per worker (and output per worker squared) as well as controlling for time-fixed effects.[9] Resource-rich countries employ fewer workers in the manufacturing sector and (implicitly) more workers in the non-manufacturing sector; a doubling of resource windfalls is associated with a 1.4 percentage point decline in the manufacturing employment share. These results are statistically significant at the one percent level.

Columns (2) and (3) of table 2 show how (the log of) manufacturing and non-manufacturing productivity varies with (the log of) resource windfalls and aggregate productivity. Higher aggregate (or sector neutral) productivity is unsurprisingly associated with higher

9. Since employment share in manufacturing is simply one minus the employment share in non-manufacturing, the regressions for non-manufacturing employment are the same with opposite signs on coefficients. As in Kuralbayeva and Stefanski (2013), I take a log transformation of resource windfalls since the data is concentrated near zero. This ensures that the transformed empirical distribution is closer to normal. Importantly this transformation does not drive the results. Finally, I control for output-per-worker and output-per-worker squared since it is a well-established fact that manufacturing follows a hump shape with income. This in no way drives my results. For details and robustness tests, see Kuralbayeva and Stefanski (2013).

Table 2. Baseline Results in Current Sample of Data

	(1)	(2)	(3)	(4)
	M. Emp.	$\log(D_m)$	$\log(D_s)$	$\log(p_s)$
log(NRE)	-0.014***	0.068***	-0.012***	0.048***
	(0.002)	(0.014)	(0.002)	(0.011)
logLprod	0.650***			
	(0.127)			
sqlogLprod	-0.031***			
	(0.006)			
log(D)		1.458***	0.888***	0.838***
		(0.078)	(0.011)	(0.067)
τ_e				-0.355***
				(0.132)
Time fixed effects	yes	yes	yes	yes
No. of obs.	340	340	340	340
R^2	0.256	0.567	0.953	0.480

Source: Kuralbayeva and Stefanski (2013).
Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

sectoral productivity. However, controlling for differences in aggregate productivity, resource-rich countries tend to be more productive in manufacturing and less productive in non-manufacturing than resource-poor countries. These results are significant at the one percent level and are robust to other measures of productivity. A doubling of natural resource windfalls is associated with a 1.2% lower non-manufacturing productivity and a 6.8% higher manufacturing productivity.[10]

The positive impact of windfalls on the non-manufacturing price is an important fact that will be examined later. In Kuralbayeva and Stefanski (2013) we constructed a panel of sectoral price level data by combining ICP cross-country sectoral price levels with sectoral

10. I emphasize that these results refer to *relative* and *not absolute* productivity. Countries that have low aggregate (or sector neutral) levels of productivity will have low *absolute* levels of productivity in all sectors irrespective of the size of their resource endowments but may still have high productivity in manufacturing *relative* to aggregate productivity.

price indices from the UN. Column (4) reproduces the baseline price regression from Kuralbayeva and Stefanski (2013). In particular it shows the regression of the log of relative non-manufacturing price levels (with respect to manufacturing price levels) on the (log) measure of resource windfalls, (log) aggregate productivity, energy subsidies from WEO (2011)[11] and time-fixed effects.[12] I find that a doubling of natural resource windfalls is associated with a 4.8% increase in the price of non-traded goods and these results are significant at the one percent level.

1.4 Public Sector Employment Results

Next, I present the novel empirical results of this paper. Table 3 shows the regressions relating the size of the government sector employment with resource windfalls. In particular, column (1) shows the regression of government employment share on the log of my windfall measure. Resource-rich countries employ more workers in the public sector and (implicitly) less workers in the non-public sector. These results are statistically significant at the one percent level. Column (2), controls for time-fixed effects, while column (3) controls for changes in output per worker that may help reduce unobserved cross-country heterogeneity. Column (4) adds time-fixed effects to the regressions in column (3). In all three cases, the results remain largely unchanged. Finally, column (4) adds employment shares of the non-manufacturing sector. The results of this last regression tell us that, even controlling for the size of other non-manufacturing sectors, resource-rich countries tend to have a larger government sector. Taking column (2) as the baseline result, I find that a doubling of natural resource windfalls is associated with a 1.7% higher public sector employment share and these results are significant at the one percent level.

11. Subsidy data is an average of 2008-2010 data. We assume that these subsidies are country specific and fixed over the 1980-2007 period.

12. Notice that we included aggregate productivity to control for the so-called Penn effect, the observation that richer countries have higher non-traded goods prices than poorer countries. Furthermore, as was discussed in Kuralbayeva and Stefanski (2013), a potential issue with the ICP price data is that they reflect consumer rather than producer prices, which are the focus of the later model. This may be particularly important in resource-rich economies, where consumer subsidies are prevalent. We control for energy subsidies as an indirect attempt at controlling for the overall level of subsidies in a country's economy.

Table 3. Changes in Government Employment Share and Resource Wealth

	(1)	(2)	(3)	(4)	(5)
	G. Emp.	*G. Emp.*	*G. Emp.*	*G. Emp.*	*G. Emp.*
log(NRE)	0.014*** (0.004)	0.017*** (0.004)	0.011*** (0.004)	0.013*** (0.004)	0.021*** (0.004)
logLprod			0.041*** (0.008)	0.045*** (0.008)	0.045*** (0.008)
NM. Emp.					-0.595*** (0.103)
Time fixed effects	no	yes	no	yes	yes
N° of obs.	340	340	340	340	340
R^2	0.045	0.061	0.115	0.139	0.220

Source: See section 1.1.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, notice that while in Kuralbayeva and Stefanski (2013) we controlled for time and country-fixed effects, in the above regressions I include only time-fixed effects. There are two reasons for this. First, I have a far more limited sample of data and therefore not enough variation over time in the sample. Most of the variation over time in windfalls comes from variation in price which tends to be common across countries. Since much of the price variation in natural resources took place in the 1980's and much of our public employment data is missing in that period, there is very little temporal variation in the remaining data.[13] Second, and perhaps more importantly, the focus of this paper will be government employment. This type of work is often characterized by tenure or unionization and is thus often quite unresponsive to shocks over time, at least in the short-run. As such, to examine the persistent effects of resource endowments, it makes more sense to look at cross-country differences that can be interpreted as long-run effects.

13. A rule of thumb here is to regress the independent variable log(NRE) on country-fixed effects. If the value of $1/(1-R^2)$ from the resulting regression is less than ten, the rule of thumb suggests that there is enough variation in the data to include that variable. In our case $1/(1-R^2) = 11$ thus suggesting there is too little variation to include country-fixed effects.

2. The Model

In this section, I introduce a small, open, multi-sector economy with heterogeneous agents that can account for the observed facts in productivity and employment. The model closely follows Kuralbayeva and Stefanski (2013) but introduces a role for government. There are three final goods in the economy: manufacturing goods (m), private non-manufacturing goods, which, for brevity, I will call services (s) and a windfall good which, also for brevity, I will refer to as oil but could equally as well be any other natural resource or alternative source of windfall revenue. I assume that manufacturing and oil are traded internationally, while services are assumed to be non-traded. Oil is assumed to be an endowment good that is not used locally but only exported abroad (and thus serves as a windfall of income) while manufacturing and services can be produced locally using labor but no oil. I also assume the existence of a government sector (the public non-manufacturing sector) which provides the manufacturing, service and oil sectors with inputs such as institutional frameworks, transportation, rule of law, arbitration, etc. that are productivity enhancing, but are external to firms (and workers). Thus, while workers can be employed in the government sector, the sector produces no final goods directly, but rather provides an input that looks like a higher level of productivity to other sectors of the economy. Finally, I assume that the external benefits produced by government cannot be imported from abroad.

