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Abstract
Over the past decade, trade between China and Africa has rapidly expanded and has led to strong growth rates in Africa mainly buoyed by natural resource export. The boom in trade has partly been made possible by the use of resource-for-infrastructure swap agreements (the so-called "Angola-mode deals"), in which Chinese companies finance and build infrastructure in Africa in exchange for access to natural resources. The concomitant increase in resource export to China has however raised serious concerns that these trade arrangements may reinforce Africa's resource dependence rather than reduce it. In this article we use a dynamic panel data model to examine whether the Angola-mode deals have reinforced resource dependence and impeded export diversification in African countries. Our results indicate that by helping African countries reduce existing infrastructure bottlenecks, resources-for-infrastructure swap deals enabled them to increase their diversification capacity.

Keywords: Angola-mode, infrastructure, natural resources, export diversification.

JEL Classification: F4, O13, O33, O55.

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1. Introduction

Over the last 10 years, Sub-Saharan Africa has recorded unusually strong growth rates, mainly as a result of a spectacular increase in natural resource exports to China. Sino-African trade volumes grew rapidly to reach more than US$ 200 billion in 2013[1], driven particularly by a trade structure known as the "Angola mode", in which African natural resources are exchanged for the financing and construction of infrastructure projects by Chinese companies. The Chartered Standard Bank projected this volume to reach US$ 280 billion in 2015, so the economic potential of this trade promises to form a powerful engine for growth for resource-rich African countries if properly managed. But until 2002, when African countries started to record strong growth rates as a result of a buoyant demand from China, the abundance of natural resources seemed to have brought a curse rather than a blessing to African populations, and appeared to validate the "resource curse" thesis (Auty, 1993; Sachs and Warner, 1997)[2]. By introducing this alternative source of financing infrastructure to otherwise credit-constrained African economies, Sino-African trade brought new dynamics to the growth of African economies and has put them among the fastest growing in the world, many of them having real growth rates in excess of 6.5% as illustrated by growth data from the African Development Bank (see Table 1).

Nonetheless, the multiplication of these kinds of trade agreements has also raised serious concerns that Africa’s chronic dependence on natural resources. There have indeed been worries that some of the projects financed this way may have been undertaken simply to facilitate more resource extraction without any other developmental impact on other sectors. Therefore, some analysts fear that resource dependence may be worsened by the resulting trade boom, which would jeopardise long-term growth prospects by further delaying industrialisation. The emphasis put on infrastructure development in the Chinese funded projects is indeed partly motivated by the need to remove the bottlenecks that prevents

[1] According to UNCTAD trade statistics, export values have increased from less than US$ 4 billion in 2001 to more than US$116 billion in 2012 with total trade volume in excess of US$ 200 billion in 2013.

[2] The symptoms of the resource curse can appear in various forms, but the most important ones are rampant corruption practices that cripple the economy, the risks of violent conflicts and civil wars for the control of resources, as shown by Collier and Hoeffler (2002), the Dutch disease that crowds out investment and human capital, and environment degradation, as exemplified by the Niger Delta.

African countries from maximising their resource export (Foster et al, 2008). This may include power for processing, and rail and port facilities for outward transportation. This would mean that rather than facilitating diversification, the investment in infrastructure acts in the sense of reinforcing dependence on natural resource export.

Insert Table 1 here.

At the same time, however, the development of infrastructure in resource-rich African countries is essential for their development because it plays a key role in enabling export diversification. Infrastructure is indeed a critical factor for the successful adoption and diffusion of innovations (Lall, 1992). Various surveys in African countries have also identified deficient and costly public infrastructure as one of the most important obstacles to their economic diversification (Reinikka and Svensson, 1999). Indeed, infrastructure deficits have hindered an optimal utilisation of natural resources and delayed the emergence of modern manufacturing sectors. For example, Estache (2005) estimated that infrastructure deficiency may have been costing Africa as much as one percentage point of per capita GDP growth per year. Esfahani and Ramirez (2003) also attributed Sub-Saharan Africa's (SSA) past poor growth performance partly to the deficient provision of electricity and telecommunication infrastructure.

Given the crucial importance of export diversification for economic growth, and the key role played by infrastructure in enabling this diversification, the aim of this article will be to examine whether the new way of financing infrastructure projects under "Angola-mode" hinders export diversification by worsening resource dependence, or on the contrary, contributes to overall diversification improvement. The positive contribution of infrastructure swap deals is expected to come from their effects on easing the infrastructure bottlenecks that constrain the development of the industrial sector. It also runs through the relaxations of foreign exchange constraint because the swaps allow countries to build the needed infrastructure without money changing hands. This paper first estimates the overall effects of infrastructure on export diversification for a panel of African economies over the period 1995-2009 using panel data on infrastructure density and export concentration. It then assesses the role of infrastructure and the resource-for-infrastructure swaps in enabling diversification in African countries.

The remainder of this paper is organised as follows: the next section looks closely at the role of infrastructure in the process of growth and diversification and examines the growing role of Chinese infrastructure financing and construction in exchange for access to African natural resources. Section 3 uses a panel data analysis to empirically estimate the effects of infrastructure development on export diversification. By comparing the infrastructure-diversification nexus between the 24 African countries where Chinese firms have undertaken infrastructure projects under the "Angola-mode" trade arrangements and African countries where they have not, we assess whether the use of this infrastructure financing method has intensified resource dependence and hindered export diversification[3]. The implications for African diversification and development prospects are summarised in the concluding section.

2. Infrastructure and diversification

2.1 Link between infrastructure and diversification

In many African countries, the lack of export diversification has been a structural constraint on growth and has undoubtedly contributed to their inability to generate economic prosperity for their populations. Dependence on the export of a few primary commodities has long been a source of vulnerability to external shocks and was one of the primary reasons for the dismal economic performance that preceded the current strong growth numbers (Collier, 2002). Export diversification is indeed crucial to growth as it provides economic agents with a mechanism to protect themselves against income fluctuations and allows national economies to gain in productivity through learning by exporting (Herzer, 2005). That is why, in spite of all theoretical arguments for specialisation according to comparative advantage, policymakers in developing countries are interested in diversifying their export structure to reduce vulnerability to external shocks.

Infrastructure services, such as energy supply, transport, telecommunications, provision of water, and sanitation, are widely recognised as fundamental for that diversification. They are critical for the modernisation of production and exportation because access to new export markets is dependent thereupon (World Development Report, 1994). The theoretical analysis of the link between infrastructure and diversification outcomes is rooted in growth theory and the new economic geography literature. On the basis of the growth theories, there are multiple channels

[3] It should be noted that while more than 26 African countries have benefited from Chinese financing of infrastructure against some form of natural resource barter, more than 70% of the infrastructure project financing of this kind is concentrated in just four countries: Nigeria, Angola, Sudan and Ethiopia.

linking infrastructure services to export diversification. They include transaction cost reduction, improved communication and productivity gains from better access to energy and public facilities.

