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Long-Run Effects of Resource Rents in Developing Countries: The role of public investment management

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Long-run effects of resource rents in developing countries: The role of public investment management

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Abstract

The paper studies the long-run effects of shocks to resource rents on the economy using a structural vector error correction model for 37 developing countries. First, the long-run relations involving resource rents and the economy differ for resource importers and exporters. Second, there is an indirect effect from resource rents to output through public capital accumulation for resource exporters. Third, although resource rents have a positive long-run impact on output, good public investment management is required for resource rents to improve non-resource output.

JEL classification: O13; O43; Q32

Keywords: Resource rents; Resource exporters; PIMI

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1. Introduction

There are different options on how to manage natural resource rents. The income obtained can be used for education, health, public investment, debt reduction, and investment on interest bearing assets. (van der Ploeg and Venables 2011) argue that developing countries which are faced with the challenge of little public infrastructure can benefit from improving public infrastructure that enhances growth among other recommendations. (Lin and Doemeland 2012) state that the return on infrastructure investment is high in developing countries and investment in infrastructure requires capital goods that are produced in high income countries.

The long-run effects of resource rents will depend on the amount of resource imported and exported[2]. Resource rents and government revenue will have positive correlation for resource exporting countries, regardless of the sources of resource rents increase. If prices are the main drivers of resource rents, then government revenue in net resource importing countries can decline even when resource rents increase. For example, Benin's consumption of oil is much larger than its production according to US energy information administration[3]. An increase in the price of oil will affect government revenue negatively if the government decides to subsidize oil. If the government fully passed-through the oil price increase, this will have significant negative effects on consumption and output as shown by (Vencatachellum and Abdul 2007) in net oil importing countries. (Baig et al. 2007) show that half of the developing and emerging market countries in their sample have fully passed-through the increase in international fuel prices. Hence, public investment and output are likely to be adversely affected when resource rents increase in net resource importing countries.

This paper is based on 37 developing countries. Countries are classified into two categories, namely, resource exporters and importers (a measure to be discussed below). The scaled de-trended annual series of real GDP per capita and public capital growth are plotted over time in the left side of Figure 1 for 15 resource exporting and 21 resource importing countries (aggregated). The scaled de-trended annual series of resource rents and public capital growth are plotted over time in the right side.

[2] Resource rents refer to rents from coal, oil, natural gas, mineral, and forest. Resource rents are defined as the difference between the value and costs of production.
[3] http://www.eia.gov/countries/country-data.cfm?fips=BN#pet

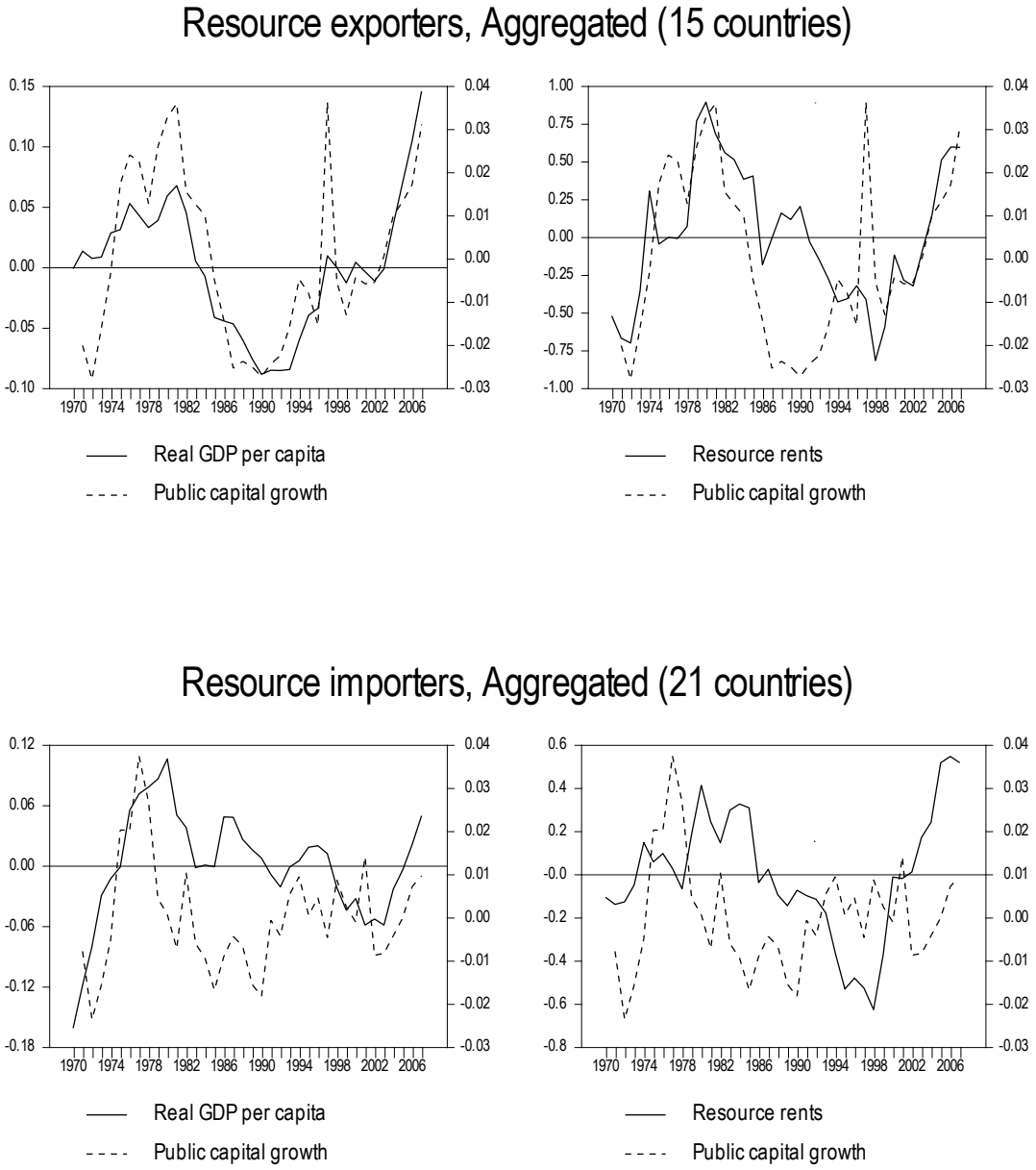

Figure 1 Aggregated data for resource exporters and importers

There are non-deterministic co-movements between public capital growth and real GDP per capita and resource rents and public capital growth excluding the period between mid-1980s to mid-1990s for resource exporting countries. The period covering mid-1980s to mid-1990s is attributable to structural adjustment program where many developing countries were downsizing the public sector. There are no visible co-movements between real GDP per capita, public capital growth, and resource rents for resource importers.

The cost of public investment is not the value of public capital in developing countries and not all the money spent on public investment adds to the value of public capital (Pritchett 2000; van der Ploeg 2012). Public investment is the focus of attention because the public sector is expected to be less efficient. A Public Investment Management Index (PIMI), which measures the process of strategic guidance, project appraisal, selection, budgeting, implementation, evaluation, and audit, is published by (Dabla-Norris et al. 2012). Poor selection and implementation of projects are expected to lower the return from public investment, and concentrate public investment in resource exporting sectors in the context of resource rich economies. (Page 2008) argues that successful diversification away from natural resource dependence is a consequence of public policies using country cases. Diversification is desirable at the early stage of development because it would help dampen the aggregate effects of sector-specific shocks, and can satisfy the preference of consumers that display diversity in tests in the presence of high trading cost (Imbs and Wacziarg 2003). Better management of public investment can play an important role in the diversification of resource rich economies. Therefore, resource exporters are classified into countries with good and bad PIMI (the classification will be discussed below). The scaled de-trended series of non-resource real GDP per capita and public capital growth are plotted over time in the left side of Figure 2 and resource rents and public capital growth are plotted over time in the right side of Figure 2 for countries with good and bad PIMI (aggregated).

There are co-movements between non-resource real GDP per capita and public capital growth and public capital growth and resource rents for countries with good PIMI in the upper panel of Figure 2. Public capital growth is volatile and the co-movements are less visible in the lower panel for countries with bad PIMI.