2.1 Households

Suppose there is a measure one of agents, indexed by i. Preferences are given by

$$U(c_s^i, c_m^i) \equiv \left((c_s^i)^{\frac{\sigma-1}{\sigma}} + \nu (c_m^i)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (3)$$

Each agent in the economy is endowed with a unit of time and assumed to have a vector of innate sector specific skills or talents, $\{z_s^i, z_m^i\}$, representing the efficiency of that unit of time in the service sector (s) and the manufacturing sector (m). Endowments of skills $\{z_s^i, z_m^i\}$, are exogenous and are assumed to be randomly drawn from a distribution common to the whole population $N(z_s, z_m)$. Since skills are assumed to be perfectly observable, agents earn a wage income, w^i. The agent is also endowed with a resource tree that provides a stream of O units of oil each period. Oil is not directly used by the agent but is exported and provides windfall revenues. Finally, each agent also potentially faces a lump-sum tax T, paid to government. The budget constraint of the agent is thus given by:

$$p_s c_s^i + c_m^i \leq w^i + G_m(L_g) p_o O - T \tag{4}$$

where p_s is the relative price of service sector goods and p_o is the relative price of oil determined on international markets. Traded manufacturing goods are taken as numeraire. Finally, in the above, $0 \leq G_m(L_g) \leq 1$ is a function capturing the external productivity benefits of government for the export of oil. These are assumed to be positively dependent on the employment size of the government sector L_g. I describe this function in more detail in the following paragraphs.

2.2 Production

I assume a competitive market in all final good sectors so that each worker gets paid its marginal product. The output of worker i in sector $k = s$, m is given by $Y_k^i = AG_k z_k^i$, where A is aggregate (potentially sector specific) efficiency, z_k^i is the worker's sector specific productivity and $0 \leq G_m(L_g) \leq 1$ is the impact of government on productivity that is external to workers and firms but depends positively on the size of government employment L_g in the manner described in the following paragraph. Aggregate output in sector $k = s$, m is given by

$$Y_k \equiv \int_{i \in \Omega^k} Y_k^i di = AG_k(L_g)\tilde{L}_k \tag{5}$$

where Ω^k is the set of agents electing to work in sector k, $L_k \equiv \int_{i \in \Omega^k} di$ is the number of workers in private enterprises in sector k and $\tilde{L}_k \equiv \int_{i \in \Omega^k} z_k^i di$ represents the total effective labor units (privately) employed in sector k. Finally, notice that for simplicity, I assume that $G_m(L_g)$ is common to both the oil sector and the manufacturing production sector.

2.3 Trade

It is assumed that manufacturing goods and oil are traded while service sector goods are not traded. In order to close the model, I assume a period-by-period balanced budget constraint given by

$$m - G_m(L_g)p_oO = 0, \tag{6}$$

where m is the value of imported traded goods (recall that traded goods are assumed to be the numeraire) and $G_m(L_g)$ is the impact of government on how effective imports are, capturing the idea of a type of iceberg transport cost. As mentioned above, for simplicity, I have assumed that the government contribution to the productivity of exporting (or producing) oil is the same as the corresponding term in the manufacturing sector. Finally, in the above setup, all oil endowments are exported in exchange for manufacturing imports. A country with no oil (i.e., $p_oO = 0$) is thus assumed to be closed to trade.

2.4 Government

The government employs L_g workers to provide public goods and services such as infrastructure, a justice system, law and order, etc. that enhance sectoral productivity of the consumption sector $G_k(L_g)$ according to the following production function:

$$G_k(L_g) = 1 - \frac{\psi^k}{\psi^k + L_g}, \tag{7}$$

where $\psi^k \geq 0$ is a sector specific constant capturing the importance of government services to production in a particular sector. When $\psi^k > 0$, $G'_k(L_g) > 0$, that is, more government employees contribute more, ceteris paribus, to the output of a sector. Zero employment in the government sector implies $G_k(0) = 0$ and, hence, zero output in sector k. Consequently, with $\psi^k > 0$, a positive employment in government is necessary for production to take place. If $\psi^k = 0$, then $G_k(L_g) = 1$ and the model collapses to the non-government world of Kuralbayeva and Stefanski (2013). I let Ω^G be the set of workers employed in the government sector while the number of workers employed in government is given by $L_g \equiv \int_{i\in\Omega^G} di$. Finally, for simplicity, and to capture the inherent equity of government employment, I assume that government pays each employee the same wage, w^g. Alternatively, we can think of this as a technological constraint either on the ability of government to observe worker specific skills or on the fact that production in the government sector requires a constant level of skill. As such, the government's budget constraint, which is assumed to be balanced period by period, is given by

$$T = w_g L_g. \tag{8}$$

Thus, the government levies a per period lump-sum tax on each worker to pay for the wages of all its employees.

2.5 Market Clearing

Defining $\Omega = \Omega^m U \Omega^s U \Omega^G$, the market clearing conditions for manufacturing, services and employment are given by

$$\int_{i\in\Omega} c_m^i di = Y_m + m \text{ and } \int_{i\in\Omega} c_s^i di = Y_s \text{ and } L_m + L_s + L_g = 1 \tag{9}$$

2.6 Competitive Equilibrium

For each price of oil p_o, every endowment level of oil O, and for a given size of government L_g, equilibrium in the above economy consists of a relative price of service goods p_s, agent-specific wages w^i, and allocations for all agents, firms and government so that labor and output markets clear, and trade, as well as the government budget constraint, remains balanced period by period.

2.7 Solution

Each manufacturing and service sector firm chooses a non-negative quantity of labor to hire. Due to perfect competition, firms offer the following wage schedule to consumer i:

$$w_m^i = AG_m(L_g)z_m^i \text{ and } w_s^i = p_s AG_s(L_g)z_s^i, \tag{10}$$

in manufacturing and service sectors respectively. Consumer i, who decides to work in a non-governmental sector, chooses employment in the sector that provides a higher wage given its particular talent vector. The wage offer for each worker in non-governmental work is thus given by $w_{ng}^i = \max\{w_s^i, w_m^i\} = \max\{p_s A G_s(L_g) z_s^i, A G_m(L_g) z_m^i\}$, which gives rise to the following simple cut-off rule: a worker i employed in non-government work, will choose to work in services if and only if

$$p_s > \frac{G_m(L_g) z_m^i}{G_s(L_g) z_s^i}. \tag{11}$$

Finally, given a worker's wage offer in the private sector, a worker will choose to work in government if he receives a higher wage there. Consequently, the wage of each worker is given by $w^i = \max\{w_{ng}^i, w_g\}$.

Agents take prices, as well as the wage offers arising from the firm and government problems, as given (and, hence, the above decision rules). Having picked their specialization, they then proceed to maximize (3) subject to (4), which results in the following demands of each agent:

$$c_s^i = \frac{(w^i + G_m(L_g) p_o O - T)}{p_s + \nu^\sigma p_s^\sigma} \text{ and } c_m^i = \frac{\nu^\sigma p_s^\sigma (w^i + G_m(L_g) p_o O - T)}{p_s + \nu^\sigma p_s^\sigma}. \tag{12}$$

Using the goods market clearing conditions in equation (9) and the demands of each agent from equations (12), I can show that

$$\nu^\sigma p_s^\sigma Y_s = Y_m + G_m(L_g) p_o O \tag{13}$$

Substituting (5) into (13), provides an implicit expression for p_s as a function of the value of oil endowment $p_o O$ and the level of government employment.[14]

2.8 Observed and Optimal Government

In this paper I consider two ways of determining government employment: First, I will assume the government employment is exogenous and taken directly from the data. Second, I will suppose that government employment emerges from choices of a benevolent

14. Notice that I have assumed that windfall income is distributed evenly across agents. This assumption plays no role in our results since equation (13) and, hence, the equilibrium price and cutoff condition holds regardless of how windfalls are distributed.

social planner who wishes to maximize the utility of workers. In particular, a benevolent government will take the demand functions of agents–derived above in equation (12) as given, and solve a Ramsey-type problem for the optimal size of government employment L_g^{opt} by maximizing the expected utility of workers

$$\max_{0 \le L_g \le 1} \mathbb{E}_{\gamma_i}(U(c_s^i(L_g), c_m^i(L_g))), \tag{14}$$

where $\mathbb{E}_{\gamma_i}(U(c_s^i, c_m^i)) = \int_0^1 \gamma_i U(c_s^i(L_g), c_m^i(L_g))di$. In this expression, $\gamma_i : \mathbb{R} \to \mathbb{R}$ is a function that specifies the weight that a government places on individual i. If $\gamma_i = 1$, as it will be in our baseline, then the government cares equally about every individual. In appendix B, I consider the case when different agents have different weights.