One of the most obvious benefits of investing in infrastructure is to facilitate private investments by lowering the production and transaction costs as shown by Gannon and Liu (1997) and Agénor and Moreno-Dorson (2006). By so doing, infrastructure development facilitates access to new export markets or improves the servicing of existing ones. Especially for developing countries, basic industrial and technological infrastructure is necessary to support the processing of primary commodities or the initiation and expansion of manufacturing activities as argued by Lall (1992) and Collier (2002). Reliable infrastructure for the distribution of electricity and other sources of energy plays a key role in the efficiency of economic activities. Indeed, the availability of affordable energy supply allows substantial improvements in workers' productivity, and improves the competitiveness of firms and their capacity to export to global markets (Agénor and Moreno-Dodson, 2006).

Likewise, the growth of data exchange involving telecommunications infrastructure is central to the efficiency of operations in manufacturing and the financial sector which leads to similar increases in competitiveness and access to global markets. Moreover, infrastructure also has positive effects on education and health as shown by Agénor (2005): good health and high education levels of the labour force result in better human capital outcomes, which increase the likelihood of a better export performance.

As argued by Wood and Mayer (2001) education and human capital stocks are an important determinant of export diversification and explain much of the differences in export structure between Africa and other developing regions. The availability of infrastructure services also increases the likelihood of more foreign investments, thereby increasing diversification of production as shown by surveys of prospective foreign investors over a wide range of countries (World Bank, 1994).

As for the new economic geography theory, numerous authors have also emphasised the importance of geographical barriers in the determination of export structure and performance (Redding and Venables, 2003). Their argument is that high transport costs in geographically isolated areas that are remote from large markets or suppliers inhibit the successful development of manufacturing activities. This leads to a lack of competitiveness and makes it difficult for the country in question to export manufactured goods. Based on this theory, countries with less transport infrastructure should have more concentrated export patterns and a lower ability to develop diversified manufacturing exports than those without these geographical barriers. Transportation infrastructure also helps individuals and firms in previously unconnected and underdeveloped areas to get connected to core economic activities, thus allowing them to access additional productive opportunities (Estache, 2005). Mainly through its effects on enabling economic diversification, infrastructure is thus indispensable for the process of economic development.

These theoretical arguments are corroborated with factual evidence. For example in Sub-Saharan Africa, transport costs are the highest of any region of the world and as a result, the region is the least competitive in terms of export performance. A 1999 study by the African Development Bank on the exports of the region to the United States found that freight charges, as a proportion of cost, insurance and freight (CIF) value, are on average 20% higher for exports from poor countries of the region than for comparable products from other low-income countries, which constitutes a heavy drag on the ability of African countries to export.

2.2 Other factors affecting diversification

Natural resources endowment is the most salient reason why an economy may have a large share of primary commodities in its exports. Countries endowed with abundant natural resources tend to have this endowment reflected in their export structure. The lack of export diversification in Africa is to a large degree attributable to natural resources as argued by Wood and Mayer (2001). Other factors that are likely to influence the level of diversification include human capital stocks, the level of per capita income and the population size. Theoretical explanations of the link between the degree of diversification and the size of the country's economy can be found in the New Trade Theory (Dixit and Norman, 1980; Helpman and Krugman, 1985; Krugman, 1981). They argue that market size directly affects the degree of product differentiation. The link between per capita income levels and diversification is also rooted in structural transformation, in which economic growth leads to a technological advancement that makes it possible to produce increasingly diverse goods and services, as argued by Kuznets (1971) and Matsuyama (2005) among others. Diversification and growth in per capita income are thus intertwined aspects of the same complex phenomenon of "modern economic growth" as defined by Kuznets (1971).

This also implies that increasing per capita output leads to modifications in the structure of the economy through a shift towards goods with higher demand elasticity. This mechanism, in turn, influences sectoral productivity which changes relative prices and consequently, modifies the structural composition of the economy, as highlighted by Parteka and Tamberi, 2008). Nonetheless, while it may be argued that higher diversification affects economic growth positively, it may be also the case that richer countries are more able to diversify their production structures. Empirical evidence in this regard indicates the existence of a nonlinear relationship between income and production diversification (Imbs and Wacziarg, 2003; Agosin et al., 2011): as per capita income rises, production concentration falls, but after a certain level of income has been reached, production tends to become more concentrated[4]. The direction of causality between per capita income and the extent of diversification remains therefore indeterminate and using per capita income as an explanatory variable for diversification has the potency of carrying an endogeneity bias.

As for the population, size also affects a country's export diversification. Countries with larger population sizes are more likely to develop varied technical and productive skills that can be deployed in different fields. Likewise, countries with populations spread over large geographical areas can benefit from distinct regional specialisation.

Finally, other factors such as trade openness, trade policies and institutions also have an influence on export diversification. Countries that export more are more likely to be open to trade in terms of trade restrictions, tariff and non-tariff barriers and other impediments. Various measures of trade openness exist which can be used to control for this effect in the regression. Many other factors such as research and development efforts, market size institutions, and incentive regimes also play a role in stimulating diversification[5].

2.3 Infrastructure projects under the "Angola mode"

For many of Sub-Saharan African countries, infrastructure deficiency has put a major constraint on development. According to estimates by Foster (2008), infrastructure deficiency

[4] According to Imbs and Wacziarg (2003), sectoral concentration follows a U-shaped pattern in relation to per capita income: first, sectoral diversification increases, but there exists a level of per capita income beyond which the sectoral distribution of economic activity starts concentrating again.

[5] The effects of some of the institutional and policy variables on economic performance have been analysed in previous studies (see Agosin et al., 2011) and do not necessitate repetition here. Because there are many other factors affecting the diversification that cannot all be included in our specification, our estimated coefficients are likely to be slightly overestimated. However, attempting to include more factors in our specification would make it unnecessarily complex and reduce its usefulness.

depresses firm productivity by around 40%. For most countries, the negative impact of deficient infrastructure is at least as large as that associated with corruption, crime, financial market and red tape constraints. As illustrated in Table 2 below, delays in obtaining electricity connection and frequent power cuts cause a significant loss of production and hinder business operations. Sub-Saharan Africa (SSA) currently lags behind other developing regions of the world on most standard indicators of infrastructure development. Many African countries seeking to invest in large infrastructure projects to boost their export potential have long been constrained by a lack of access to adequate financing. The infrastructure financing gaps were estimated by the World Bank at about US$ 10 billion a year for minimum investment needs of US$ 22 billion required to meet the Millennium Development Goals (MDG).

Insert table 2 Here

Whereas Africa has a huge unmet demand for infrastructure financing and construction, China has developed one of the world's largest and most competitive construction industries, with particular expertise in the civil works critical for infrastructure development (Chen et al., 2007). In order to fuel its fast growth, China needs African oil and minerals. It has therefore become a leading global supplier of construction services of interest for African countries in need of infrastructure and has accumulated substantial financial reserves to finance the needed construction works. The complementarities between mineral-rich Africa, faced with infrastructure bottlenecks, and manufacturing giant China, play a key role in the dynamics of Sino-African trade.