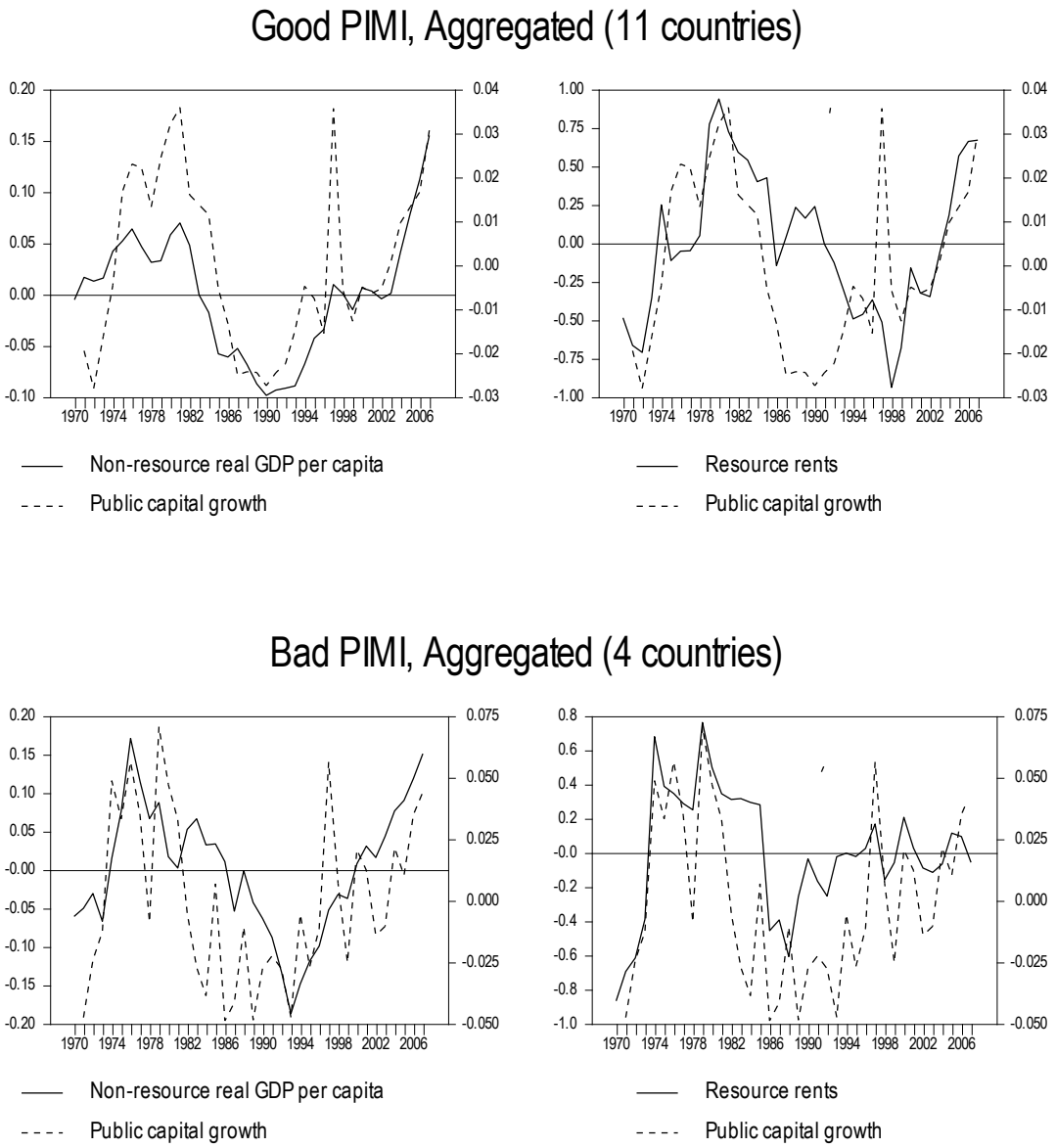

Figure 2 Non-resource real GDP per capita in good and bad PIMI countries

In this paper, we show that there is one equilibrium relation between real GDP per capita, private capital growth, public capital growth, population growth, and resource rents for resource importers. Real GDP per capita and resource rents are related negatively in the long-run. However, the negative relationship can be explained by the effects of changes in prices as resource rents and prices are closely related. The increase in prices will cost governments of resource importers more than it benefits them as they try to stabilize domestic prices. Moreover,

the increase in prices will also reduce disposable income of households, and increase the costs of input for producers. A positive equilibrium relation between real GDP per capita and public capital growth (after controlling for private capital growth and population growth) and another relation between public capital growth and resource rents are found for countries that are resource exporters. Hence, resource rents have an indirect effect on real GDP per capita through public capital accumulation. The response analysis shows that resource exporters with good PIMI experience statistically significant and positive non-resource income and public investment effects from resource rents. On the other hand, countries with bad PIMI have small and insignificant effects.

The negative effect of natural resource abundance on subsequent growth has been established in the empirical literature following the paper by (Sachs and Warner 1995) and (Sachs and Warner 2001) and it is referred to as the *resource curse*. Subsequent studies have focused on uncovering why natural resource abundance leads to slow growth. The appreciation of the real exchange rate that adversely affects the competitiveness of the traded sectors, the nature of the natural resource sectors that make them prone to rent seeking activities, and volatility of resource revenue as a result of price fluctuations that harms output growth are mentioned as possible explanations (van der Ploeg 2011). Empirical evidence suggests that the resource curse is less likely if a country has good institutions (Mehlum et al. 2006).

(Alexeev and Conrad 2009) test the resource curse hypothesis from a different angle. Instead of studying the effect of natural resource abundance on growth rates, they examine the effect of resource abundance on the level of per capita income. They argue that the level of income per capita captures growth that might have occurred before the growth data became available. They conclude that the effect of natural resource abundance on income in the long-run is positive.

(Collier and Goderis 2012) use panel cointegration methodology where a cointegration relation between income per capita and commodity prices captures the long-run equilibrium relation. This approach is less prone to omitted variable bias compared to cross sectional studies. (Collier and Goderis 2012) conclude that non-agricultural commodity prices and real GDP per capita move in opposite directions for countries with bad governance in the long-run. However, in countries with good governance the negative relation is not present and, if anything, there is a

positive co-movement. Their result shows that the resource curse is less likely in countries with good institutions.

In cross sectional studies, if the abundance of natural resources in a given period is associated with a lower level of output (other things being constant), it shows the resource curse. In time series studies, a negative relationship between commodity prices and output per capita might not necessarily indicate the resource curse. This is because some countries are net importers of natural resources. Even in the absence of the resource curse, it is possible to have resource rents increasing and output decreasing for resource importers. (Collier and Goderis 2012) use commodity prices for which a country is net exporter. If commodity prices move together, the approach used by (Collier and Goderis 2012) is not going to avoid confusing the resource curse with the negative effects of the increase in prices for resource importers. (Pindyck and Rotemberg 1990) and (Palaskas and Varangis 1991) have shown that there is excessive co-movement of commodity prices. (Collier and Goderis 2012) also study only one co-movement between commodity prices and output controlling for other factors such as investment. However, resource rents are likely to affect the economy through public capital accumulation. Therefore, it is important to account for the mechanism through which resource rents enter into the economy to take into account the indirect effect of resource rents.

Three points separate this paper from the voluminous literature on the resource curse. First, it adopts a time series approach to study the effects of resource rents on the economy by classifying countries into resource importers and exporters. Second, it takes into account the indirect effect of resource rents on the economy. Third, it studies the effect of public investment management on diversifying the economy away from natural resource dependence. If resource rents have an indirect effect, ignoring it will underestimate the effect of resource rents on output. Moreover, if we do not distinguish between net importers and exporters, we will run the risk of interpreting the negative effects of the increase in prices as the resource curse in resource importing countries. A Vector Error Correction Model (VECM) is better suited for this purpose because it allows for a system of equations (instead of a single equation), and thus captures the indirect effect.

The rest of this paper is organized as follows. Section 2 presents regression results from reduced form VECM for resource importers and exporters. Section 3 focuses on resource exporters and

presents the long-run effects of resource rents from structural vector error correction models for countries with good and bad PIMI. Section 4 checks the robustness of the result. Finally, section 5 concludes.

2. Reduced form regression

Structural vector autoregressive (SVAR) models are widely used to study the effects of shocks on macroeconomic variables. In this paper, we are interested in the long-run effects of resource rents. Therefore, we will employ the closely related VECM. (Lutkepohl and Reimers 1992) propose impulse response analysis (using Choleski decomposition) for VECM where individual variables are non-stationary and a stationary combination of the variables is interpreted as a long-run relation. (Phylaktis and Girardin 2001) use similar model to study exchange rates in China. Other studies (Brüggemann 2006; King et al. 1991; Vlaar 2004) impose structure on the error terms of the VECM based on economic theory. These models are called structural vector error correction models (SVECM). We start with a reduced from VECM in this section and a structure will be imposed in the next section.