3. Heterogenity and Government

3.1 A Simple Example

To illustrate the impact of worker heterogeneity and government on sectoral productivity, I begin with a simple example.[15] Suppose the skill distribution N is degenerate and given by $\{z_s^i, z_m^i\} = \{e_i, e^{1-i}\}$ for each worker $i \in [0,1]$. Furthermore, assume Cobb-Douglas utility ($\sigma = 1$), equal utility weights ($\nu = 1$), normalize A to unity and suppose that $\psi_m = \psi_s > 0$ so that $G \equiv G_s = G_m$. Agent i receives wage offers $w_s^i = p_s G z_s^i$ in services, $w_m^i = G z_m^i$ in manufacturing and w_g in the government sector and will choose to work in the sector that pays most. This gives rise to two cutoff agents, $\bar{i}_m$ and $\bar{i}_g$ who are respectively indifferent between manufacturing and government sectors, so that $w_g = w^{\bar{i}_m}$, as well as between service and government sectors, so that $w_g = w^{\bar{i}_g}$. Suppose that government hires L_g workers. To do so, it will have to offer a wage large enough so that $L_g = \bar{i}_g - \bar{i}_m$. Using these relationships, I can calculate these two cutoffs as a function of price and the size of the government employment so that $\bar{i}_m(p_s, L_g) = (1 - \log p_s - L_g)/2$ and $\bar{i}_g(p_s, L_g) = (1 - \log p_s + L_g)/2$. I illustrate the problem of the worker in figure 1(a) which plots the wage offers in each sector and the cutoffs $\bar{i}_k(p_s, L_g)$ for $k = m, g$. Agents to the left of $\bar{i}_m(p_s, L_g)$ are

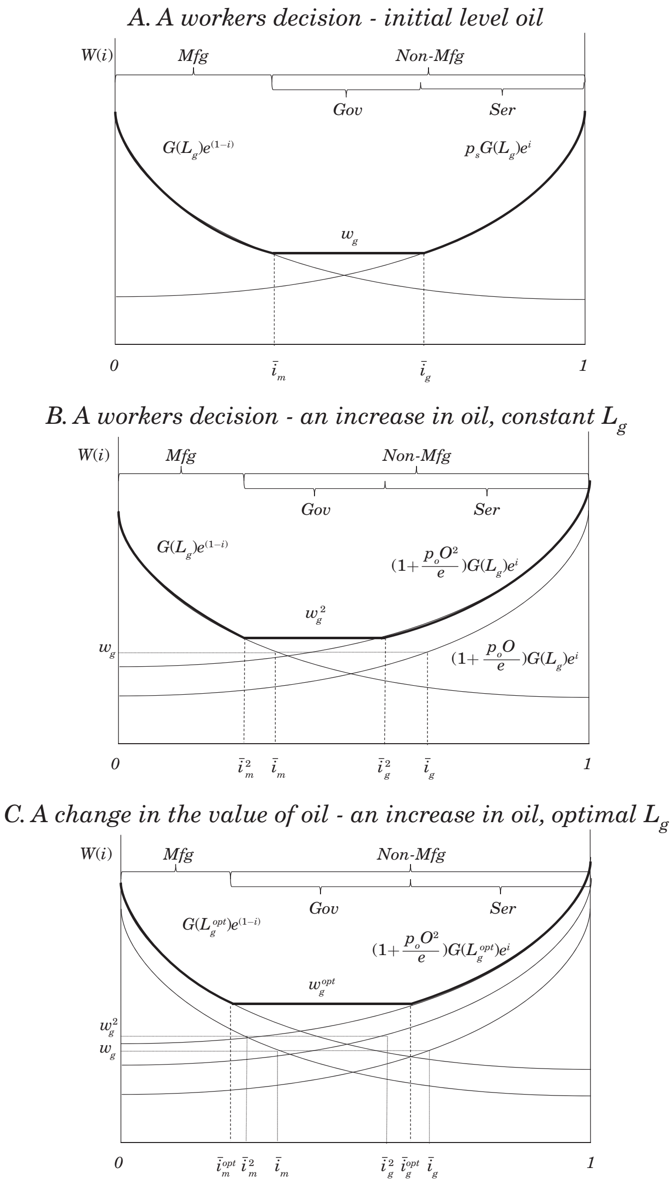
15. While I focus on heterogeneous workers, this setup can easily be related to one with heterogeneous firms without changing the results.

relatively more skilled in manufacturing sector tasks and, hence, have higher wage offers than in services or government and, hence, choose to work in the manufacturing sector. Agents to the right of $\bar{i}_g(p_s, L_g)$ are relatively more skilled in service sector tasks and, hence, have higher wage offers and choose to work in services. Agents in between the cutoffs will have a comparative advantage in government work and will, hence, choose to work in the government sector.

The cutoff values are dependent on the price of service goods and the size of government employment. For the moment, suppose that government adjusts its wage to maintain a constant level of employment and consider the impact of a higher oil windfall. A windfall will influence the price of services and, hence, the distribution of workers across sectors. A windfall of revenue generates a greater demand for both types of consumption goods. To satiate the higher demand for non-traded service sector goods, more workers are needed in the service sector. However, new workers will choose to work in services only if service wages rise, which, in turn, can only happen if the service sector price increases. More formally, I can write output in each sector as a function of the respective cutoff (and, hence, the price): $Y_s\,(p_s; L_g) = G_s(L_g)(e - e^{\bar{i}_g(p_s;\, L_g)})$ and $Y_m(p_s) = G_m(L_g)(e - e^{1-\bar{i}_m(p_s;\, L_g)})$. Using these equations as well as the relationship between the two cutoffs and equation (13), I can determine the equilibrium price of non-manufacturing $p_s = 1 + p_0 O/e$. A higher windfall translates into a higher service sector price which results in an increase in service sector wage offers. In order for employment in government to remain unchanged despite the higher price, wages in the government sector must also rise. This results in a shift of workers from manufacturing to government and from government towards services resulting in a leftward shift of both cutoffs to $\bar{i}_m^2(p_s^2; L_g^s)$ and $\bar{i}_g^2(p_s^2; L_g^s)$. As both cutoffs shift left, manufacturing productivity $(Y_m/\bar{i}_m = (e - e^{1-\bar{i}})/\bar{i}_m)$ rises: the workers who remain in the manufacturing sector are most skilled in manufacturing sector work. At the same time, service sector productivity $(Y_s/(1 - \bar{i}_g) = (e - e^{\bar{i}})/(1 - \bar{i}_g))$ falls: new entrants in non-manufacturing pull down productivity since they are, on average, less skilled than those already employed in non-manufacturing. Finally, I can also show that non-manufacturing sector productivity $(Y_s/(1 - \bar{i}_s + L_g) = (e - e^{\bar{i}})/(1 - \bar{i}_g + L_g)$ also falls as long as the government sector is not "too large."[16]

16. In particular $L_g < -2 - log(e + p_o O) + 2\Omega(e(e + p_o O))$ where $\Omega(\cdot)$ is the product logarithm function.

Figure 1. The Mechanics of the Model in a Simple Example



Source: Author's elaboration.

3.2 Government

So far, I have taken the size of government employment as fixed. Suppose, however, that the fiscal authority takes the demand functions of agents derived above in equation (12) as given, cares equally about every agent so that $\gamma_i = 1$, and solves the Ramsey-type problem for the optimal size of government employment L_g^{opt} in equation (14). Taking the first order condition from this maximization problem, and applying the implicit function theorem to the resulting first order condition, it can be shown that the optimal size of government increases with the size of the oil endowment $\partial L_g^{opt} / \partial p_o O > 0$. Intuitively, higher oil endowment means a greater demand for both traded and non-traded goods. Demand for traded, manufacturing goods can be satiated by imports from abroad. Demand for non-traded goods however, which includes government services, is satiated with locally produced goods and, hence, results in a shift of labor towards the non-traded sectors of services and government. This is shown in figure 1(C). The impact on manufacturing productivity is unambiguous: manufacturing productivity will increase both due to the smaller size of the manufacturing sector (and, thus, its more specialized nature) and the larger government sector, which, in turn, increases each workers productivity. The impact on non-manufacturing productivity is mixed and will depend on specific parameters but can potentially be negative.