The use of infrastructure financing guaranteed by future access to natural resources in the trade with China has allowed credit constrained countries to undertake infrastructure projects that they previously were not able to afford. Under these Sino-African trade arrangements, the Angola-mode financing of infrastructure projects is usually achieved through the Export-Import Bank of China (China Ex-Im Bank), which provides the necessary loans for the infrastructure projects executed by Chinese firms, whereby repayment of the loan is made in terms of concession of natural resources, which are extracted by Chinese mining companies. These deals are mutually beneficial because of the complementary needs between Africa and China.

Under these types of agreements many large infrastructure projects were undertaken in various African countries. The power sector has attracted the largest amount of Chinese infrastructure financing, with more than US$ 5.3 billion in cumulative committed investments as of 2008. Much of this effort has been concentrated in the construction of hydroelectric power plants. Given the current power supply shortage in Africa and the underdeveloped but identified high hydroelectricity potential, these investments are critical for Africa's economic development. The development of this hydroelectric potential through Chinese financing is thus of strategic importance for the African power sector. As of the end of 2007, the Chinese were involved in financing 10 major dams in 9 African countries, with a combined generating capacity of more than 6,000 MW of electricity. The total cost of these projects was estimated to be more than US$ 5 billion, of which the Chinese were financing over US$ 3.3 billion (Chen et al., 2007).

In recent years, China has also been very active in the African rail and road sector, with financing commitments of US$ 4 billion for railways and about US$ 550 million for road construction (World Bank-PPIAF Chinese Projects Database, 2007). Railway projects include rehabilitation of more than 1,350 kilometres of existing railway lines and the construction of more than 1,600 kilometres of new railroad. Chinese companies have also been very active in building paved roads across Africa, the most active Chinese road construction firm being the China Road and Bridge Corporation (CRBC).

The Chinese financial commitments to infrastructure projects are a significant contribution with respect to the infrastructure financing needs of Sub-Saharan Africa of US$ 22 billion per year. Total value of China Ex-Im Bank loans to Sub-Saharan Africa in the infrastructure sector was estimated to amount to more than US$ 12.5 billion by mid-2006 (Bosshard, 2007). Foster et al. (2008) documented eight resource-backed deals of this kind worth more than US$ 3 billion (and covering oil, mineral resources and agricultural products) while Corkin et al. (2008) report that more than 800 Chinese construction firms were already active in Africa by the end of 2007. Cumulative value of Chinese financing of infrastructure in SSA has exceeded US$ 50 billion and is still growing. In comparison, commitments of official assistance to infrastructure projects in Sub-Saharan Africa from OECD countries amounted to around US$ 5 billion for the year 2006 (Infrastructure Consortium for Africa, 2007).

3. Estimating the diversification effects of infrastructure

3.1 Estimation model and method

For infrastructure to positively enable export diversification it must act in combination with many other factors that are equally indispensable for increasing the variety of production and trade. Such factors include the availability of human capital, investment in physical capital accumulation and supporting institutions and incentive systems such as secure property rights, trade openness and other public policies that encouraging export. In order to analyse the relationship between infrastructure and diversification, we will thus express the diversification measure as a function of the measure of available infrastructure stocks, human capital, investment in physical capital accumulation and a measure of trade policy.

For a country, the availability of human capital at a given point of time should increase the diversification potential, which results in an actual measure of diversification observed at a future time. With a given level of human capital, a country investing more in capital accumulation should also proportionally increase its diversification potential more, while the provision of more infrastructure services facilitates business contacts, reduces transaction costs and provides facilities for firms to engage in new activities. Intuitively, diversification should be positively related to each of these variables. Trade policies aimed at supporting export also provide incentives for private businesses to invest in various economic activities that increase the variety of export products.

Moreover, countries with a higher level of per capita income are also more likely to have diversified export for reasons explained by Imbs and Wacziarg (2003): as countries grow richer they have more resources to invest in variegated industries, while diversification also creates growth advantages that lead to higher income. Many of the effects of per capita income on diversification are however already captured by the capital accumulation and infrastructure effects, with which they are usually correlated. The estimation of diversification effects with per capita income as one of the explanatory variables may thus entail some multicollinearity problems[6] in addition to an endogeneity bias resulting from reverse causality between per capita income and export diversification pointed out by Imbs and Wacziarg

[6] Parteka and Tamberi (2011) signal a similar problem of multicollinearity, whereby the significance of per capita as one of the explanatory variables for diversification (using a different measure of diversification than ours) in a multivariate estimation disappears if this variable is put alongside other economic variables like free trade indicators.

(2003). In order to overcome these difficulties, we will use the Generalised Method of Moments (GMM) estimation, which has been shown to be a consistent and robust method to deal with endogenous regressors, even in the presence of autocorrelation and heteroskedasticity (Hansen, 1982). By making use of the orthogonality conditions, GMM allows for an efficient estimation even in the presence of heteroskedasticity of unknown form. To control for the effects due to natural resource endowments, such as oil, natural gas or mineral ores, we introduce the natural resources variable into the equation, which capture the effects of resource endowment on the export concentration of the corresponding country. Country size in terms of population also matters for the degree of diversification. Theoretical arguments for the nexus between the degree of diversification and country size can be found in New Trade Theory (Dixit and Norman, 1980; Helpman and Krugman, 1985) who posit that market size directly affects the degree of product differentiation. We therefore also include the country's population size as a control variable to capture its potential influence and a measure of trade openness to account for the effects of institutional, market access and policy variables on diversification. When interacted with infrastructure, trade openness might better explain why countries that trade more tend also to have a larger variety of export products and possess enabling infrastructure. The degree to which the financing of infrastructure is facilitated by Angola-mode swaps is also expected to contribute to the diversification effect by easing the foreign exchange constraints.

Diversification is driven by many other factors that are dependent on market conditions, competition, incentive systems, resources and technologies necessary to invest profitably in new markets, new goods and services. The precise relationship between these various factors and the level of the resulting export diversification is a complex issue and an attempt to exhaustively analyse the individual and collective effects of all relevant factors would make the model rather intractable.

The length of the time lag between the measure of each element of absorptive capacity and its corresponding effect on export diversification can vary as a result of diverse factors. For human and physical capital to produce their effects on productivity and diversification, a more or less sizeable period of time may be necessary. Some other factors, such as infrastructure services (once available for use) and trade policies are less likely to have delayed effects.

3.2 Model specification

Specifying an appropriate model to link export diversification to its determinant is a complex task. From many studies linking export diversification to productivity and output, the view that diversification can be considered as an outcome of production and its determinants linked to it in an endogenous growth model is an appealing approach. The commonality of certain determinants (such as human capital) between growth and diversification would indeed suggest an endogenous model using various factors to produce output can be applied to determine how the produced output results in concomitant export diversification. However among the various studies that so far have put export diversification on the left-hand side of the equation and income on the right-hand side, such as the already cited Imbs and Wacziarg (2003), Koren and Tenreyro (2007), Klinger and Lederman (2006) and Cadot et al. (2011), most found a U-shaped relationship between export concentration and GDP per capita. Moreover, Feenstra and Kee (2008) showed that changes in export variety explain only about 1% of the variation in TFP across time and countries. This divergence in pattern between the change in income production (economic development) and export diversification makes an output-based growth model ill-suited to analyse the determinants of diversification.