The reduced form VECM examines the relation between resource rents and other macroeconomic variables as equilibrium relations where deviations from the equilibrium would trigger adjustment back to the equilibrium. The approach tries to exploit the time series properties of variables to identify equilibrium relations. There are some forces in the economy that pushes the relations out of equilibrium and there are other forces that bring the variables back to the equilibrium.

A VECM with one lag:

$$\Delta x_t = \alpha\beta' x_{t-1} + \Gamma\Delta x_{t-1} + \phi * D_t + \varepsilon_t \quad (1.1)$$

$$\varepsilon_t \sim IN_5(0, \Omega)$$

Where x_t is a vector of five variables of the system. The variables in the system are $y_t, \Delta k_t, \Delta g_t, n_t,$ and r_t representing logs of real GDP per capita, private capital growth (k is the log of private capital), public capital growth (g is the log of public capital), population growth, and the log of resource rents, respectively. The choice of the variables included in the model will

be discussed in the next section together with the economic identification of long-run relations. D_t is a vector of deterministic terms in the model and ε_{it} is a vector of independently distributed multivariate error terms. Γ is a coefficient matrix of the short-run effects. α and β are matrices containing the loading coefficients and the cointegration vectors, respectively. (Collier and Goderis 2012) use a single-equation error correction model to analyze the long-run relationship between real GDP per capita and commodity prices. This formulation assumes that there is only one cointegration relation and one error correcting variable. However, there could be more than one equilibrium relations. Assume resource rents are collected by the government, and used to finance public investment. In this case, one equilibrium relation will exist between public capital growth and resource rents and another equilibrium relation could exist between real GDP per capita and public capital growth (assuming saving rate and long-run income per capita are positively related as in the Solow model). In addition, more than one variable can also adjust to the disequilibrium. For example, real GDP per capita adjusts to the equilibrium relation between public capital growth and real GDP per capita and public capital growth adjusts to the relation between resource rents and public capital growth. Therefore, we have used VECM that enables us to capture the indirect effect of resource rents.

2.1. Specification

Different responses are expected for resource importers and exporters as stated in section 1, therefore, countries are ranked based on the ratio of the average current dollar value of export to import of oil, ores, and minerals for the period 1970 to 2007. Resource exporters are defined as countries with export to import ratio greater than 1. Of the 37 developing countries considered, 15 countries are classified as exporters of natural resources (see Appendix I)[4]. Then, the 15 resource exporters and the remaining 21 resource importers are aggregated separately. Analysis based on aggregated data has been used by (Kilian et al. 2009) for oil exporters and importers and (Vlaar 2004) for Euro zone countries. In the following analysis, we treat resource importers and exporters separately[5].

[4] Availability of data on private capital, public capital, real GDP, population, and resource rents has influenced the number of developing countries considered.

[5] Although we have not reported results from country-by-country regression, it has been done to check within group consistency.

Equation 1.1 above has variables in levels and differences. If the variables in levels are integrated of order one, then the variables in differences will be stationary. Since the sum of stationary and non-stationary variables cannot be stationary, the matrix β' combines the variables in levels to achieve stationary combinations. Therefore, with exception of the case where all variables in levels are stationary, $\alpha\beta'(=\Pi)$ will be a reduced rank matrix. The rank of Π determines the number of equilibrium relations. The determination of the rank is important and it requires appropriate specification of the model.

The specification of a VECM involves choosing the appropriate lag length and ensuring the model passes misspecification tests. SC (Schwarz Criterion) and HQ (Hannan-Quinn Criterion) information criteria are used to determine the number of lags to be included in the model. Misspecification (no autocorrelation) of the model is considered when making lag length determination as recommended by (Juselius 2006). For both resource importers and exporters, lag one is chosen (see Table 1). This is because we have annual data and most of the short-run effects are not captured by the data.

Dummy variables are used to account for extra ordinary events, and achieve normally distributed and uncorrelated error terms. Permanent impulse dummies that account for extraordinary events that are not corrected for in subsequent periods are used for resource exporting countries for 1986 and 1997. The period between 1986 and 1997 coincides with the implementation of structural adjustment program. In mid-1980s, many developing countries started implementing the structural adjustment program. By the mid-1990s, developing countries are abandoning the structural adjustment program. A permanent impulse dummy for 1991 is used for both resource importers and exporters and a transitory impulse dummy that accounts for an extra ordinary event that is corrected for in the next period is used for 2001 for resource importers[6].

Next, we determine the number of long-run relations. The determination of the cointegration rank is based on the trace test. The trace test indicates two cointegration relations for resource exporters and only one cointegration relation for resource importers (see Table 1). Other indicators such as t-values on the adjustment coefficients and characteristic roots of the model have led to the same conclusion.

[6] In 1991, the coalition force fought Iraq and 2001 is the year of the September 11th terrorist attack. These events have significant implications on commodity prices.

Since the variables in the system should be at most integrated of order one, we have tested the order of integration of the variables. The log of public capital, log private capital, and the log of population are found to be integrated of order one only after differencing. Therefore, the differences of log of private capital, log of public capital, and log of population are used in the analysis. The log of real GDP per capita and log of resource rents are integrated of order one. Therefore, the levels of the log of real GDP per capita and the log of resource rents are used in the analysis.

To gain an initial insight into the relationships between the variables of the system, we have performed tests of stationarity, weak exogeneity, and exclusion for the chosen cointegration rank. If a variable is weakly exogenous, then the variable will not adjust when the system is out of equilibrium. Weak exogeneity is checked by imposing zero restrictions on the adjustment coefficients (α). If the exclusion test for a variable cannot be rejected, then the variable is not part of the equilibrium relations. Exclusion is checked by imposing zero restrictions on the cointegration coefficients (β).

Table 1 shows that all variables are non-stationary. Resource rents cannot be excluded but are exogenous for both resource importers and exporters. Whereas exclusion is rejected with a p-value of 0.01 for resource exporters, it is rejected with a larger p-value of 0.1 for resource importers. Resource rents are weakly exogenous for both resource exporters and importers.

Table 1 Tests based on (Juselius 2006)

Resource Importing countries, aggregated					
Lag Length tests	HQ	SC			
k=1	-42.93	-41.62			
k=2	-42.26	-40.23			
LM test for k=1	LM(1)	LM(2)			
	32.29	20.15			
Trace test for rank (r)	$r=0$	$r=1$	$r=2$	$r=3$	$r=4$
	95.37*	44.61	22.65	8.64	1.81
Tests for rank $(r=1)$	y_{it}	Δk_{it}	Δg_{it}	r_{it}	n_{it}
Stationarity	41.01***	48.36***	44.94***	52.41***	18.20***
Exclusion	6.75***	0.79	4.00**	3.68*	32.43***
Weak exogeneity	4.20**	2.91*	2.10	0.57	27.11***
Resource Exporting countries, aggregated[7]					
Lag Length tests	HQ	SC			
k=1	-42.86	-41.40			
k=2	-42.51	-40.33			
LM test for k=1	LM(1)	LM(2)			
	24.58	21.71			
Trace test for rank (r)	$r=0$	$r=1$	$r=2$	$r=3$	$r=4$
	138.61**	63.93*	25.34	13.71	4.79
Tests for rank $(r=2)$	y_{it}	Δk_{it}	Δg_{it}	r_{it}	n_{it}
Stationarity	31.60***	22.62***	27.11***	32.18***	33.42***
Exclusion	16.72***	15.48***	12.67***	41.96***	65.10***
Weak exogeneity	8.92*	10.16***	12.65***	4.61	22.80***

* denotes p-value less than 0.1, ** denotes p-value less than 0.05, and *** denotes p-value less than 0.01. LM (1) and LM (2) are first and second order autocorrelation tests, respectively. They are based on auxiliary regressions, and are χ^2 distributed.

2.2. Economic identification of long-run relations

The identification of the cointegration relation is based on the neoclassical growth model where the steady state level of output per capita depends on saving rate (positively), depreciation rate (negatively), population growth (negatively), and exogenous technological growth (Mankiw et al. 1992; Solow 1956). The growth rates of private and public (instead of the saving rates) are used because they take the depreciation of public and private capital into account, and are made available by (Gupta et al. 2011). We have also included population growth following the literature. Other control variables (for example: human capital, openness, etc.) are not included as this will result in a large number of parameters compared to the sample size in the VECM. Since we are only exploiting the time series variation, the issue of omitted variable bias will be limited.

[7] Indonesia is excluded from resource exporters group because it is an outlier in the group. It is the only country in the group where resource rents and public capital growth have a negative relationship. Indonesia is also found to have a different response among oil exporters by (Esfahani et al. 2012).