4. Solving the Model

4.1 Distribution Function

To calibrate and solve the model, I must pick a particular parametric form for the distribution of skills $N(z_s, z_m)$ since the Roy model cannot be identified from cross-sectional wage data alone.[17] In what follows, I assume that skills are drawn independently from a normalized Type II extreme value (or Frechet) distribution with CDF

17. This is because we observe only the outcomes of workers choices (in the form of a worker's observed wages) and not the talent draws (and hence the sectoral wage offers) that underpin these outcomes.

$$N(z_s) = e^{-z_s^{-\theta}} \text{ and } N(z_m) = e^{-z_m^{-\theta}} \tag{15}$$

where $\theta > 1$. The log of a random talent draw $\log Z_i$ has a standard deviation $\pi/(\theta\sqrt{6})$, where π is the constant. The parameter θ thus governs the amount of variation in skills and, hence, the observed productivity dispersion: lower values of θ imply more heterogeneity in ability and higher productivity dispersion. Notice that I assume that θ is common to both manufacturing and service sectors and that talent draws are independent of each other. While both these assumptions may seem restrictive, they allow me to derive simple, analytic solutions which provide insights into the workings of the model. In Kuralbayeva and Stefanski (2013) we extended the "non-government version" of the model to allow correlated talent draws and different dispersions across sectors and we showed that, quantitatively, these channels only played a limited role.

I focus on the Frechet distribution for several reasons. First and foremost, this distribution is one of three extreme value distributions. According to the Fisher-Tippet-Gnedenko theorem from extreme value theory, there are only three types of distributions that are needed to model the maximum or minimum of the collection of random observations from the same distribution. More specifically, the maximum of a sample of i.i.d. random variables converges in distribution to either the Gumbel, the Frechet, or the Weibull distribution.[18] In my case, choosing an extreme value distribution can be thought of as capturing the distribution of agents' "best" talents in each particular sector. Secondly, of these three distributions I choose the Frechet in keeping with the literature. Obviously, Kuralbayeva and Stefanski (2013) chose this distribution. Furthermore, Eaton and Kortum (2001) have used this distribution to parameterize a Ricardian model of international trade, and Lagakos and Waugh (2014) have used it to model talent distribution across sectors. Finally, the Frechet distribution also provides very tractable analytic solutions which allow for easy interpretation of results and does a very good job of fitting the data.

18. Broadly speaking, if one generates N data sets from the same distribution, and then creates a new data set that includes only the maximum values of these N data sets, the resulting data set can only be described by one of the above distributions. For more details see De Haan and Ferreira (2006).

4.2 Employment

Since z_s and z_m are independently drawn from a Frechet distribution, the joint density function can be expressed as $g(z_s, z_m) = g(z_s)g(z_m)$. Using this, I can relate sectoral labor supply allocation to the parameter that controls the dispersion of skills across sectors.

First, I start with government employment. In order to induce L_g workers to work in the government sector, the government will have to offer a wage w_g such that enough workers are drawn to that sector by earning more than they could in either manufacturing or non-manufacturing. Consequently, the chosen wage will be defined by

$$\begin{aligned} L_g &= P\left(w_g > w_m, w_g > w_s\right) \\ &= P\left(w_g > G_m z_m, w_g > p_s G_s z_s\right) \\ &= \int_0^{\frac{w_g}{G_s p_s}} \int_0^{\frac{w_g}{G_m}} g(z_s) g(z_m) dz_m dz_s \end{aligned} \tag{16}$$

Taking the level of government employment (and, hence, government wage) as given, the expected employment in services and manufacturing are

$$\begin{aligned} L_s &= P\left(w_s > w_m, w_s > w_g\right) \\ &= P\left(p_s G_s z_s > G_m z_m, p_s G_s z_s > w_g\right) \\ &= \int_{\frac{w_g}{G_s p_s}}^{\infty} \int_0^{p_s G_s z_s / G_m} g(z_s) g(z_m) dz_m dz_s \end{aligned} \tag{17}$$

$$\begin{aligned} L_m &= P\left(w_m > w_s, w_m > w_g\right) \\ &= P\left(G_m z_m > p_s G_s z_s, G_m z_m > w_g\right) \\ &= \int_{w_g / G_m}^{\infty} \int_0^{\frac{G_m z_m}{p_s G_s}} g(z_s) g(z_m) dz_s dz_m \end{aligned} \tag{18}$$

Given the Frechet distribution of talent draws, the above equations can be simplified into the following expressions, which only depend on the given level of government employment and the price of non-manufacturing goods:

$$
\begin{aligned}
L_s &= \frac{G_s^\theta p_s^\theta}{G_m^\theta + G_s^\theta p_s^\theta}\left(1 - L_g\right), \\
L_m &= \frac{G_m^\theta}{G_m^\theta + G_s^\theta p_s^\theta}\left(1 - L_g\right), \qquad (19) \\
L_g &= e^{-\frac{G_m^\theta + G_s^\theta p_s^\theta}{w_g^\theta}}
\end{aligned}
$$

Solving this for w_g I obtain

$$
w_g = \left(-\frac{G_m^\theta + G_s^\theta p_s^\theta}{\log(L_g)}\right)^{\frac{1}{\theta}}. \qquad (20)
$$

4.3 Output

Normalizing $A = 1$, the output of each sector can be expressed as

$$
\begin{aligned}
Y_s &= G_s \int_{\frac{w_g}{G_s p_s}}^{\infty} \int_0^{p_s G_s z_s / G_m} z_s g(z_s, z_m) dz_m dz_s, \\
Y_m &= G_m \int_{w_g / G_m}^{\infty} \int_0^{\frac{G_m z_m}{p_s G_s}} z_m g(z_s, z_m) dz_s dz_m \qquad (21)
\end{aligned}
$$

Since z_s and z_m are independently drawn from a Frechet distribution, this simplifies to

$$
\begin{aligned}
Y_s &= G_s \left(\frac{G_s^\theta p_s^\theta}{G_s^\theta p_s^\theta + G_m^\theta}\right)^{1-\frac{1}{\theta}} \Lambda(\theta, L_g), \\
Y_m &= G_m \left(\frac{G_m^\theta}{G_s^\theta p_s^\theta + G_m^\theta}\right)^{1-\frac{1}{\theta}} \Lambda(\theta, L_g). \qquad (22)
\end{aligned}
$$

where $\Lambda(\theta,L_g) \equiv \Gamma(1-1/\theta) - \Gamma(1-1/\theta, -\log(L_g))$, while $\Gamma(\cdot)$ and $\Gamma(\cdot,\cdot)$ denote the complete and incomplete gamma functions.

For a given level of government employment L_g, using the above equations for sectoral output and (13), it is easy to show that $\partial p_s/\partial p_o O > 0$. It then follows that oil endowments result in a reallocation of labor $\partial L_s/\partial p_o O > 0$ and $\partial L_m/\partial p_o O < 0$. This shift in labor generates specialization (in manufacturing) and de-specialization (in services), $(\partial Y_s/L_s)\ /\partial p_o O < 0$ and $(\partial Y_m/L_m)/\partial p_o O > 0$. If I instead consider productivity in the non-manufacturing sector, I can also show that $(\partial Y_s/(L_s + L_g))/\partial p_o O < 0$ as long as government employment is not "too-large," i.e., if, and only if, $L_g < (1/\theta - 1)(L_s/L_s + L_m)$. Later, in the calibration, it is easy to verify that this condition is satisfied for every country-date in our dataset.