Moreover, since the focus of this study is on how Sino-African trade patterns affect the corresponding export diversification this diversification measure needs to be examined separately as a dependent variable. In one such an analysis looking at the relationship between export diversification patterns and per capita income, Parteka and Tamberi (2011) use an additive model in which the measure of diversification (whose upper bound is the log on the number of productive sectors) is explained by the summation of its modelled determinants. They also use a loglinear model, in which the coefficient can readily be interpreted as elasticities.

In the present study, we similarly consider the various determinants of diversifications as factor inputs which produce a certain measure of export diversification and examine how variation in each of them contributes to the change in observed diversification pattern, so that the estimated coefficients represent the elasticities with respect to changes in each corresponding factor. This suggests the simplest specification of this model as an augmented production function of the exponential functional form unconstrained in its coefficients:

$$Div_{it} = C_i * H_{it}^{\beta 1} * I_{it}^{\beta 2} * INFR_{it}^{\beta 3} * NATRES_{it}^{\beta 4} * y_{it-1}^{\beta 5} * L_{it}^{\beta 6} * OPEN_{it}^{\beta 7} * SWAP_{it}^{\beta 8} * \boldsymbol{\xi_{it}} \quad (1)$$

where C, β_1, β_2, β_3, β_4, β_5, $\beta_6\beta_7$, and β_8 are the constant parameters to be estimated, while H, I, INFR, NATRES, y, L, OPEN and SWAP are respectively the measures of human capital stock, capital equipment investment, the relative infrastructure density, the share of natural resources in export, the level of per capita income, the population size in country *i* at the beginning of the year *t* in which the measure of diversification is recorded and trade openness. ξ is a stochastic term representing the measurement errors. SWAP represents the measure of involvement of country *i* in Angola-mode swap agreement.
This yields a loglineal model that enables us to analyse how changes in factors affect the change in the diversification measure. The underlying hypothesis is that the increase in the levels of human capital, supply of infrastructure services, capital investments, the measure of trade openness and income[7] will tend to increase export diversification and therefore result in a lower Herfindahl index. In contrast, the increase in natural resource endowment is expected to result in export concentration and thus be positively correlated with the log of the Herfindahl index. The degree of resource for infrastructure swap deals, which is the main variable of interest is also conjectured to exacerbate concentration as it would enhance the quantity of exported natural resources, but with time, it can be thought to indirectly ease resource dependence as it facilitates the rapid accumulation of infrastructure stocks. The value and sign of the corresponding coefficient will show whether there are significant difference of diversification among countries due to this involvement in resource-for- infrastructure swap agreements. The null hypothesis is that none of these factors affects export diversification either positively or negatively.

The functional form we use in equation (1) is analogous to the Cobb-Douglas production function but has no restriction on the input factor shares. This may be thought of as considering the diversification as an outcome produced with available infrastructure, human capital stock and capital accumulation as factor inputs. Trade openness and natural resource endowments are the catalysts and moderators of this diversification. Taking the logs of both sides of equation 1, equating ln (C) to β_0 and ln(ξ) to the stochastic error term ε, we obtain:

[7] The relationship between per capita income and export diversification is taken to be positive at the low levels of income. However, as shown in Imbs and Wacziarg (2003) this relationship is not monotonically positive. Above a certain level of per capita income (US$ 9, 000 in 1985 constant value), countries re-concentrate their production structure, whether measured by employment or value added (recall footnote 4). Using different data, Koren and Tenreyro (2007) confirmed the existence of a U-shaped relationship between the concentration of production and the level of economic development.

$$\ln(Div_{it}) = \beta_0 + \beta X' + \beta_8 \ln(SWAP_{it}) + \varepsilon_{it} \quad (2)$$

where β is a vector of coefficients, X' a column vector of the covariates mentioned in equation 1 and ε_{it} represents the error terms.

Given the correlation between per capita income and most of the other independent variables as discussed above, the estimates based on the specification of equation 2 would potentially suffer from problems of multicollinearity and endogeneity biases. Indeed, the existence of a reverse causality between diversification and per capita income creates an endogeneity bias and renders the OLS estimation of equation 2 inconsistent. Even the within transformation of the fixed effects method does not eliminate this bias, especially when the time dimension is relatively short. The application of Generalised Method of Moments (GMM) estimator is an efficient way to deal with this problem of endogeneity in the presence of unknown heteroskedasticity (Baum et al., 2003). The GMM estimator is constructed by exploiting the orthogonality conditions of the sample moments. The idea is to create a set of estimating equations for the coefficients that make sample moments match the population moments. By exploiting the orthogonality conditions, the GMM estimator selects the best linear combination among a set of moment restrictions and produces a consistent estimator for any weighting matrix. Using GMM with heteroskedasticity and autocorrelation correction (HAC), allows for an efficient estimation even when some of the regressors are endogenous and heteroskedastic. In models for which there are more moment conditions than model parameters, GMM estimation also provides a straightforward way to test the specification of the proposed model.

For the GMM estimation needed to deal with the endogeneity problem pointed out above, we thus also express the reverse causality equation with per capita income as a function of diversification, human capital, trade openness, previous per capita income and capital accumulation (equation 3), so as to estimate the system of simultaneous equations formed by this equation together with equation 2.

$$\ln(Div_{it}) = \beta_0 + \beta X' + \beta_8 \ln(SWAP_{it}) + \varepsilon_{it} \quad (2)$$

$$\ln(y_{it}) = \gamma_0 + \gamma_1 \ln(Div_{it}) + \gamma X' + \epsilon_{it} \quad (3)$$

where γ is another column vector of coefficients to be estimated. The measurement of the different variables used in this estimation and corresponding data sources are explained in Appendix A1.

3.3 Empirical Results

3.3.1 Endogeneity bias and GMM estimation

For the data analysis, various panel regressions were run with data covering the period 1995-2009 to enable a comparison between Sub-Saharan countries with Chinese-funded infrastructure projects under the "Angola mode" and other African countries. For each sub-sample, we estimated the effects of various components of absorptive capacity on export diversification by regressing the log of the Herfindahl index as the dependent variable[8] on the various explanatory variables as presented in equation 2 above. The analysis made separate use of two alternative measures of human capital, the Barro and Lee (2001) measure of educational attainment and the rate of literacy in the population (percentage of population aged 15 years and above that can read and write).