The expected cointegration relations for resource exporters are a production relation between real GDP per capita, private capital growth, public capital growth, and population growth and a public capital accumulation relation linking public capital growth and resource rents. A long-run relationship is expected between resource rents and public capital growth because resource rents are expected to increase government revenue (and hence public investment) in resource exporting countries.

A negative cointegration relation between real GDP per capita and resource rents is expected for resource importers. This is because prices are the main drivers of resource rents. (van der Ploeg and Poelhekke 2009) show that world commodity prices are extremely volatile and the volatility of commodity prices is the main reason for the volatility of natural resource export revenues. Prices affect not only the public but also the private sector. Hence, the increase in prices associated with resource rents acts as a constraint to production making intermediate inputs expensive. The expected long-run relationships between the variables of the system are described in equation 1.2 for resource exporters and importers.

For resource exporters,

$$\begin{gathered} y_{it} = f(\Delta k_{it}, \Delta g_{it}, n_{it}) \\ \Delta g_{it} = h(r_{it}) \\ f_{\Delta k} > 0, f_{\Delta g} > 0 \; and \; f_n < 0 \\ h_r > 0 \end{gathered} \tag{1.2}$$

For resource importers,

$$\begin{gathered} y_{it} = f(\Delta k_{it}, \Delta g_{it}, n_{it}, r_{it}) \\ f_{\Delta k} > 0, f_{\Delta g} > 0, f_n < 0 \; and \; f_r \leq 0 \end{gathered}$$

The estimated cointegration relations and the adjustment coefficients are presented in Table 2. There is just one cointegration relation between the five variables of the system for resource importing countries (as shown in Table 1) and no further assumption is required to identify it. The sign and statistical significance of the expected cointegration relationship fits the description above. The negative relationship between resource rents and output per capita is similar to (Collier and Goderis 2012). However, we cannot conclude the negative relationship as evidence for the resource curse. The negative cointegration relation in resource importing

countries can be explained by payments made for imports, which wipe out the positive gain from resource rents.

Two relations are identified for resource exporting countries. In the first relation, a zero restriction is imposed on resource rents. In the second relation, zero restrictions are imposed on real GDP per capita, private capital growth and population growth. In the production relation (the first relation), the cointegration coefficients between real GDP per capita, private capital growth, public capital growth, and population growth have the expected signs, and are statistically significant for resource exporters. The coefficient on real GDP per capita and population growth adjust to this equation. This reinforces the expectation that the first relation is a production relation. In the public capital accumulation relation (the second relation), there is a positive long-run relation between resource rents and public capital growth. Public capital growth and population growth adjust to the relation as indicated by the statistically significant adjustment coefficients. This indicates that public capital accumulation is a channel through which resource rents enter into the economy.

Table 2 Equilibrium relations and adjustments

	Resource exporters				**Resource importers**	
Cointegrating Vector	β_{1i}	t-value	β_{2i}	t-value	β_{1i}	t-value
y_{t-1}	0.01	(2.13)	-	-	-0.02	(-4.38)
Δk_{t-1}	-0.04	(-2.90)	-	-	0.01	(0.94)
Δg_{t-1}	-0.18	(-12.66)	1.00	-	0.04	(2.69)
n_{t-1}	1.00	-	-	-	1.00	-
r_{t-1}	-	-	-0.04	(-11.65)	-0.001	(-2.39)
Loading	α_{i1}	t-value	α_{i2}	t-value	α_{i1}	t-value
Δy_t	-3.17	(-3.09)	-0.26	(-1.18)	-5.66	(-2.48)
$\Delta^2 k_t$	-0.53	(-0.68)	-0.23	(-1.38)	-1.65	(-1.84)
$\Delta^2 g_t$	-1.04	(-1.73)	-0.43	(-3.33)	-1.55	(-1.59)
Δn_t	-0.52	(-5.20)	-0.09	(-4.24)	-0.84	(-8.03)
Δr_t	25.51	(1.80)	3.72	(1.24)	11.26	(0.76)

In conclusion, there are two positive long-run relations between resource rents and public capital growth and public capital growth and real GDP per capita for resource exporting countries. There is a negative relationship between resource rents and real GDP per capita for resource importers. The negative relation cannot be attributed to the resource curse because of the association between resource rents and prices. Therefore, in the remaining analysis we will focus

on resource exporters to study the effects of shocks to resource rents on macroeconomic variables.

3. The structural VECM

(Lutkepohl 1994) states that a cointegration coefficient from VECM does not have the same interpretation as a coefficient from single-equation regression. This is because all variables are potentially endogenous. Moreover, the error terms from the reduced form VECM cannot be interpreted as structural shocks. This is because a change in the error term to one variable can be correlated to a change in the error term of another variable as the contemporaneous relations are left in the residuals in the reduced form VECM. Therefore, a transformation that deals with the contemporaneous correlation will be necessary to interpret changes in the error terms as shocks in the structural innovations. The different methods to identify shocks are discussed by (Fry and Pagan 2011). Impulse responses from a structural model that capture the responses of variables to resource rents shocks will be presented in this section. The two relations identified for resource exporters will be imposed for the cointegration relations throughout the rest of the paper. The analysis will examine the effects of shocks to resource rents on the economy using both contemporaneous and long-run restrictions.

The focus will be on the response of non-resource real GDP per capita to resource rents shocks. Since we do not have non-resource private and public capital growth, we will continue with private and public capital growth. A comparison is made for countries with good and bad public investment management as measured by PIMI to examine the role public investment management has played in diversification of resource exporting economies. (Gupta et al. 2011) adjusts public investment to study the link between public capital and growth. In this paper, we use a different approach of classifying countries into those with good and bad PIMI. We have chosen this approach because PIMI is a constant developed for ranking countries. The PIMI ranges between 0.5 for Congo Republic to 3.5 for South Africa for resource exporting developing countries. A cutoff point is chosen by running a country-by-country regression and putting countries with the same result together. Accordingly, four resource exporting countries with lowest PIMI are grouped as countries with bad PIMI. These are Congo Republic (0.5), Togo (0.9), Senegal (0.9), and Gabon (1). These countries will be aggregated as resource exporters

with bad PIMI in the rest of the paper and the remaining 11 resource exporting countries will be aggregated as resource exporters with good PIMI.

3.1. Contemporaneous restrictions

The covariance matrix of the error terms provides information that can be used to transform the error terms into structural innovations. However, the information in the covariance matrix will not be sufficient for the transformation of the error terms. Therefore, the information in the covariance matrix together with the expected theoretical relations of the different variables of the system will be used to transform the error terms into structural innovations that are uncorrelated with each other. Consider the error term (ε_t) and a transformation matrix B.

$$\varepsilon_t = Bu_t \tag{1.3}$$

u_t is a 5-dimensional vector, which is normally distributed with expectation zero and a $5-$dimensional identity covariance matrix (I_5). With five variables in the system, identification exercise requires 5×5 square matrix (B) to transform the error terms into structural innovations.

To estimate the elements of the square matrix (B), we will use the covariance matrix Ω.

$$\varepsilon_t \varepsilon_t' = \Omega = Bu_t u_t' B' = BI_5 B' \tag{1.4}$$

Since the covariance matrix given in equation 1.4 is symmetric, it can only be used to estimate $\frac{5(5+1)}{2}$ of 5^2 relations and the remaining $\frac{5(5-1)}{2}$ relations have to come from theory (see (Lütkepohl and Krätzig, eds 2004). Because $\Omega = BB'$, a reversed sign of B will also give an admissible solution. A unique solution for B is obtained by restricting the signs of the diagonal elements to be positive. This implies that we are considering a positive shock to a variable of interest.

The number of restrictions is a necessary condition for identification. In addition, the restrictions have to be linearly independent to be identifying. (Rubio-Ramirez et al. 2010) show that this is achieved if exactly one column has i zeros for each i from 0 to $p-1$ where p is the number of variables in the system. Contemporaneous restrictions to identify structural innovations from disturbance terms are used by (Blanchard and Watson 1986) and (Bernanke 1986).