5. Calibrating the Model

5.1 Estimating Skill Dispersion

The parameter θ governs the dispersion of (unobserved) underlying skills. To match this parameter to observed variables, I make use of the properties of the Frechet distribution. The distribution of wage offers in each (non-government) sector is given by

$$N_s^w(w_s) = Pr\{W_s \le w_s\} = Pr\{p_s AG_s Z_s \le w_s\}$$
$$= Pr\{Z_s \le \frac{w_s}{p_s AG_s}\} = e^{-(p_s AG_s)^\theta w_s^{-\theta}} \qquad (23)$$

$$N_m^w(w_m) = Pr\{W_m \le w_m\} = Pr\{AG_m Z_m \le w_m\}$$
$$= Pr\{Z_m \le \frac{w_m}{AG_m}\} = e^{-(AG_m)^\theta w_m^{-\theta}} \qquad (24)$$

These are both Frechet density functions with the same dispersion parameter (θ) as the talent distributions.[19] Thus, the wage offers in the non-governmental sector are the maximum an agent could earn

19. Notice that these are not distributions of observed wages in a given sector, but the distribution of (unobserved) wages that agents could earn if they chose to work in a particular sector.

in either sector $w_{ng} = \max\{w_s, w_m\}$. The distribution of this wage $N^{ng}(w)$ is then the maximum order statistic of wage offers in non-governmental sectors and is given by

$$N^{ng}(w) = N_s^w(w)N_m^w(w) = e^{-A^\theta(G_m^\theta + G_s^\theta p_s^\theta)w^{-\theta}}. \tag{25}$$

The above distribution is also a Frechet with the same dispersion parameter (but with a different mean) as the skill distribution. This is a consequence of the assumption that the original talents were drawn from an extreme value distribution. Finally, agents with a non-governmental wage offer drawn from this distribution will choose to work in government if, and only if, the wage offered by government w^g is higher than their non-governmental wage offer. Consequently, the distribution of observed wages will be given by

$$N(w) = N^{ng}(w)\mathbf{1}_{w \geq w_g}(w). \tag{26}$$

In order to match the parameter θ, I use a method of moments. In particular, I calculate the standard deviation of a sample of log wages in a "resource-poor" country and match it to the implied standard deviation of log wages in the model. As in Kuralbayeva and Stefanski (2013), I obtain cross-sectional wage data from the 2009 U.S. Current Population Survey (CPS) and find that the standard deviation of log wages in this sample is 0.58.[20] Then, I calculate the corresponding theoretical standard deviation of the log-wage and choose $\theta = 2.10$ so that the two match.[21]

5.2 Government Parameters

To calibrate the government parameters, I first impose the restriction that $\psi \equiv \psi^s = \psi^m$ so that the impact of government on

20. Following Kuralbayeva and Stefanski (2013), Lagakos and Waugh (2014) and Heathcote and others (2009), I include individuals aged 25 to 60 who have non-missing data on income and hours worked. Wages are before tax and are taken to be the sum of wage, business and farm income. The sample is further restricted to include workers who average more than 35 hours per week of work and earn at least the Federal minimum wage.

21. To do this, notice that for any integrable function f, I can write $\mathbb{E}(f(w)) = f(w_g)\int_0^{w_g} dG^{ng}(w) + \int_{w_g}^{\infty} f(w)dG^{ng}(w)$. Noting that the standard deviation of log-wages in the model σ is given by $\sigma = \sqrt{Var(\log(W))} = \sqrt{\mathbb{E}(W^2) - (\mathbb{E}(W))^2}$, I use the above formula and the CDF of $N^{ng}(w)$ to calculate θ.

productivity is the same in both manufacturing and service sectors. The reason for this assumption is twofold: first, it simplifies the analysis and, second, there is no *a priori* reason to believe that the impact of government spending should affect productivity more in one sector than in another. I choose $\psi = 0.015$ so that the predicted optimal government employment in resource-poor countries in the model exactly matches government employment in the lowest decile of resource exporting countries in the data of approximately 17 percent.

This is a logical benchmark. I wish to reproduce the observed economic structure of resource-poor countries and examine the impact of adding natural resources to those countries. Notice, however, that if observed public sector employment in resource-poor countries were larger than optimal, then the above assumption will underestimate the extent of misallocation and government inefficiency in resource-rich countries. In other words, if resource-poor countries have inefficiently large government, then the scale of misallocation in resource-rich countries will be even larger than the model suggests. Of course, if resource-poor countries have governments that are "too-small" relative to the optimum, because higher levels of public-sector employment in resource-rich countries could be seen as getting closer to the efficient levels of public sector employment, my measure of government inefficiency will overestimate the extent of misallocation.

Of the two cases, it seems eminently more plausible that we are in the first and that we are underestimating the extent of misallocation in resource-rich countries. After all, resource-rich countries exhibit worse (rather than better) economic outcomes than resource-poor countries, so it would be surprising if it were resource-poor countries that were further away from the optimum. Furthermore, notice that the public sector employment of 17% is a very reasonable choice. For example, in the U.S., government sector employment is approximately 13% of the labor force, while in the OECD it is approximately 19%. Our assumption that, in resource-poor countries, optimal government employment share is 17% is, thus, a half way point between these two extremes. Nonetheless, I demonstrate the robustness of this assumption on ψ in appendix B. Finally, I also impose that $\gamma_i = 1$ so that the government cares equally about all agents. I also examine this assumption in further detail in appendix B.

5.3 Preference Parameters

Finally, I follow Kuralbayeva and Stefanski (2013) in estimating preference parameters σ and ν. From the household's problem, I can derive an equation relating relative consumer expenditure on the relative price $c_m/c_s = (\nu p_s)^\sigma$. Taking logs of this equation, I estimate elasticity of substitution between manufacturing and non-manufacturing goods using ICP data and find that $\sigma = 0.94$. Finally, I choose the preference parameter to be $\nu = 0.29$ to match the employment share in the manufacturing sector in resource-poor countries in the model to the employment share in manufacturing in the lowest decile of exporters in our sample (approximately 19%).

6. Results

To examine the implications of the calibration, I consider three different versions of the model: 1) a model without government, 2) a model where government employment is taken directly from the data, and 3) a model where government employment is chosen optimally.

Table 4 compares the empirical windfall elasticities from the data (shown in tables 2 and 3) with the corresponding windfall elasticities implied by the different versions of the model for

Table 4. Changes in Sectoral Employment and Sectoral Productivity Associated with Resource Wealth in the Data and Model

	Data	*Model*			*Model/Data*		
		(1)	*(2)*	*(3)*	*(1')*	*(2')*	*(3')*
		No Gov.	*Obs. Gov.*	*Opt. Gov.*	*No Gov.*	*Obs. Gov.*	*Opt. Gov.*
M. Emp., L_m	-0.014	-0.009	-0.015	-0.008	0.65	1.09	0.53
M. Prod, D_m	0.068	0.025	0.062	0.025	0.37	0.90	0.36
NM. Prod, D_s	-0.012	-0.007	-0.003	-0.004	0.53	0.21	0.36
NM. Price, p_s	0.048	0.031	0.073	0.030	0.65	1.53	0.63
G. Emp., L_g	0.017	-	0.017	0.002	-	1.00	0.12

Source: see section 1.1.

sectoral employment, productivity and prices.[22] First, in column (1) and (1') of table 4, I consider a version of the model without a government.[23] A doubling of natural resource windfalls in the optimal model results in a 0.9 percentage point decline in manufacturing employment, a 2.5% increase in manufacturing productivity, a 0.7% decline in non-manufacturing productivity and a 3.1% increase in the price of non-manufacturing goods. With respect to these measures the model does well to explain between 37% and 65% of the observed changes. This is in line with the results of Kuralbayeva and Stefanski (2013).

In column (2) and (2') of table 4, I now consider a case with government, where the observed government employment shares are fed directly into the model. Notice that the findings of Kuralbayeva and Stefanski (2013) continue to hold. The model captures all—and even slightly over-predicts—the elasticity of manufacturing employment. It also explains 90% of the elasticity in manufacturing productivity and 21% of the productivity in non-manufacturing productivity. Finally the model over-predicts the increase in non-manufacturing prices and—by construction—it accounts for all of the government employment elasticity.

Finally, in columns (3) and (3') of table 4, I examine how the elasticities in the data compare to the model where government employment shares are chosen optimally. The model once more does relatively well and accounts for between 36% and 63% of the non-governmental employment and productivity. Where the optimal model does very poorly is in explaining the elasticity of government employment. Here a doubling of windfalls in the model is associated with only 0.2 percentage point increase in government employment; whereas, in the data, a doubling of windfalls is associated with a 1.7 percentage point increase. Thus, the model explains only 12% of the observed elasticity. This suggests that resource-rich countries

22. In the data, we measure resource wealth as the ratio of current price exports of natural resources to current price GDP measured in international dollars. International dollars are constructed to have the same purchasing power over GDP as the U.S. dollar has in the United States. Since the U.S. is a resource-poor country (according to this measure), we can view GDP in international dollars as the GDP of a country measured using a resource-poor country's prices. As such, in the model, we construct our resource wealth measure as the value of exports of natural resources divided by GDP, measured with the prices of a resource-poor country (i.e., one that has $p_0 O = 0$).