Due to the relatively short time span of our data, the estimation was carried out with the system GMM estimator to reduce the finite sample bias in standard errors that would otherwise make difference GMM inferences unreliable, as explained by Roodman (2006). Indeed, as shown by Blundel and Bond (1997), standard GMM estimation (as in Arellano and Bond, 1991) has poor finite sample properties and is also downwards biased, especially when the time dimension T is small. The bias is only sufficiently small for T = 30 or more. To avoid this bias for shorter time dimensions, Blundel and Bond (1997) proposed the use of the system GMM estimator, derived from the estimation of a system of two simultaneous equations. The basic idea is to estimate a system of equations in both first-differences and levels, where the instruments used in the levels equations are lagged first-differences of the series, as suggested by Arellano and Bover (1995). These instruments are valid under restrictions on the initial conditions. By exploiting additional moment conditions, system GMM can significantly reduce the finite sample bias (Blundell et al., 2000)[9]. The system GMM estimator has been shown to perform better than the difference GMM in multivariate dynamic panel models when series are persistent, which is why it was chosen for this analysis. For the robustness of GMM results, the choice of instrument must however be made very judiciously, since the inclusion of too many instruments may bias the Hansen J-statistic downward and reduce the usefulness of the estimates, as cautioned by Roodman (2009). Mehrhoff (2009) also suggests the use of a limited lag length to overcome the problem of too

[8] Higher values of log of the Herfindahl index indicate higher export concentration.

[9] Judson and Owen (1999) have also provided Monte Carlo simulation evidence that GMM is superior to other estimation techniques when it comes to estimating dynamic panel data.

many instruments pointed out by Roodman (2009). His Monte Carlo simulation results strongly suggest the use of factorised instruments because these produce the lowest bias and root mean square error. Furthermore, he recommends the collapsing of the instrument set prior to factorisation. Likewise, Windmeijer (2005) has also shown that GMM becomes more efficient when the lag depth is limited, and thus when fewer instruments are employed in the estimation. The choice of the instruments in the used regressions is therefore based on these considerations.

Table 3 presents the regression results of the system GMM estimation. The Hansen-J statistic tests for over identifying restrictions confirm the validity of the used set of instruments set[10]. All Sargan p-values of the reported statistics at the corresponding degrees of freedom are below 10%.

The estimated results as reported in regressions 1 and 2 represent the elasticities of export diversification with respect to the various determinants used in this study. In other words, they show how proportional variations in each covariate affect changes in the Herfindahl concentration index, and thus the ability of SSA countries to change the composition of their exports and free themselves from resource dependence. The two regressions use different measures of human capital: regression 1 uses literacy rate while regression 2 is estimated on the basis of Barro and Lee's (2001) measure of educational attainment in number of years of schooling. Regressions 3 and 4 do the same using data for all African countries.

>> Insert Table 3 here

Salient are the elasticities of export diversification with respect to capital accumulation, infrastructure and literacy. An increase in each of these factors results in a more than proportional reduction in the concentration index (regression 1), so that for the Sub-Saharan economies they represent the strongest determinants of export diversification in our study. Population size and lagged per capita income are also significant contributors to the reduction of export concentration, be it with lower elasticities. This comes as no surprise, since they

[10] In a well specified, overidentified model with valid moment conditions, the J−statistic is distributed as χ^2, with degrees of freedom equal to the number of overidentifying restrictions. If the model is mis-specified and or some of the moment conditions do not hold, then the J−statistic will be large relative to a chi-square random variable with $K - L$ degrees of freedom. The J−statistic acts as an omnibus test statistic for model specification. A too large J−statistic indicates a mis-specified model.

corroborate our hypothesis that these factor constitutes the basis for the absorptive capacity necessary to put in place the production technologies needed to diversify export composition.

We also note the significant elasticity for population size across all regressions, which implies that part of the differences in export diversification across African countries can be ascribed to differences in population size, with more populous countries being more likely to have a larger export variety.

Trade openness does not come out as significant, but when interacted with infrastructure, it also emerges as strongly significant in explaining export diversification: this means that only countries with more open trade policies backed by the necessary supporting infrastructure are more likely to increase their export diversification. Consistent with the Dutch disease hypothesis, the presence of natural resources tends to crowd out the other tradables and thus hamper export diversification.

Surprisingly, the results also show a beneficial effect of Angola-mode trade arrangements on improving export diversification. Though the extent of use of the resource-for-infrastructure swap arrangements could be thought to worsen the resource dependence, it displays a significantly negative correlation with the concentration index across all regressions. This means that more use of Angola-mode deals contributes to improving export diversification. By relaxing the financing constraint for the development of the badly needed infrastructure, this financing method is an effective method to speed up the easing of the infrastructure bottlenecks.

When the Barro and Lee's (2001) measure of educational attainment is used as the proxy for human capital (regression 2), the elasticities become lower but remain significant. Likewise in the comparative sample including other non-SSA African countries, the sign pattern of the regressions remains broadly similar, but with lower elasticities for the 2 measures of human capital (regressions 3 and 4 respectively). The elasticity of capital accumulation drops even to insignificant levels in the larger sample. Nonetheless the general picture implies that the export diversification determinants are broadly linked to the Herfindahl concentration index in a similar way, whether we take Africa as a whole or look only at Sub-Saharan economies.

It is interesting to note that the coefficient for infrastructure remains one of the strongest throughout all regressions, irrespective of the sub samples. This underscores once again the crucial role played by infrastructure services in supporting the adoption of technologies that enhance the capability to diversify export. The boost in infrastructure construction, facilitated by the resource swap agreements, has therefore led to the likelihood of more export diversification because of the strong effects of infrastructure on diversification in those countries.

4. Conclusion

Deficient infrastructure is one of the major reasons Africa has failed to diversify its exports and continues to depend on natural resource in its international exchanges. In this article, we have analysed the role played by the availability of infrastructure services in increasing export diversification in African countries. Given the critical role played by infrastructure bottlenecks in constraining growth in many African countries, we attempted to estimate the effects of infrastructure improvements under the Angola-mode arrangements on the ability of the corresponding countries to diversify their exports. Our results clearly indicate that the degree of infrastructure service provision is positively correlated with export diversification in African countries in general and in countries that entered infrastructure-for-resource swap agreements with China in particular. Other factors such as human capital stocks and trade openness also play a positive role in increasing the diversity of exports. Although trade openness on its own does not explain export diversification in resource-rich African countries, it is an important catalyst when combined with infrastructure. Abundance of natural resources is a major impediment for export diversification across African economies.

Resource-rich African countries that have made use of resource-for-infrastructure swap agreements with China under the so-called Angola mode were found to strongly benefit from their infrastructure stocks in terms of fostering export diversification. Furthermore, we did not observe any increase in export concentration due to investment in infrastructure guaranteed by natural resource repayment. Angola-mode countries have moreover taken advantage of the boom in infrastructure construction to post strong growth rates both before and after the 2008 global financial crisis. In those countries, infrastructure is the most important element explaining their ability to diversify export. This may be due to the positive effects of the availability of infrastructure services, which allows productive firms to start their businesses and operate in many economic sectors beside the natural resource sector. These results have important implications for the current effort of many African countries to boost manufacturing production in order to reduce their vulnerability to recurrent fluctuation in the prices of raw materials in world markets.