Table 3 Contemporaneous restrictions

	ε_{y_t}	$\varepsilon_{\Delta k_t}$	$\varepsilon_{\Delta g_t}$	ε_{n_t}	ε_{r_t}
$\log(Non-reousece\ Real\ GDP\ per\ capita)_t$			0		
$\Delta\log(Private\ Capital)_t$			0		
$\Delta\log(Public\ Capital)_t$		0			
$\Delta\log(Population)_t$	0	0	0		
$\log(Resource\ Rent)_t$	0	0	0	0	

The zero restrictions used to identify the B matrix are given in Table 3. Shocks to resource rents are allowed to affect all variables of the system contemporaneously. We have left the effects of shocks to resource rents unrestricted because we want to analyze resource rents (see the last column in Table 3). A shock to population growth rate is assumed to have no effect on resource rents (see the fourth column in Table 3). The justification for this is that resource rents are unlikely to be affected by what happens in the domestic economy as they are mainly determined by the international resource prices. A shock to public capital growth is not expected to have effects on other variables contemporaneously (see the third column in Table 3). Public investment projects are likely to take more than a year to complete. In the last year of the project, there might be contemporaneous effects. However, if a large portion of the investment is made before the project commissioning year, then the contemporaneous effects are going to be small. A shock to private capital growth is assumed to have no effects on public capital growth, population growth, and resource rents contemporaneously (see the second column in Table 3). The public sector responds slowly to what happens in the private sector. Resource rents are exogenous to changes in the domestic economy and population growth rate cannot adjust instantaneously. Finally, a shock to non-resource real GDP per capita is assumed to have no effects on resource rents and population growth contemporaneously (see the first column in Table 3). As before, resource rents are exogenous to what happens in the domestic economy and population growth responds with some lag.

Based on these restrictions, the responses of non-resource real GDP per capita, private capital growth, public capital growth, and resource rents to resource rents shocks are compared across country groups with good and bad PIMI in Figure 3. The response of population growth is not reported to save space as the main interest is on the macroeconomic variables. Non-resource real GDP per capita, private capital growth, and public capital growth are plotted on the same scale.

Using bootstrapped standard errors, 95% confidence bands are also plotted together with the responses[8].

A doubling of resource rents increases non-resource real GDP per capita by 6.4% and growth rate of public capital by 2.7% in the long-run for resource exporting countries with good PIMI[9]. Non-resource real GDP per capita and public capital growth have increased by 3.9% and 2% on impact, respectively. Resource rents shocks are persistent, and will not return to the previous levels. Therefore, shocks to resource rents will have long-run effects on non-resource real GDP per capita and public capital growth. It is also possible to have negative shocks to resource rents, which work in the opposite direction at some future date. Later on, we will examine the effects of shocks to resource rents that do not persist by modeling resource rents exogenously.

The effect of shocks to resource rents on non-resource real GDP per capita is not statistically significant for resource exporting countries with bad PIMI. As shown in Figure 3, the 95% confidence band is wide and the long-run impact estimate is small for non-resource real GDP for countries with bad PIMI. This is despite a statistically significant big effect on real GDP per capita, which is not reported to save space. Hence, countries with bad PIMI will be dependent on the resource exporting sectors. On the other hand, countries with good PIMI are able to diversify their economy away from natural resource dependence.

[8] The bootstrapped standard errors are obtained using 500 replications.
[9] A doubling of resource rents is on average 7.5% of GDP for resource exporting countries with good PIMI for the period 1970 to 2007.

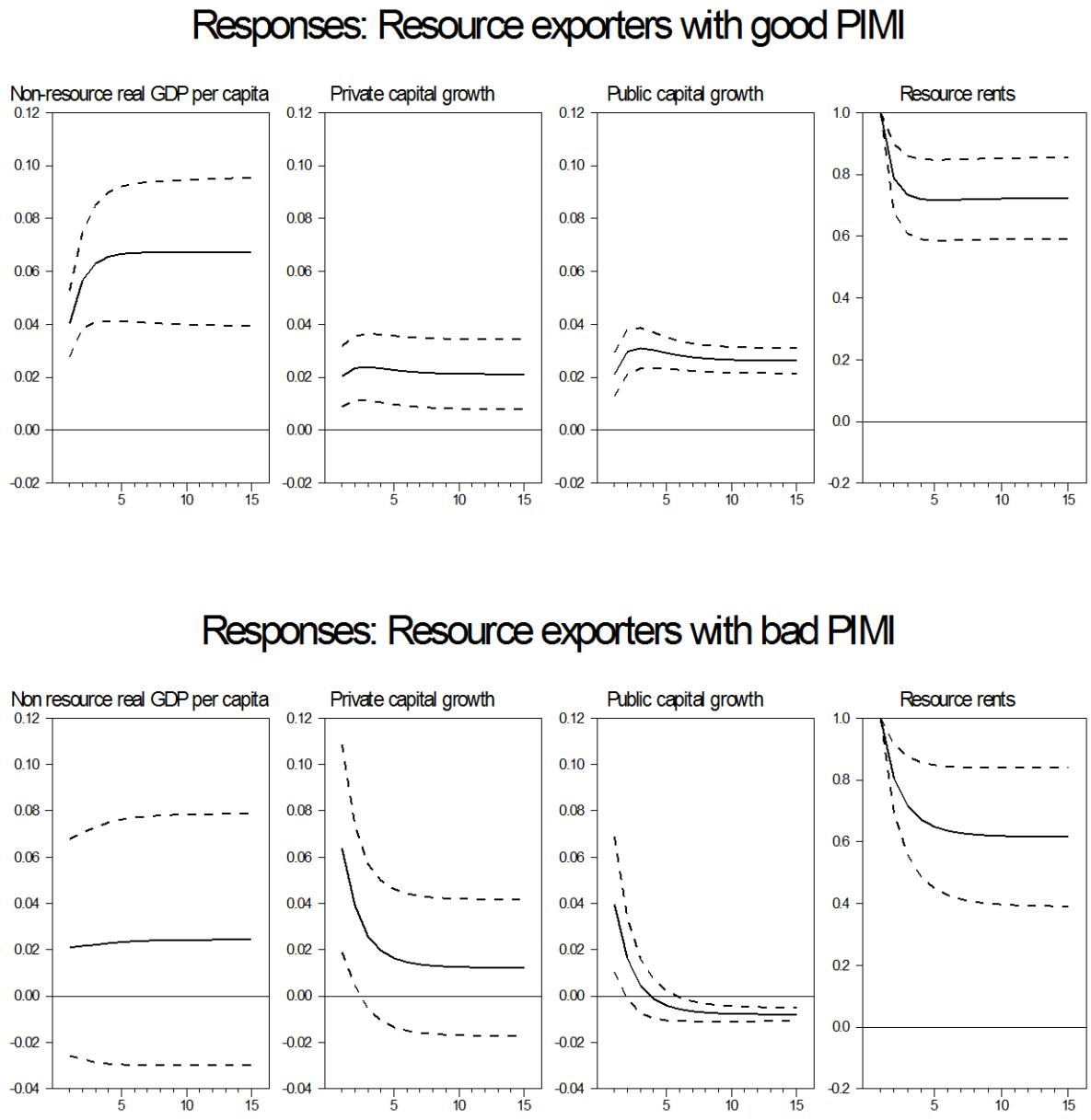

Figure 3 Responses to resource rents shocks using contemporaneous restrictions

3.2. Long-run restrictions

The contemporaneous restrictions above are excessive and the economic justifications for the restrictions are weak. Alternatively restrictions can be imposed on the long-run impacts of shocks and there are better economic justifications for imposing long-run restrictions. Long-run restrictions imply that the contemporaneous and lagged effects cancel each other out, and leave

no effects in the long-run. A moving average representation of equation 1.1 gives the levels of the variables as a function of the structural shocks (u), a stationary component, and a deterministic term. The long-run effects of shocks are contained in the long-run impact matrix (C).

$$x_t = C\sum u_{\mathrm{t}} + \text{stationary component} + \text{determnistic term} \qquad (1.5)$$

(Vlaar 2004) imposes restrictions on the long-run impact matrix and other studies (Brüggemann 2006; King et al. 1991) use long-run restrictions combined with contemporaneous restrictions to achieve just identification. In this paper, we will use a combination of restrictions on the long-run impact matrix (C) and the impact matrix (B). To do this, shocks have to be divided into transitory and permanent shocks. The division of shocks into permanent and transitory shocks can be based on the number of cointegration relations. The rank from the reduced form regression gives us the number of transitory shocks (Juselius 2006). Since we have five variables and two cointegration relations for resource exporting countries with good and bad PIMI, there are three $(=5-2)$ shocks pushing the system out of the equilibrium and the rest are transitory shocks. Shocks to private and public capital growth are treated as transitory demand shocks. This approach is similar to (King et al. 1991) that treats shocks to investment as demand shocks with no long-run effects. Aggregate demand shocks are not going to have long-run impacts assuming long-run aggregate supply is fixed. Therefore, zero restrictions are imposed on the respective columns of the growth rates of private and public capital in the C matrix. Since the C matrix has a reduced rank of three, this will introduce six restrictions. Just as in the previous case, the number of restrictions required for identification is $\frac{5(5-1)}{2}$. Therefore, we are left with four more restrictions to achieve a just identified model.