23. Thus, the model is re-calibrated here in that ψ is set to zero, and all other parameters are chosen to match the relevant moments described in the paper. In particular, I choose $\nu = 0.22$, $\theta = 2.23$, and $\sigma = 0.94$.

have a much higher government employment share than the model predicts they "should."

The message from this exercise is that the specialization mechanism introduced in Kuralbayeva and Stefanski (2013) is strong enough to explain a big part of the large differences in sectoral employment shares and asymmetric productivity differences between resource-rich and resource-poor countries. Furthermore, the differences in the size of government employment between resource-rich and resource-poor countries act to magnify the differences in sectoral productivity and employment produced by the specialization effect. Thus, the large size of government in resource-rich countries effectively amplifies the "Dutch-disease" effects of a smaller manufacturing sector and higher non-manufacturing prices. Finally, and most importantly, the observed government employment shares in resource-rich countries tend to be significantly "too-large." I explore the impact of this latter effect on welfare and productivity in the following section.

7. The Resource Curse

The resource-curse: a well-known, stylized fact relating negative economic outcomes to resource windfalls. In the context of this paper, the mechanism for a resource curse is clear. If there is a misallocation of public sector employment in resource-rich countries so that government employment is either too large or too small relative to the optimum, we will observe a lower productivity and welfare in the model. Table 5 shows the regressions of the ratio of observed-to-optimal aggregate productivity and welfare respectively emerging from the model versus the size of natural resource windfalls (and the log of natural resource windfalls). Observe in the data from columns (1) and (2) that a doubling of the natural resource windfall is associated with productivity that is 0.6% lower and a welfare that is 0.4% lower than it otherwise could be if government employment were not misallocated. Equivalently, from columns (3) and (4), a one percentage point increase in resource export shares in GDP is associated with a productivity that is 0.17% lower than it otherwise could be and a welfare that is 0.11% lower than it otherwise could be. Notice, that these are big effects. Countries that have natural resource exports accounting for 10 percent of GDP, will have a productivity that is, on average, 1.7% lower and a welfare that is 1.1% lower than it otherwise could be. Countries with 40%

resource export share will have an aggregate productivity that is, on average, a massive 6.8% lower and a welfare that is 4.4% lower than it otherwise could be.

Table 5. Regressions of the Ratios of Productivity and Welfare in the Observed and Optimal Models with Respect to Resource Wealth

	(1)	(2)	(3)	(4)
	Rel. Prod. (D^{obs}/D^{opt})	*Rel. Welf.* (U^{obs}/U^{opt})	*Rel. Prod.* (D^{obs}/D^{opt})	*Rel. Welf.* (U^{obs}/U^{opt})
log(NRE)	-0.006***	-0.004***		
	(0.001)	(0.001)		
NRE			-0.172***	-0.111***
			(0.022)	(0.021)
Time FE	yes	yes	yes	yes
Obs.	340	340	340	340
R^2	0.114	0.086	0.181	0.108

Source: See section 1.1.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As I showed before, the misallocation occurs due to a government sector that tends to be too large in resource-rich countries. Importantly, I make absolutely no claims as to why the size of government employment tends to be what it is and, in particular, why government employment tends to be higher in resource-rich countries. Government employment in resource-rich countries can be non-optimal for a range of reasons (some associated with natural resources, and others not), but this paper takes no stand on the issue and simply takes the observed size of government in resource-rich countries as given. As such, the observation that resource-rich countries have larger than optimal government is a characteristic of the given sample of data, and will not necessarily hold in every single resource-rich country. The findings here thus reflect the fact that, in this particular sample of data, resource-rich countries tended to have public employment that was "too-large." It is, of course, entirely possible to find examples of resource-rich countries in the sample that the model predicts had "too-small" or "just-right" government. As two such specific examples, consider the cases of Chile and Canada in 2007. Chile's windfall measure was approximately 20 percent of GDP. This was associated with a productivity that was approximately 2% lower and a welfare that was approximately 3% lower than they otherwise could have been. This lower productivity and welfare was a consequence of a government sector employment share that was, according to the above model, approximately 8.4 percentage points too small relative to the predicted optimum. In the case of Canada, its windfall measure was approximately 11% of GDP in 2007. This was associated with a productivity that was only 0.2% lower and a welfare that was approximately 0.1% lower than they otherwise could have been. This was a consequence of the fact that Canada almost had "the right" levels of government employment given its resource windfall.

The above fits in well with the institutional view of the resource curse. In particular, by emphasizing the role of government misallocation, my theory lends support to arguments by Robinson and others (2006), van der Ploeg (2010) and others where explanations of the resource curse should be sought outside economic structure perhaps, as they suggest, in areas such as political economy, weak institutions or property rights.

8. The Role of Weights

In the baseline model I focused on governments that weigh individuals equally within and across countries so that $\gamma_i = 1$ in equation (29). Now I consider a government that can potentially weigh workers unequally and I allow these weights to vary across countries. In particular, I assume that governments value public sector workers differently from private sector workers according to this function:

$$\gamma_i = \begin{cases} m_g, & \text{if } i \in \Omega^g \\ 1, & i \notin \Omega^g \end{cases} \tag{27}$$

In the above, m_g is the mass placed on public-sector relative to private-sector workers. I allow these weights to potentially vary across countries. In particular, I choose m_g to reconcile the discrepancies between optimal and observed government employment in resource-rich countries. Since the baseline model is chosen to match public sector employment in the lowest decile, for that particular decile, m_g will be one and all other parameters will remain exactly as in the baseline. To match the observed public sector employment share of approximately 25% in the highest decile of resource-rich countries, I must set $m_g = 1.38$. Thus, in order for the model to optimally reproduce the higher observed public sector employment in the top decile of resource-rich countries, the governments in those countries must implicitly value public sector workers 38% more than private sector workers. Thus, in principle, the model can optimally reproduce observed differences in public sector employment between resource-rich and resource-poor countries, but only if we assume a larger weight is placed by the social planner on government sector employees in resource-rich countries. While there may be some justification to such a weighing scheme,[24] it nonetheless seems to be difficult to justify why governments in resource-rich countries should place more weight on the public sector than governments in resource-poor countries. This is an interesting and suggestive result that can be seen as a complement to the discussion of the resource curse in the previous section. The higher weights on public sector workers can be interpreted as a measure of how much government workers in resource-rich countries manage to bias government policy in their favor. Thus, this is further indication that there may be institutional failures in resource-rich countries that lead governments to effectively care more about their own employees than the employees of other sectors. Finally, since the model now exactly matches employment shares in the government sector, the sectoral and aggregate employment and productivity results are once more given by columns (2) and (2') of table 4, although now, given the particular choice of weights, the observed government employment is optimal and there is no misallocation in the model.

9. Conclusion

Kuralbayeva and Stefanski (2013) show that, in the data, resource-rich regions have small and productive manufacturing

24. For example, in the model, government sector employees will be the lowest wageworkers and, hence, placing greater weight on them can be seen as a form of progressive taxation.

sectors and large and unproductive non-manufacturing sectors and propose a mechanism that explains these productivity differences through a process of self-selection. Windfall revenues induce labor to move from the (traded) manufacturing sector to the (non-traded) non-manufacturing sector. A self-selection of workers takes place. Only those most skilled in manufacturing sector work remain in manufacturing. Workers that move to the non-manufacturing sector are, however, less skilled at non-manufacturing sector work than those who were already employed there. Resource-induced structural transformation thus results in higher productivity in manufacturing and lower productivity in non-manufacturing.

In this paper, I show that, in addition to the above facts, in the data, resource-rich countries also tend to employ a larger proportion of workers in the government sector than resource-poor countries. I then adapt the model of specialization of Kuralbayeva and Stefanski (2013) to include a productive government sector and proceed to examine optimal government employment in resource-rich countries. In particular, I show that the model can generate higher employment in the government sector when windfalls are higher. In a nutshell, government services are non-traded. Higher windfalls will increase demand for all goods and services, including government services, but since these cannot be imported, workers will shift to the government sector to satiate demand. Furthermore, even with a government sector, the specialization mechanism introduced in Kuralbayeva and Stefanski (2013) is strong enough to explain a large part of the asymmetric differences in sectoral employment shares and productivity between resource-rich and resource-poor countries. In addition, the differences in the size of government between resource-rich and resource-poor countries act to magnify the differences in sectoral productivity and employment shares produced by this specialization mechanism. Finally, the observed government employment shares in resource-rich countries tend to be "too-large" relative to optimum. In the calibrated, best-case-scenario model, government employment is nearly 10 times smaller than in the data. This implicit misallocation of resources has a large, negative impact on welfare and aggregate productivity. Using the calibrated model, I find that a ten percentage point increase in resource windfalls is associated with a 1.72% lower aggregate productivity and a 1.11% lower welfare arising from government misallocation in resource-rich countries.