First, for many African countries, the financing of large infrastructure projects has long been constrained by the lack of access to the required financing. Through its intensive use of the "Angola mode" trade structure, which provided a new way of financing infrastructure projects, the Sino-African trade helped to ease the infrastructure bottlenecks in the power generation and transport sectors and has enabled resource-rich African countries to enjoy unprecedented growth rates. By building the much needed infrastructure in Africa, China has given an impulse to a new growth momentum in African economies, which contributed to the emergence of the so-called African "lion economies”, such as Angola and Nigeria. Given the positive role of infrastructure for export diversification, the financing facilities offered by the Chinese Ex-Im Bank for the construction of needed infrastructure projects in Africa constitute therefore an important opportunity for building the necessary capacity for a structural transformation and greater export variety in the future.

Secondly, one of the major threats to the sustainability of the strong growth that these resource-rich African countries have experienced in recent years remains their continued dependence on raw material export. The abundance of natural resources has a negative effect on export diversification, which confirms the crowding-out effects. However, the conversion of the resource proceeds into needed infrastructure projects, such as in the Angola-mode swap agreements, reduce constraints on manufacturing production and has the potency to facilitate the emergence of a diversified industrial sector through increased mobility, better access to inputs and reduced transportation costs.

Finally, despite the justifiable optimism due to the impressive growth performance with marginal diversification of the African lion economies, it is important to keep in mind that this economic boom, rather than reducing resource dependence, may in fact be aggravating it in the short run. Africa's ability to sustain the high growth rates of its lion economies in the long run will depend on its capacity to mobilise the profits from the natural resource sector so that they can yield sufficiently large surpluses for investment in a modern manufacturing sector. For such a mobilisation to take place efficiently, an increase in regional integration with trans-national infrastructure projects will be essential to take advantage of the scope effects, as suggested by Page (2011). In that regard, intra-regional transportation and communication infrastructure can also boost intra-African trade and thereby provide supplementary export markets to African manufacturers. This represents a non-negligible potential new source of export diversification for many African economies.

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References

Agénor, P.-R., 2005. Infrastructure, Public Education and Growth with Congestion Costs. Centre for Growth and Business Cycles Research Working Paper No 47, University of Manchester.

Agénor P.-R. and Moreno-Dodson, B., 2006. Public Infrastructure and Growth: New Channels and Policy Implications. The World Bank Policy Research Working Paper 4064.

Agosin, M., R. Alvarez, and Bravo-Ortega, C., 2011. Determinants of Export Diversification Around the World: from 1962 to 2000. *The World Economy*, DOI: 10.1111/j.1467 9701.2011.01395.x: 1-21.

Arellano, M. and Bond, S., 1991. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies*, 58, 277-297.

Arellano, M. and Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, 68, 29-52.

Auty, R., 1993. Natural Resources, Development Models and Sustainable Development. International Institute for Environment and Development.

Barro, R. and J.-W. Lee, 2001. International Data on Educational Attainment. *Oxford Economic Papers*, 3, 541-563.

Baum, C., E. Schaffer and Stillman, S., 2003. Instrumental Variables and GMM: Estimation and Testing. *Stata Journal*, 2003, 3-1, 1-31.

Blundell, R. and Bond, S., 1997. Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics*, 87, 115-143.

Blundell, R., Bond, S and Windmeijer, F., 2000. Estimation in Dynamic Panel Data Models: Improving on the Performance of the Standard GMM Estimators. The Institute of Fiscal Studies Working Paper, No. 00/12.

Bosshard, P., 2007) *China's Role in Financing African Infrastructure*. International Rivers Network.

Cadot O., Carrère, C. and Strauss-Kahn, V., 2011. Export diversification: what's behind the hump?. *The Review of Economics and Statistics*, 93, 590-605.

Centre for Chinese Studies (2006). China's Interest and Activity in Africa's Construction and Infrastructure Sector. Stellenbosch University, South Africa.

Chen, C., Chiu, P., Orr, R. and Goldstein, A., 2007. An Empirical Analysis of Chinese Construction Firms Entry into Africa. Conference Paper, CRIOCM2007. International Symposium on Advancement of Construction Management and Real Estate, Sydney, Australia.

Collier, P., 2002. Primary Commodity Dependence and Africa's Future. The World Bank, Washington D.C.

Collier, P. and Hoeffler, A., 2002. On the Incidence of Civil War in Africa. *Journal of Conflict Resolution*, 46, 13-28.

Corkin, L., C. Burke, and Davies, M., 2008. China's Role in the Development of Africa's Infrastructure. SAIS Working Papers in African Studies, The Johns Hopkins University.

Dixit, A. and Norman, V., 1980. *Theory of International Trade: A Dual, General Equilibrium Approach*. Cambridge University Press, Cambridge.

Esfahani, H. and Ramirez, M., 2003. Institutions, infrastructure and economic growth. *Journal of Development Economics*, 70, 443-477.

Estache, A., 2005. What Do We Know About Sub-Saharan Africa's Infrastructure and the Impact of the 1990s Reforms? Mimeo, World Bank, Washington D.C.

Fedderke, J. and Bogetic, Z., 2006. Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impact of 19 Infrastructure Measures. World Bank Policy Research Working Paper 2989.

Feenstra, R. and Kee, H. L., 2008. Export Variety and Country Productivity: Estimating the Monopolistic Competition Model with Endogenous Productivity. *Journal of International Economics* 74, 500-518.

Finger, J. and Kreinin, M., 1979. A Measure of Export Similarity and its Possible Uses. The *Economic Journal of Conflict Resolution*, 89, 905-912.

Foster, V., 2008. Africa Infrastructure Country Diagnostic: Overhauling the Engine of Growth: Infrastructure in Africa. The World Bank, Washington D.C.

Foster, V., Butterfield, W., Chen, C. and Pushak, N., 2008. Building Bridges: China's Growing Role as Infrastructure Financier for SSA. TheWorld Bank, Washngton D.C.

Foster, V. and Briceno-Garmendia, C., 2010. Africa’s Infrastructure: A Time for Transformation. The World Bank, Washington D.C.

Gannon, C. and Liu, Z., 2005. Poverty and Transport. World Bank, Washington D.C.

Grier, R., 2003. The Interaction of Human and Physical Capital Accumulation: Evidence from Sub-Saharan Africa. Working Paper, University of Oklahoma, Norman, OK.

Hansen, L., 1982. Large sample properties of generalized method of moments estimators. *Econometrica*, 50, 1029-1054.

Hanushek, E., 1995. Interpreting Recent Research on Schooling in Developing Countries. World Bank.

Helpman E. and Krugman, P., 1985. *Market structure and foreign trade*. The MIT Press, Cambridge (MA).

Herzer, D., 2005. Exportdiversifizierung und Wirtschaftswachstum in Chile: Eine Oekonometrische Analyse. *Jahrbuch für Nationalöconomie und Statistik*, 225, 163-180.

Helpman, E. and Krugman, P., 1985. *Market Structure and Foreign Trade*, The MIT Press, Cambridge.

Imbs, J and Wacziarg, R., 2003. Stages of Diversification. *American Economic Review*, 93: 63-86.

Infrastructure Consortium for Africa, 2007. ICA Annual Report 2006. ICA Secretariat, Tunis.