Since the long-run restrictions are not enough to identify the model, we have imposed contemporaneous restrictions. To identify the transitory shocks, the effect of a shock to private capital growth on public capital growth is set to zero contemporaneously. The justification is that the public sector responds slowly compared to the private sector. To distinguish between the permanent shocks, we have assumed shocks to resource rents affect all variables contemporaneously. However, shocks to population growth and non-resource real GDP per capita do not affect resource rents. As before, resource rents are assumed exogenous to changes

in the economy. This will leave us with one restriction required to distinguish between a population growth shock and a non-resource real GDP per capita shock. We have assumed public capital growth responds to a non-resource real GDP per capita shock but not to a population growth shock contemporaneously. The restrictions are shown in Table 4. As before, the restrictions have to be linearly independent to be identifying.

Table 4 Short-run and long-run restrictions

Long-run restrictions					
	ε_{y_t}	$\varepsilon_{\Delta k_t}$	$\varepsilon_{\Delta g_t}$	ε_{n_t}	ε_{r_t}
$\log(Non-resouce\ real\ GDP\ per\ capita)_t$		0	0		
$\Delta \log(Private\ Capital)_t$		0	0		
$\Delta \log(Public\ Capital)_t$		0	0		
$\Delta \log(Population)_t$		0	0		
$\log(Resource\ Rent)_t$		0	0		
Short-run restrictions					
	ε_{yt}	$\varepsilon_{\Delta kt}$	$\varepsilon_{\Delta gt}$	ε_{n_t}	ε_{rt}
$\log(Non-resouce\ real\ GDP\ per\ capita)_t$					
$\Delta \log(Private\ Capital)_t$					
$\Delta \log(Public\ Capital)_t$		0		0	
$\Delta \log(Population)_t$					
$\log(Resource\ Rent)_t$	0			0	

Based on the above restrictions, Figure 4 shows the responses of non-resource real GDP per capita, private capital growth, public capital growth, and resource rents to resource rents shocks. The responses are similar to pervious case where only contemporaneous restrictions are used. Shocks to resource rents are persistent as before and they have statistically significant long-run effects on non-resource real GDP per capita and public capital growth for countries with good PIMI. The response of non-resource real GDP is very small, and has wide 95% confidence band for countries with bad PIMI.

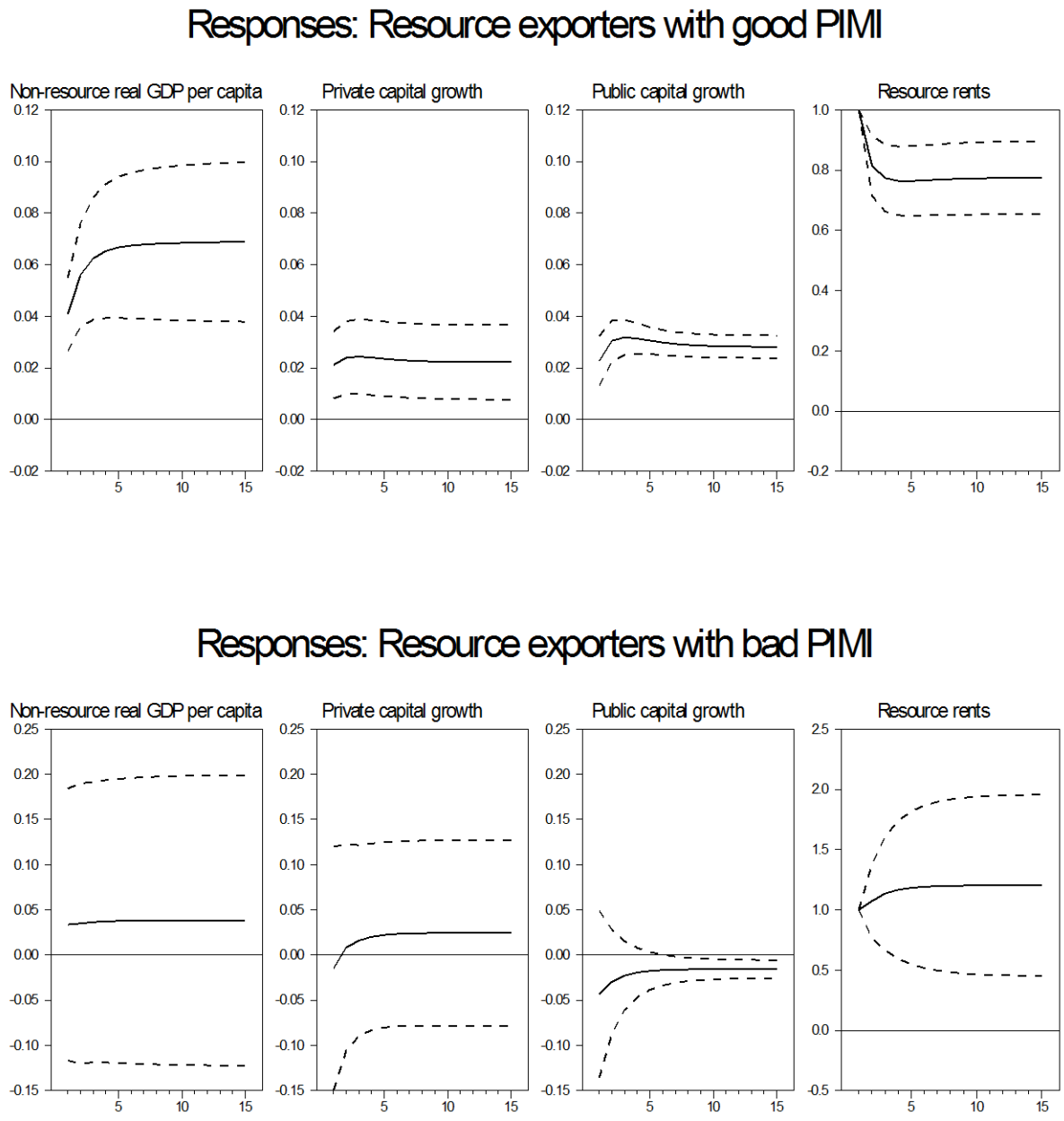

Figure 4 Responses to resource rents shocks using long-run and short-run restrictions

Imposing sign restrictions is another approach to identify shocks based on the expected differences in the signs of the responses to a given shock. Since we do not have identifiable expected sign differences in responses from the shocks, this approach is not explored.

3.3. Forecast error variance decomposition

An important point related with the response analysis above is the forecast error variance decomposition that answers the question of how important resource rents shocks are compared with the other shocks in determining variations in non-resource real GDP per capita and public capital growth in countries with good and bad PIMI.