As such, the above theory and empirical evidence suggest that institutions may play a key role in driving the resource curse. In particular, this paper lends support to arguments by Robinson and others (2006), van der Ploeg (2010) and others that explanations of the resource curse should be sought outside economic structure, perhaps, as they suggest, in areas such as political economy, weak institutions or property rights which induce governments to be particularly large in resource-rich countries.

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Appendix A
Data

A.1 Resource wealth

I follow Sachs and Warner (2001) and Kuralbayeva and Stefanski (2013) in defining natural resource "wealth" as the ratio of exports of natural resources (fuels, ores and metals) to GDP using WDI (2007) data. Following Kuralbayeva and Stefanski (2013), I use PPP GDP (in current prices) in the denominator of our measure since higher endowments of resources can potentially impact prices of non-resource goods (and, hence, measured GDP) influencing both the numerator and the denominator of our measure. Using PPP GDP keeps prices fixed across countries and, hence, the measure only captures changing resource wealth. I have experimented with both measures and resource wealth, as well as other measures such as the ratio of net exports of natural resources to gross domestic product (both observed price and PPP). The results, however, are unaffected. For more detail of data construction, see the appendix of Kuralbayeva and Stefanski (2013).

A.2 Labor shares

To calculate the measure of productivity, I need to find expressions for labor shares $1 - \alpha s$ for each sector s. Although these shares can potentially vary across countries, due to a lack of comprehensive cross-country sectoral data, I make use of OECD data to calculate the average annual share of employee compensation for each sector in OECD countries for the longest period of time that data is available. I calculate the labor share as the ratio of total compensation of employees (wages and salaries before taxes, as well as employer's social contributions) over sectoral value-added.[25] I find labor share in manufacturing is 0.57 while in non-manufacturing it is 0.53.[26]

A.3 Sectoral employment

I obtain sectoral employment data for 1980-2006 from the ILO KILM online database. To obtain the largest set of employment data, I combine ISIC revision 2 and ISIC revision 3 employment data.

25. Tables 7 and 8 in the OECD Annual National Accounts, volume 2, 1970-2008 (2009 prov.) Detailed aggregates, in millions of national currency.

26. For more detail of data construction see the appendix of Kuralbayeva and Stefanski (2013).

A.4 Prices

Since I want to compare sectoral productivity across countries, it is crucial to control for any price differences that may exist between sectors, across countries, and over time. To do this, I use the methodology and data from Kuralbayeva and Stefanski (2013). In particular, in that paper, we constructed country and sector-specific price levels for each sector by combining the sectoral price levels from the World Bank's 2005 International Comparison Program (ICP) database and sectoral price indices from the UN (2009). The resulting series gives the price level of a particular sector in each country relative to the price of the same sector in the U.S. in 2005.

Importantly, as is mentioned in Kuralbayeva and Stefanski (2013), although the ICP study is especially built to provide accurate cross-country measures of price differences, it does have some well-known limitations. The main objection is that expenditures are valued at the actual transaction prices paid by purchasers and, hence, may include delivery charges and any taxes payable (or subsidies received) on purchased products. This may be an issue if taxes/subsidies vary systematically with resource wealth. We recognize this fact, but our hands are tied for lack of better data. In the main body of the paper, we use a simple version of our model to show that, to account for observed productivity differences, unrealistically large subsidies would be necessary. Notice also that this re-basing is not driving our results and we see similar productivity differences when value-added is left in constant U.S. dollars.

A.5 Aggregate capital

I follow Caselli (2005) and Kuralbayeva and Stefanski (2013) and use the Penn World Tables (version 6.3) to construct estimates of aggregate capital stock. This is done using the perpetual inventory method with the depreciation rate set to 0.06.

A.6 Sectoral capital

I follow Caselli (2005) and Kuralbayeva and Stefanski (2013) in estimating sectoral capital. First, assume that economies consist of five sectors: agriculture (A), mining and utilities (MU), manufacturing (M), construction (C) and services (S). Then, assume that the production function of each sector s is of the form given in equation 2. If I also assume that the rates of return on capital are equalized across sectors (an arbitrage condition), then it is easy to show that the above functional form implies that for any two sectors *s* and *s'*, the following holds:

$$\alpha_s \frac{P_s^D Y_s}{K_s} = \alpha_{s'} \frac{P_{s'}^D Y_{s'}}{K_{s'}} \tag{A1}$$

Where P_sD is the domestic producer price of sector *s* goods. For more detail of data construction see the appendix of Kuralbayeva and Stefanski (2013).

A.7 Aggregate human capital

I follow Kuralbayeva and Stefanski (2013), Caselli (2005) and Hall and Jones (1999) in constructing a measure of aggregate human capital from the Barro and Lee (2010) average years of schooling data set.

A.8 Sectoral human capital

To calculate sectoral human capital, I follow Kuralbayeva and Stefanski (2013) and Caselli (2005) when estimating sectoral human capital. I assume that the ratio of human capital between any two sectors is constant across countries and time and equal to the corresponding ratio in the U.S. and that labor shares in the last two measures of productivity, $1 - \alpha_s$, are identical across countries, constant over time and equal to OECD averages.

A.7 Public sector employment

Public sector employment data is from the ILO which covers all employment of the general government sector as defined in System of National Accounts of 1993 plus employment of publicly owned enterprises and companies residing and operating at central, state (or regional) and local levels of government. It covers all persons directly employed by those institutions without regard for the particular type of employment contract. A limited subset of the public employment data is provided at the ISIC one sector level and, in that (very limited) subset, public employment is overwhelmingly in the non-manufacturing sector. As such, in the baseline experiment of this paper, in order to maintain as large a sample of data as possible, I shall assume that all government employment belongs entirely to the non-manufacturing sector.

A.8 Summary statistics

Table A1 presents summary statistics for the main economic variables: sectoral employment shares (ISIC), public or government sector employment share, sectoral TFP (physical and human capital), value-added per worker (this is the sum of all sectoral value-added data divided by the total labor force), GDP/capita in international 2005 dollars from the WDI, and the natural resource export share.

Table A1. Summary Statistics for Data

Variable	*Sector*	*N*	*mean*	*sd*	*min*	*max*	*p10*	*p90*
Emp. share	A	340	0.10	0.10	0.01	0.67	0.02	0.21
	C	340	0.08	0.02	0.03	0.14	0.06	0.10
	S	340	0.18	0.04	0.07	0.30	0.12	0.24
	M	340	0.65	0.10	0.22	0.82	0.51	0.76
Emp. share	G	340	0.21	0.08	0.06	0.54	0.11	0.34
TFP	A	340	2.80	0.81	0.99	5.23	1.70	3.84
	C	340	216.95	54.41	98.75	417.48	143.08	280.86
	S	340	128.14	21.09	72.99	234.69	106.34	147.25
	M	340	139.17	54.24	26.84	382.27	74.90	193.26
	ACS	340	106.96	19.51	49.37	204.96	90.29	126.21
	ACSM	340	111.75	22.29	50.10	223.95	86.90	134.65
VA/worker	-	340	50,553	21,644	6,038	170,198	18,150	71,069
gdp/capita	-	340	23,279	11,281	2,489	72,783	8,586	35,164
NR	-	340	0.04	0.06	0.00	0.39	0.01	0.08

Source: See section 1.1.