Judson, R. and Owen, A., 1999. Estimating dynamic panel data models: a guide for macroeconomists. *Economics Letters*. 65: 9-15.

Klinger, B. and Lederman, D., 2006. Diversification, Innovation, and Imitation inside the Global Technology Frontier. World Bank Policy Research Working Paper #3872, The World Bank, Washington D.C.

Koren, M. and , Tenreyro, S., 2007. Volatility and Development. *Quarterly Journal of Economics*, 122, 243-287.

Krugman, P., 1981. Intra-industry Specialization and the Gains from Trade. *The Journal of Political Economy*, 89, 959-973.

Kuznets, S., 1971. Modern Economic Growth: Findings and Reections. Lecture to the Memory of Alfred Nobel, December 11, 1971. Nobel Lectures.

Lall, S., 1992. Technological Capabilities and Industrialisation. *World Development*, 20: 165-186.

Leipziger, D., Fay, M., Wodon, Q. and Yepes, T., 2003. Achieving the Millennium Development Goals: The Role of Infrastructure. World Bank Policy Research Working Paper 3163.

Matsuyama, K., 2005. Structural Change, chap. in: Blume L. and S. Durlauf (eds.). *The New Palgrave Dictionary of Economics*, 2nd edition, Palgrave Macmillan.

Page, J., 2011. Should Africa Industrialize? UNU-WIDER Working Paper No2011/47.

Parteka, A. and Tamberi, M., 2011. Determinants of Export Diversification: An Empirical Investigation. Quaderni di Ricerca no 359, Universita Politecnica delle Marche.

Redding, S. and Venables, A., 2003. Geography and Export Performance: External Market Access and Internal Supply Capacity. NBER Working Paper No. 9637.

Reinikka, R. and Svensson, J., 1999. Confronting Competition Investment Response and Constraints in Uganda. Development Research Group, World Bank, Washington DC

Roodman, D., 2006. How to do xtabond2: An introduction to "Difference" and "System" GMM in Stata. Center for Global Development, Working Paper 103.

Roodman, D., 2009. A Note on the Theme of Too Many Instruments. *Oxford Bulletin of Economics and Statistics,* 71, 135-158.

Sachs, J. D. and Warner, A. M., 1997. Natural Resources Abundance and Economic Growth. *Harvard Institute for International Development*, November, 11, 1-25.

UNCTAD, 1995. UNCTAD Handbook of Statistics. Geneva, Switzerland.

UNCTAD, 2013. UNCTAD Handbook of Statistics. Geneva, Switzerland.

Windmeijer, F., 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, 126, 25-51.

Wood, A. and Mayer, J., 2001. Africa's Export Structure in a Comparative Perspective. *Cambridge Journal of Economics*, 25, 369-394.

Yepes, T., 2007. New Estimates of Infrastructure Expenditure Requirements. World Bank, Washington D.C.

Table 1 - Real GDP Growth Rates of some fast growing African countries, 2004-13

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 (estimates)
Angola	10.2	20.9	19.0	23.2	13.8	2.4	3.4	3.9	7.9	8.2
Chad	34.3	7.9	2.7	8.4	3.4	4.1	14.0	1.6	7.2	7.4
D.R. Congo	6.6	7.8	5.6	6.3	6.2	2.8	7.2	6.9	7.2	8.2
Ethiopia*	13.6	11.8	10.8	11.5	10.8	8.7	12.7	11.2	6.9	6.6
Ghana	5.6	5.9	6.4	6.5	8.4	4.0	8.0	14.4	7.1	8.0
Liberia	4.1	5.9	9.1	13.0	6.2	5.4	6.1	8.2	8.9	7.7
Mozambique	7.9	8.4	8.7	7.3	6.8	6.3	6.8	7.3	7.4	8.5
Nigeria	10.5	6.5	6.0	6.4	6.0	7.0	8.0	7.4	6.6	6.7
Tanzania	7.8	7.4	6.7	7.1	7.4	6.0	7.0	6.4	6.4	6.9
Zambia	5.4	5.3	6.2	6.2	5.7	6.4	7.6	6.8	7.3	7.5

- **Note:** * Fiscal year July (n-1)/June (n)
- **Sources:** AfDB Statistics Department, Various domestic authorities and AfDB estimates.

Table 2: Impact of unreliable infrastructure services on the productive sector

Service bottleneck	SSA	Average developing countries
Electricity		
Delay in obtaining electricity connection (days)	79.9	27.5
Electricity outage (days per year)	90.5	28.7
Value of lost output due to electricity outage (% of turnover)	6.1	4.4
Firms maintaining own generator (% of total)	47.5	31.8
Telecommunication		
Delays n obtaining telephone connection	96.6	43.0
Telephone outage (days per year)	23.1	9.1

Source: Yepes (2007)

TABLE 3: Regression results of the diversification effects of infrastructure investments

Dependent variable: diversification (log of normalised Herfindahl index)

Regression:	1: SSA countries (literacy)			2: SSA countries (educ. attainment)			3: All African countries (literacy)			4: All African countries (educ. attainment)		
	Coeff.	Std err.	p-value	Coeff	Std err.	p-value	Coeff	Std err.	p-value	Coeff	Std err.	p-value
Intercept	14.773**	(6.157)	0.017	11.136**	(4.823)	0.021	11.847**	(4.938)	0.017	10.366*	(5.662)	0.068
Swaps	-0.088**	(0.037)	0.018	-0.094**	(0.042)	0.026	-0.053**	(0.023)	0.022	-0.057**	(0.022)	0.012
Human capital (lit.)	-1.723***	(0.653)	0.008				-1.580***	(0.516)	0.002			
Human capital (educ.att)				-0.448***	(0.121)	0.000				-0.469***	(0.177)	0.008
Infrastructure	-1.764***	(0.606)	0.003	-0.691**	(0.617)	0.017	-0.833***	(0.238)	0.000	-0.639***	(0.198)	0.001
Capital accumulation	-3.201**	(1.492)	0.032	-0.227*	(0.118)	0.055	-0.267	(1.771)	0.880	-0.118	(0.099)	0.234
Natural resources	0.082**	(0.037)	0.027	0.073**	(0.033)	0.027	0.166***	(0.036)	0.000	0.172***	(0.039)	0.000
Labour	1.221	(0.772)	0.114	0.472	(0.711)	0.507	0.181	(0.161)	0.262	0.146	(0.181)	0.420
Lagged GDP p.c.	-0.659***	(0.218)	0.002	-0.526***	(0.127)	0.000	-0.489***	(0.081)	0.000	-0.487***	(0.117)	0.000
Population	-0.207***	0.022	0.000	0.096	(0.061)	0.116	-0.180***	(0.019)	0.000	-0.192***	(0.018)	0.000
Trade openness	-0.035	(0.026)	0.179	-0.038	(0.028)	0.175	-0.023	(0.017)	0.177	0.039	(0.017)	0.149
Infrast X trade openness	-0.134*	(0.079)	0.091	-0.154**	(0.069)	0.026	-0.108***	(0.027)	0.000	-0.107***	(0.031)	0.000
Regression fit	Eq.1	Eq. 2		Eq.1	Eq. 2		Eq.1	Eq. 2		Eq.1	Eq. 2	
Prob. F-test	0.000	0.000										
Adj. R-squared	0.445	0.465		0.311	0.426		0.538	0.547		0.522	0.514	
D-W statistic	1.868	1.746		1.871	1.782		2.134	2.197		1.953	2.113	
J-Statistic	0.021	0.021		0.015	0.015		0.012	0.012		0.019	0.019	
N0. obs	427	453		427	453		689	704		689	704	
nJ	8.967			6.661			8.376			13.262		