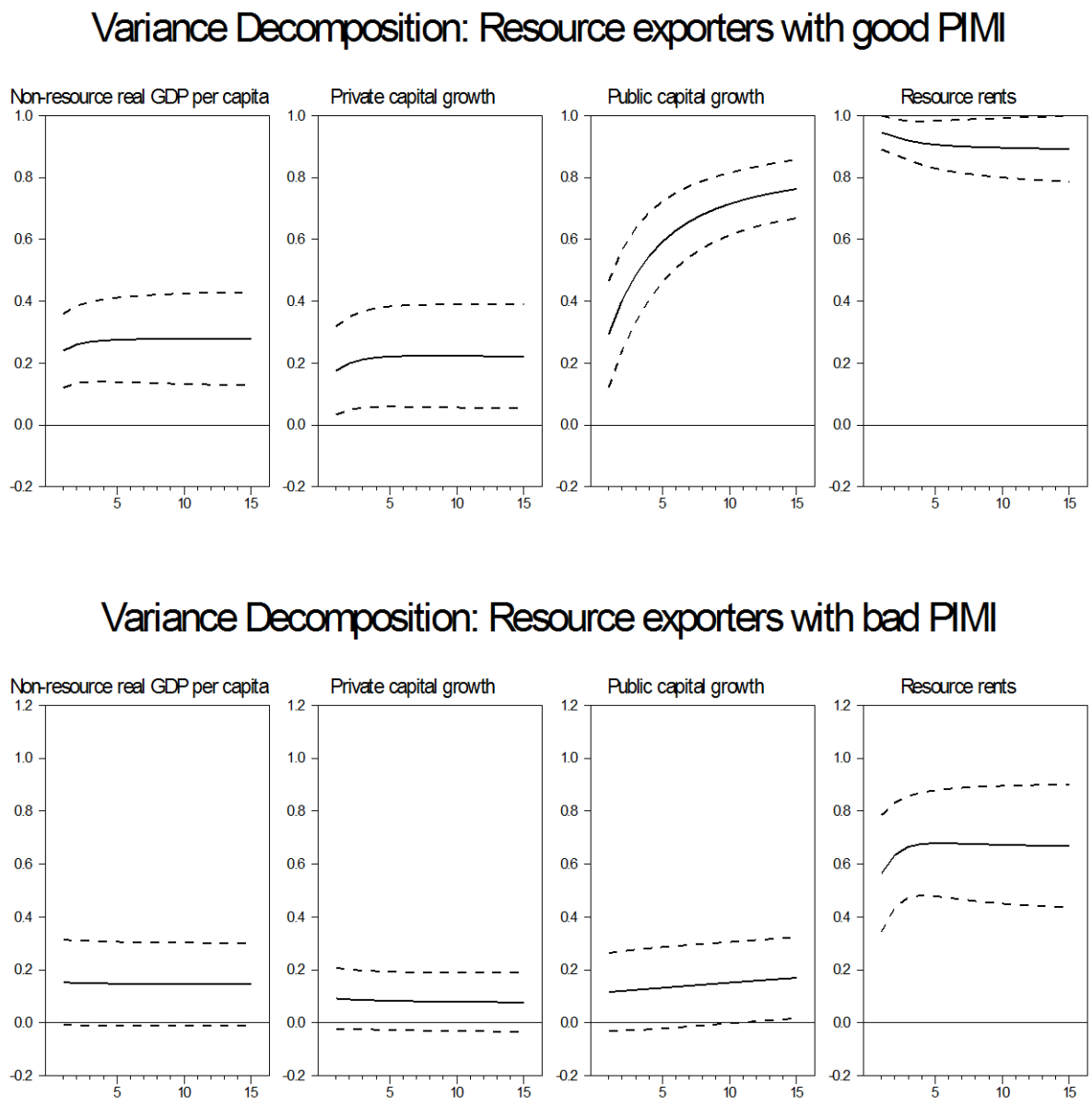

Figure 5 Fraction of forecast error variance attributed to resource rents shocks

Figure 5 shows the forecast error variance decomposition of shocks to resource rents at different horizons for resource exporting countries with good and bad PIMI using the long-run and short-run restrictions. Bootstrapped standard errors are used to construct 95% confidence bands. According to Figure 5, 30% of variations in non-resource real GDP per capita and 73% of variations in public capital growth are attributable to resource rents shocks in resource exporting countries with good PIMI. Resource rents shocks explain close to 14% of variations in non-resource real GDP per capita and 19% of variations in public capital growth for countries with bad PIMI. These effects are small and statistically insignificant. Hence, resource rents have been an important pushing force in diversifying the economy in resource exporting countries with good PIMI. On the other hand, countries with bad PIMI have remained dependent on the resource exporting sectors.

4. Short-run effects and an exogenous shock

The optimal lag length chosen for our model is one. One year lag length is accepted due to the fact that we have annual data. Nonetheless, we have added one more lag to check the sensitivity of the result to the addition. The responses of non-resource real GDP per capita, private capital growth, public capital growth, and resource rents are plotted in Figure 6 for countries with good and bad PIMI. The long-run restrictions shown in Table 4 are used for identification of shocks. Non-resource real GDP per capita has increased rapidly and public capital growth has increased in the short-run above its long-run equilibrium. This is because of short-run positive effects on non-resource real GDP per capita and public capital growth for countries with good PIMI. However, the confidence bands are wider than before because of the inclusion of insignificant lag effects. The response of non-resource real GDP per capita is weak as before and the confidence band is wider than before for countries with bad PIMI.

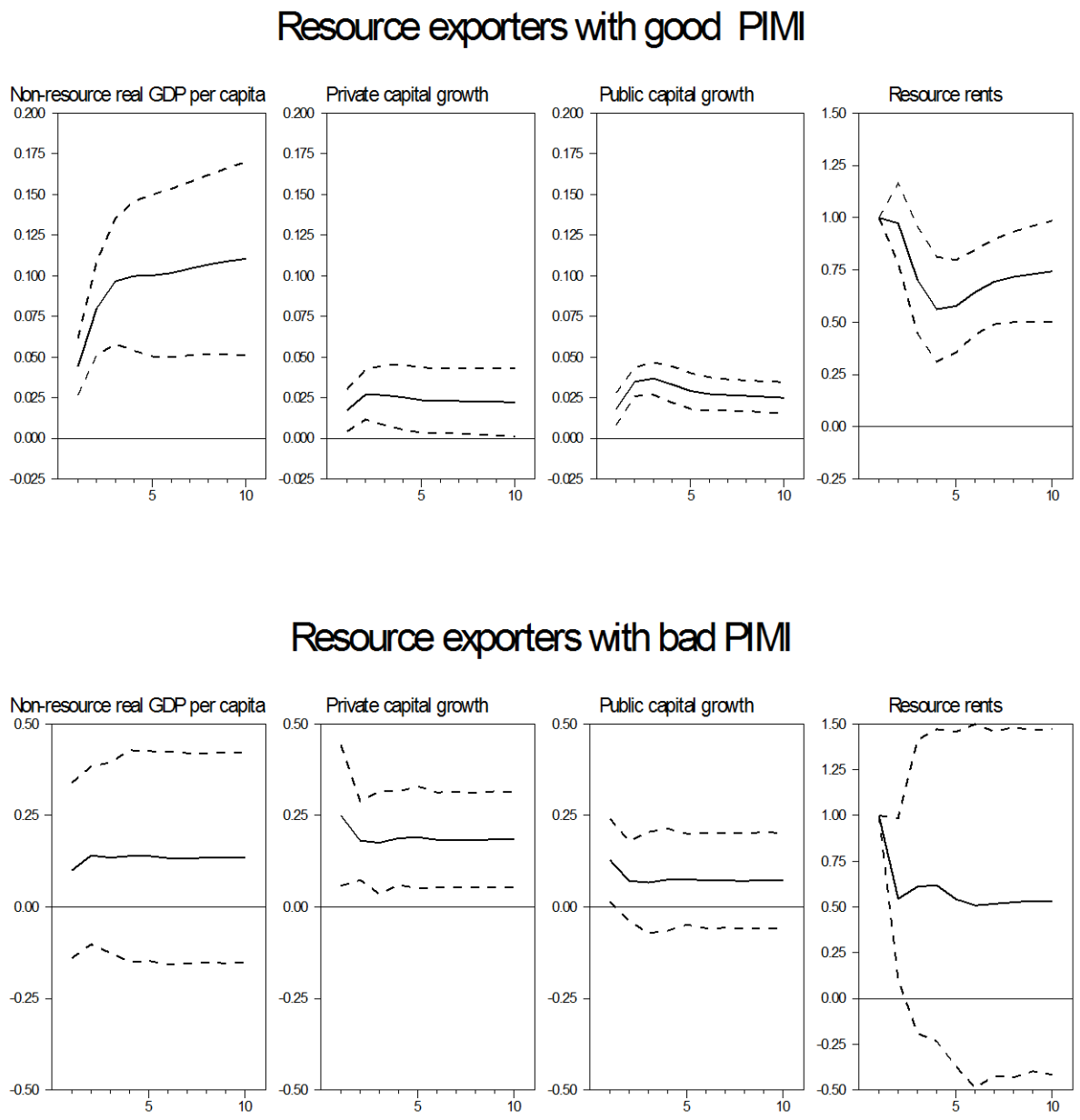

Figure 6 Responses to resource rents shocks with additional lag

So far, resource rents were modeled endogenously (driven by their past values). Therefore, shocks to resource rents have been persistent. Now, we will consider a case where shocks to resource rents will return back to their previous levels, and will not persist (by modeling resource rents exogenously). Since resource rents are now exogenous, we have four variables in the system. The identification of shocks closely follows Table 4. There are two cointegration relations and four variables. Therefore, there are two shocks with permanent effects. Growth

rates of private and public capital have no long-run effects as in Table 4. Hence, zero restrictions are imposed on the respective columns of private and public capital growth in the C matrix. This will introduce four restrictions as the rank of the C matrix is two. The number of restrictions required for identification is 6 ($=\frac{4(4-1)}{2}$). Therefore, we are left with two more restrictions to achieve a just identified model. To identify between the transitory shocks, we have assumed the public sector does not respond to a private capital growth shock contemporaneously. To distinguish between the permanent shocks, we have assumed that population growth does not respond to a non-resource real GDP per capita shock contemporaneously. The restrictions are shown in Table 5 below.