Appendix B
Robustness and Extensions

B.1 Optimality in resource-poor countries

Table B1. Changes in Sectoral Employment and Sectoral Productivity Associated with Resource Wealth in the Data and Model under Different Assumptions on ψ

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
	Model/data				
ψ =	*Opt. Gov. 0.015*	*Opt. Gov. 0.008*	*Opt. Gov. 0.020*	*Opt. Gov. 0.038*	*Opt. Gov. 0.079*
M. emp.	0.53	0.55	0.52	0.50	0.46
M. prod.	0.36	0.35	0.37	0.39	0.43
NM. prod.	0.36	0.40	0.34	0.29	0.22
NM. price	0.63	0.61	0.63	0.66	0.71
G. emp.	0.12	0.09	0.13	0.17	0.22
Imp. opt. govt. emp.:	0.17	0.13	0.19	0.25	0.33

Source: See section 1.1.

In this section, I carry out a robustness exercise on the parameter ψ that influences the optimal size of government. Column (1) of table B1 reproduces column (3') of table 4 and shows the percentage of sectoral productivity and employment explained by the baseline version of the model under the assumption of optimal government size. The top row of the table presents the value of ψ in the current calibration while the bottom row shows the observed 17% government employment share in the lowest decile of resource-poor countries that the parameter was chosen to reproduce. Notice that, in the baseline version of the model, only 12% of the increase in government employment share between resource-rich and resource-poor countries is captured by the model. As mentioned above, it is however eminently likely that most countries, including resource-poor countries, have some form of inefficiencies that translate into government sectors that are too large. In column (2), I set $\psi = 0.008$ so that the true optimal share of government employment is a lower 13% like that in the U.S. In this case the model only explains 9% of the increase in government employment share. Notice, however, from columns (3)-(5) of table B1, that choosing a larger ψ to match government employment shares in the OECD (19%), the EU (25%) or Sweden (33%), does indeed result in the model predicting slightly larger increases in government employment in resource-rich countries. Notice, however, that these increases are still significantly smaller than observed in the data and that the different choice of ψ implies the model completely misses the level of government employment found in resource-poor countries.

B.2 Uncertainty

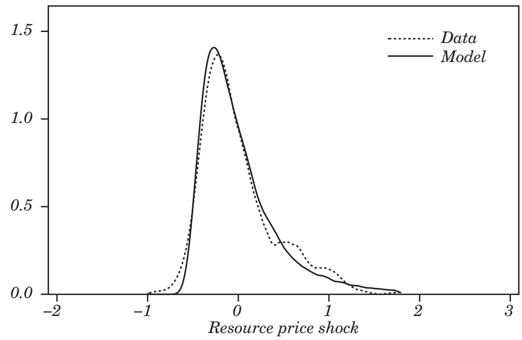
An interesting extension of the baseline model is to consider the impact that uncertainty stemming from the volatility of natural resource prices (and, in particular, the inability of government to quickly and optimally adjust employment levels in response to these shocks) plays in influencing employment, welfare and productivity in resource-rich countries. This government stickiness may be another reason why resource-rich countries tend to employ too many people in the public sector. To examine this idea, I continue to assume that the value of a country's endowment is given by $p_o O$ in each period; however, I now suppose that $p_o \equiv (1+\varepsilon)\,\bar{p}_o$. In this expression, $\bar{p}_o$ is the long-term mean of the oil price while ε is a random variable with CDF G_ε on domain Ω_ε. Thus, I assume that the price of oil fluctuates around a long-term mean and I examine the implications of this on the extent of government misallocation.

I assume that households and firms continue to take the realization of $p_o O$ and L_g as given and proceed to solve their (static) problems just as in the baseline. However, I now assume that governments are slow to respond to price shocks and no longer maximize the weighted welfare of consumers in any given period as in equation (14), but rather maximize the expected weighted welfare of consumers

$$\max_{0\leq L_g\leq 1}\int_{\varepsilon\in\Omega_\varepsilon} \mathsf{E}_{\gamma_i}(U(c_s^i(L_g,p_o(\varepsilon)O),c_m^i(L_g,p_o(\varepsilon)O)))dG_\varepsilon(\varepsilon), \tag{29}$$

with expectations taken over price shocks. In this way, governments of countries with different endowments levels will choose different levels of public sector employment, $\bar{L}_g(O)$ but will find it difficult to re-optimize after a price shock realization. Consequently, for every realization of $\varepsilon \neq 0$, the size of government will be non-optimal which will imply a misallocation of workers and hence welfare and productivity distortions.

Figure B1. Distribution of Resource Price Shocks in the Model and the Data



Source: See section 1.1.

The baseline model was calibrated to match a country with zero natural resource endowments. Since shocks to ε do not affect such a country, the previously calibrated parameters stay exactly as in the baseline. Now however, I need to choose the distribution of the price shocks, ε. In this experiment I will suppose that ε is an iid, zero-mean random variable that follows a truncated Frechet cumulative distribution G_ε on domain $[\underline{\varepsilon}, \overline{\varepsilon}]$:

$$G_\varepsilon(\varepsilon) = \frac{e^{-(\varepsilon-m)^{-\zeta}} - e^{-(\underline{\varepsilon}-m)^{-\zeta}}}{e^{-(\overline{\varepsilon}-m)^{-\zeta}} - e^{-(\underline{\varepsilon}-m)^{-\zeta}}} \tag{B1}$$

In the above m is the location parameter and $\zeta > 1$ is the parameter governing the dispersion of price shocks. The choice of the Frechet distribution will allow me to match the thick tails that are associated with fluctuations of natural resource prices while the truncation will help with the numerical solution of the problem. To estimate this distribution, for each country I calculate $(p_o O_t / \bar{p}_o) - 1$, which I take to be the realization of ε. I then set $m = -1.21$ to match the zero-mean of the shocks and $\zeta = 3.71$ to match the standard deviation 0.41 of the realizations of ε calculated above. Finally, I set the bounds on the distribution so that $[\underline{\varepsilon}, \bar{\varepsilon}] = [-1, 1.8]$. The lower bound is set so that the value of the natural resource can potentially hit zero while the upper bound is chosen to match the largest observed realization of ε in the data. The kernel density of the realizations and the simulated distribution is presented in figure 2. As we can see the fit is good and the chosen distribution does well in capturing the thick, right tail of price shocks.

Table B2. The Impact of Uncertainty on Public Sector Employment, Welfare and Productivity in the Top Decile of Resource Exporters

Top decile (NR exp. sh. = 0.17)	*(1)* L_g^{opt}	*(2)* L_g^{set}	*(3)* L_g *diff. (set/opt)*	*(4) Welfare diff. (set/opt)*	*(5) Prod. diff. (set/opt)*
$\varepsilon = \bar{\varepsilon}$	0.1881	0.1816	0.9656	0.9998	1.0007
$\varepsilon = \underline{\varepsilon}$	0.1716	0.1816	1.0583	0.9997	0.9997

Source: See appendix, section B.2.

Given the above setup, a country with an endowment of resources O will choose a level of government $\bar{L}_g(O)$ based on equation (29). Since governments are assumed to be unable to re-optimize after the initial choice of public sector employment, a price shock which changes the value of natural resource endowments will generate a misallocation of resources whenever the realization of the shock $\varepsilon \neq 0$. To give the mechanism the greatest chance of working, I consider (in the top decile of natural resource exporters) the impact of both the maximum and minimum possible shock on the extent of public sector employment misallocation and the effect this has on welfare and aggregate productivity. The results are shown in table B2.

It turns out that, while the idea of this additional channel of misallocation is intriguing, the quantitative impact is tiny. In particular, from column (3) of the above figure, notice that government misallocation arising from this friction will result in public sector employment that is 3.4% lower from the "optimal" when the maximum shock hits, and 5.8% higher when the minimum shock hits. This is very small given that the differences in government employment in the data between the decile composed of the resource-richest countries and the decile composed of the resource-poorest countries are closer to 50%. Furthermore, this small misallocation translates to even smaller changes in productivity, as seen in column (5), and welfare losses of between 0.01% and 0.03% relative to the optimum, as seen in column (4). The reason we do not observe a large impact from the inability of government to re-adjust is exactly the reason why the model does not predict the large observed increase in government between resource-rich and resource-poor countries in the first place. Since predicted optimal changes in government employment between resource-rich and resource-poor countries are small, a price shock hitting a country that acts to increase the value of the resource endowment of a country would also imply only a small re-adjustment. The model thus predicts higher government employment in the resource-rich country, but only marginally so. Thus, the cost of misallocation from not adjusting in response to a shock is very small indeed.