The Angola mode countries in this sample are: Angola, Burundi, Chad, DR Congo, Ethiopia, Gabon, Ghana, Guinea, Equatorial Guinea, Ivory Coast, Libya, Madagascar, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Sao Tome& Principe, Sudan, Tanzania, Zambia, Zimbabwe

Instruments: equation1: regressors+21 instruments: lagged dependent variable (2 lags); lagged independent variables (up to 3 lags),

Equation 2: regressors+12 instruments: lagged dependent and independent variables (up to 2 lags)

HAC standard errors in parentheses;

* = significant at 10%, ** = significant at 5%, *** = significant at 1%

Appendix A1: Variable measurement and data

A1.1 Measurement of Variables

Diversification (DIV): Our dependent variable, diversification, is a multidimensional concept that is not directly measurable because it manifests itself under various aspects. It must reflect at the same time the spread of economic activities over various sectors and the degree to which each of these sectors contributes to the overall economy. However, there are measures that can be easily associated with the extent of diversification, or conversely, with the extent of export concentration or dependence on primary commodities. Diversification can be measured with a modified Finger-Kreinin measure of similarity in trade (see Finger and Kreinin [1979] for the definition and use of this measure). However, as a result of its use of absolute value, this index is more difficult to handle in empirical analysis if one does not know exactly which observations have higher or lower shares than the average.

Another way to measure the export diversification structure of a country is to use the Hirschman-Herfindahl concentration index of the exports, such as the normalised index used by the UNCTAD (UNCTAD, 1995). This index has been normalised to obtain values ranking from 0 to 1 (maximum concentration), according to the following formula:

$$H_j = \frac{\sqrt{\sum_{i=1}^{239}\left(\frac{x_i}{X}\right)^2} - \sqrt{1/239}}{1-\sqrt{1/239}}$$

where H_j = country j's concentration index; x_{ij} = value of exports of product *i* in country *j*

$X = \sum_{i=1}^{239} x_i$ and 239 = number of products at the three-digit level of Standard Industry and Trade Classification (SITC), Revision 2.

Despite its limitations, the Herfindahl index is one of the most widely used measures of export diversification in empirical research. In this article, we chose to use the normalized Herfindahl index as a diversification measure since our aim is to assess how infrastructure contributes to reducing the concentration of natural resources in the export structure. For the explanatory variables, the measurement of the various indicators is done as follows:

Infrastructure (INFR): For the measurement of infrastructure indicators, we start from the following three aspects of basic infrastructure as components of absorptive capacity that are also used by Fedderke and Bogetic (2006) for the case of South Africa:

· Density of telecommunication networks;

· Roads, railways, waterways, ports and airports for transportation facilities;

· Electricity and other sources of energy and utilities.

However, as a consequence of the multiplicity of these various aspects, the measurement of infrastructure becomes much more complex than the other elements of absorptive capacity. Such a measure must take into account diverse aspects related to the public provision of basic facilities that facilitate economic activities in a country because they fulfil different functions. These basic infrastructure aspects can be measured by the density of paved roads and railways to allow transportation, the production of electricity to supply the necessary energy to firms for their production activities, and the telecommunication facilities as measured, for instance, by the number of land and mobile telephone lines available per thousand inhabitants. In order to circumvent the complexity caused by the diversity of basic infrastructure, we have constructed a measure of basic infrastructure score on the basis of relative density of roads and railways per land area, telephone lines per thousand inhabitants and electricity production in KWH per capita. The infrastructure score has been constructed as follows: for each of the three categories above (transportation, telecommunication, and energy), density has been computed for each country or territory as the total length of roads and railways per land area, total telephone land lines and mobile per thousand inhabitants and total KWH of electricity produced per inhabitant. Then, for each country, a relative score on each category was determined as its relative density with respect to that of the country with the best performance in that category in the world. For example, on a world scale, Germany was found to have the highest density of railways and the relative scores on this category were calculated with respect to the German density. Finally, the country's basic infrastructure provision score was computed as an un-weighted average of the different relative scores in each of the categories.

Human capital (H): Human capital is a broad concept that does not easily lend itself to measurement, since it is embodied in humans. It comprises, in addition to skills developed through education and formal training, all inherited and acquired skills and abilities, experiences, behaviours and attitudes that contribute to increasing the efficiency of economic activities. Obviously, a measure of human capital that combines the aspects of quality and quantity of human capital stocks and flow measures would be more attractive. Measures such as those representing the per capita investment in human capital accumulation can play this role of incorporating quality, if one follows the logic that more resources invested in education per inhabitant increase not only the number, but also the quality of schools and the teaching they provide, and therefore improves the education quality as suggested by Hanushek (1995). However, owing to the lack of reliable data on educational expenditures and their relation to educational quality, such a measure is unfortunately not available for use in this study.

In many empirical studies, the measure of human capital has usually been a proxy related to educational attainment or literacy, because measures of the other aspects of human capital are more difficult to estimate reliably. In this study, we thus also use educational attainment measures proposed by Barro and Lee (2001) in the form of the average number of years of schooling in the population and a measure of literacy as proxies for human capital.

Capital Accumulation (I): Investment in capital accumulation is measured by the ratio of gross fixed capital formation to total GDP. Such a measure has also been used in other studies measuring the role of physical capital accumulation, like Grier (2003). However, in a cross sectional analysis involving countries with a wide range of GDP magnitudes, the ratio may be less informative than the per capita investment.

Natural resources (NATRES): Finally, the variable related natural resources endowment takes the value of the share of oil and mineral ores in export if the country is a crude oil or natural gas exporter or when the share of mineral ores in exports is more than 30% of its total export value. Lastly, *trade openness (OPEN)* is measured by the ratio of export value to total GDP.

A1.2 Data Sources

The data on export diversification, Herfindahl export concentration index and share of oil, gas and other natural resources in export were taken from UNCTAD Statistics and from COMTRADE. Data on per capita income are the PPP adjusted per capita GDP of the World Bank's World Development Indicators (WDI); education attainment measures are those developed by Barro and Lee (2001), and were corroborated by UNESCO Institute of Statistics data. Data on infrastructure and gross domestic fixed capital formation were also collected from the WDI, and corroborated by data in CIA's World Factbook in its various yearly editions. Data on Chinese financing of infrastructure projects were obtained from the World Bank PPIAF Chinese projects database. All data have been cross-checked from different sources to increase their reliability and where discrepancies were observed, they were relatively small and these differences hardly affected the outcome of the regressions.

Notes

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