Table 5 Short-run and long-run restrictions with exogenous resource rents

Long-run restrictions					
	ε_{y_t}	$\varepsilon_{\Delta k_t}$	$\varepsilon_{\Delta g_t}$	ε_{n_t}	ε_{r_t}
$\log(Non-resouce\ real\ GDP\ per\ capita)_t$		0	0		
$\Delta\log(Private\ Capital)_t$		0	0		
$\Delta\log(Public\ Capital)_t$		0	0		
$\Delta\log(Population)_t$		0	0		
Short-run restrictions					
	ε_{yt}	$\varepsilon_{\Delta kt}$	$\varepsilon_{\Delta gt}$	ε_{n_t}	ε_{rt}
$\log(Non-resouce\ real\ GDP\ per\ capita)_t$					
$\Delta\log(Private\ Capital)_t$					
$\Delta\log(Public\ Capital)_t$		0			
$\Delta\log(Population)_t$	0				

The impulse responses of the non-resource real GDP per capita, private capital growth, and public capital growth to a doubling of resource rents are plotted in Figure 7. Non-resource real GDP per capita has increased by 2% for countries with bad PIMI on impact. However, in the next year it returned back to zero and the 95% confidence band is wide. In the case of countries with good PIMI, a doubling resource rents increases non-resource real GDP per capita and public capital growth by 3.5% and 2% on impact, respectively. The positive effects have lasted for seven years for countries with good PIMI. Hence, the effects of shocks to resource rents last for a longer period in countries with good PIMI.

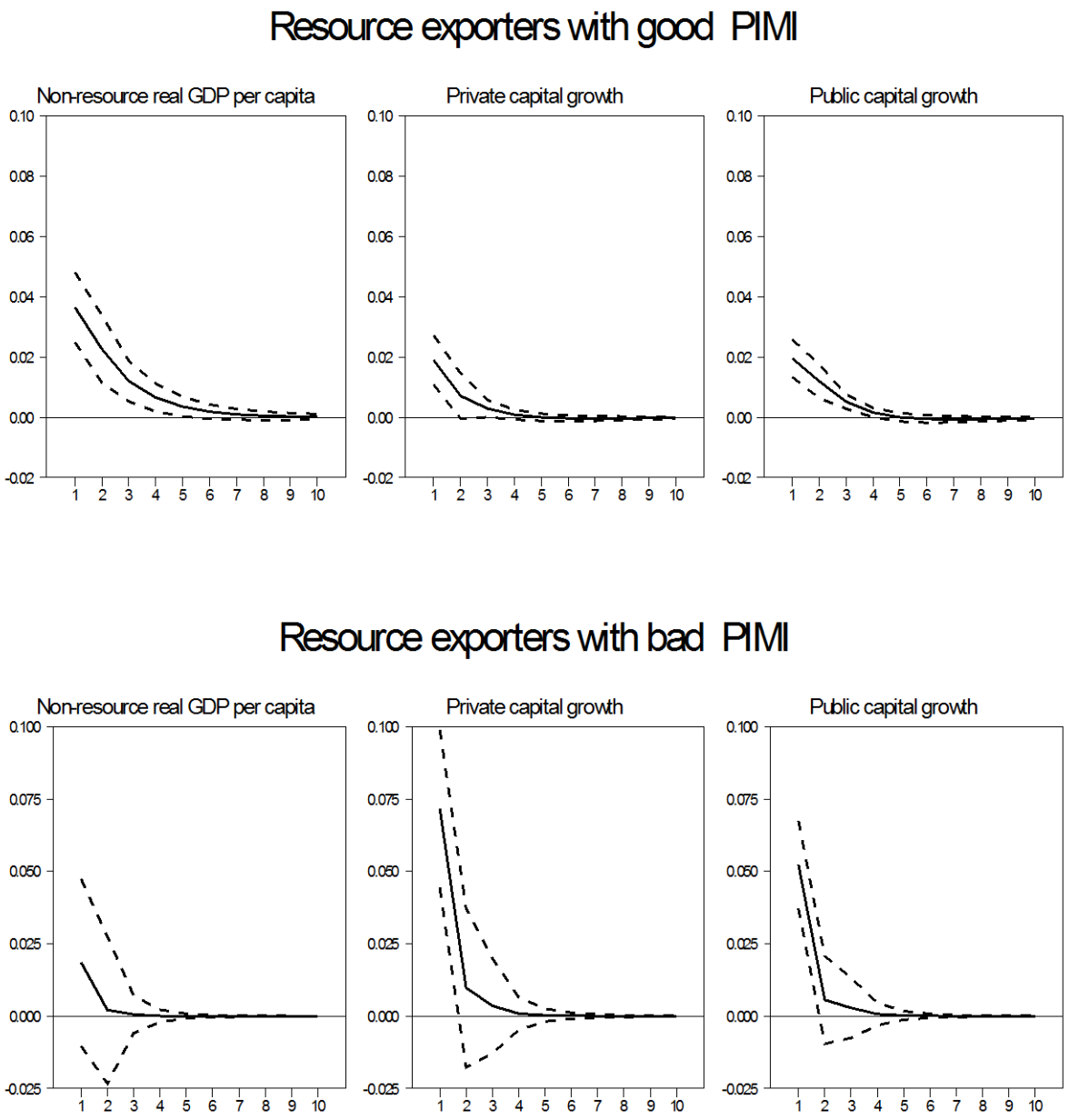

Figure 7 Impulse resonses to resource rents shocks (exogenous)

5. Conclusion

We have examined the long-run effects of resource rents shocks in developing countries focusing on public capital accumulation as an intermediate channel. We have found that resource rents are exogenous to the changes in equilibrium conditions. However, resource rents are important determinants of the long-run outcomes of the macroeconomic variables. Resource rents have a

positive long-run equilibrium relation with growth rate of public capital for resource exporters, which indicates an indirect effect of resource rents. Public capital growth has in turn a positive long-run equilibrium relationship with real GDP per capita for resource exporters. The response analysis shows that shocks to resource rents have statistically significant positive effects on non-resource real GDP per capita and public capital growth for countries with good PIMI. Resource rents shocks do not have statistically significant long-run effects on macroeconomic variables for countries with bad PIMI.

The construction of Merowe dam with a cost of 1.2 billion euros in Sudan is mainly financed by its oil revenue and loans against future oil revenue. The project has increased the demand for inputs in the construction phase of the dam. The electricity generated has also contributed to the Sudanese economy that is dependent on oil-fired thermal plants. However, in order for public investment to have long-run impact on output, it is important developing countries improve the capacity to manage public investment, and diversify the economy. South Sudan, who recently became independent, is contemplating constructing a new pipeline to export oil because of dispute with Sudan. Such investment will increase the dependence on the resource exporting sectors.

In a nutshell, a developing country with significant income from resource rents can benefit from investing the revenue in public capital. Good quality public investment management that includes technically sound appraisal, transparent selection, efficient implementation, monitoring, and evaluation assist in diversifying the economy.

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Appendix I. Data

A. Sample

Country Group	List of countries
Resource Exporters	Bolivia, Botswana, Colombia, Congo, Egypt, Gabon, Indonesia, Mauritania, Peru, Senegal, South Africa, Sudan, Togo, Trinidad and Tobago, Tunisia, Zambia
Resource Importers	Bangladesh, Belize, Benin, Brazil, Burundi, Cote d'Ivoire, El Salvador, Gambia, Ghana, Jordan, Kenya, Lesotho, Malawi, Mali, Pakistan, Philippines, Rwanda, Swaziland, Thailand, Turkey, Uganda

B. Sources of Data

Private capital Growth: Private capital growth is calculated using data from (Gupta et al. 2011).

Public capital Growth: Public capital growth is calculated using data from (Gupta et al. 2011).

Non-resource real GDP: It is defined as purchasing power party (PPP) converted GDP at 2005 constant prices from the Penn world database multiplied by the share of non-resource GDP. The share of non-resource GDP is defined as 1 minus the share of mining, quarrying and utilities in total value added based data (at 2005 constant prices) from United Nations Statistical Database (UNSD).

Real GDP: It is defined as PPP converted GDP at 2005 constant prices and the data is obtained from (Heston et al. 2011).

Population: Data is obtained from World Development Indicator.

Resource Rents: Data is obtained from World Development indicator.

Export of oil, ores, and mineral: The shares of fuel, minerals, and ores exports in total merchandise exports are obtained from World Development Indicator.

Import of oil, ores, and mineral: The share of fuel, minerals, and ores imports in total merchandise imports are obtained from World Development Indicator.

Public investment management index (PIMI): The index that measures the quality of public investment management is obtained from (Dabla-Norris et al. 2012).