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WHAT THE LAW OF COMPARATIVE ADVANTAGE MISSES IN AFRICA: A NEW MEASURE OF ECONOMIC COMPLEXITY

Abstract:

Africa is often referred to as if it were a country. This perspective flattens the understanding of a complex and highly varied set of 54 countries with widely different GDP growth rates and underlying economic complexities. More economically complex countries are able to sustain external commodity price shocks, a factor Ricardo did not consider in his famous law. A method is developed in this paper to better assess a country's economic complexity, modeled after the Herfindahl Index which is widely used in measures of market structure. Data from the MIT/Harvard Atlas of Economic Complexity is used to construct a new economic complexity index that can better track a country's move towards improved business environments. This paper argues that high GDP growth, particularly in African countries, may mask exports of a single crude commodity which is subject to volatile price changes, and hence rocky macroeconomic output.

Keywords:

Africa, Comparative Advantage, GDP growth, Economic Complexity

JEL Classification: D49, F18, F62

I. Introduction

With the exception of the anomalous 2008 financial crash, the past twenty years have seen ebbs and flows of economic growth that are fairly small in the Western world. Between the years 1995 to 2012, the annual GDP growth rates in OECD countries averaged 2.0% with a standard deviation of 1.5%, using data from the World Bank's World Development Indicators. While not fast growing and fairly stable, these countries also offer thousands of different goods and services, an indication of enormous economic complexity. In this group of nations, economic complexity is generally taken as a given, and the typical yardstick of economic performance is GDP growth or some variant.

In contrast, sub-Saharan Africa countries range from having very simple economies to quite complex ones. Their GDP growth is generally higher but more volatile. Between 1995 and 2012, 45 of 53 countries in sub-Saharan Africa averaged 5.0% GDP growth, with a standard deviation equal to 4.7%. In addition, the range between different standard deviations was extraordinary- from about 1% in Benin to more than 25% in Liberia. Regardless, GDP growth- as measured by the IMF, The World Bank or other groups- is the typical way to rank economic success.

The lack of focus on measuring economic complexity is underscored by Ricardo's powerful theory of comparative advantage, which remains a mainstay in economics textbooks. The theory posits an insightful idea that has stuck through the decades: all countries, regardless of their economic size or resources, can benefit from trade. Specialization in one product allows each country to produce a good for which it has the lowest opportunity costs. Engaging in trade then creates increased world production and income as a result.

Although the theoretical gains of Ricardo's theory are well accepted, the problem with product specialization in the modern age of global trade is twofold: first, it does not consider the volatility of commodity prices, since Ricardo assumed prices were constant. In today's world, there are no ways for poor countries to hedge against what can be very wild and unpredictable swings if they export a single product such as oil. The recent and rapid decline in oil prices in late 2014 is a good example, which has caused concerns about destabilizing oil-dependent countries from Russia to Nigeria.

The second problem with Ricardo's theory for the modern age is that it makes a case *against* markets developing into complex entities with highly varied products and services. The problem with ignoring economic complexity is that simply relying on high GDP growth rates is not necessarily indicative of a well-managed free market economy, in the same way that a high performing investment fund based on a few globally traded commodities is likely not a shrewd investment over the long haul. Outside observers and investors need a way to assess if the higher returns (as measured by GDP) are a result of internal improvements in governance and free markets or are a result of outside

forces such as higher commodity prices. In the latter, paying excessive attention to GDP growth rates will give a false sense of underlying structural changes being made, when in fact, these countries' economies could slip in the other direction quite quickly and easily.[1]

The paper proceeds in the following way. In section II, I summarize many of the important findings in the existing literature. In Section III, I give an overview of the dataset used in this paper to construct a measure of economic complexity. The data is based on international trade statistics, and was compiled by a joint Harvard/MIT research team into a report and an interactive software program called *The Atlas of Economic Complexity*.[2] Lastly, in Section IV, I show how the complexity index can be used to give greater insight into comparing two African economies that have similar GDP growth but far different trends in economic complexity. In addition, I present computed complexity data for all sub-Saharan countries for which data is available, for two years of comparison: 1995 versus 2010. The data is arranged alphabetically, by country, and also sorted by the complexity index, to allow for easy referencing.

Using this index, I conclude in Section V that the ten most complex African economies are becoming increasingly so over time, indicating an improving economic environment for starting new businesses. The ten least complex economies, on the other hand, have higher GDP growth on average but even lower complexity over time. This move towards a cruder economic output will place them at higher risk for external economic shocks, and potentially worse outcomes for ordinary citizens of that country. Without a measure of GDP complexity, we will arrive at a biased view based simply on rates of GDP growth. These rates of growth may have nothing to do with sound economic policies or a healthy business environment.

II. Literature review

Questioning the policy implications of Ricardo's theory of comparative advantage is not new, of course. Academic debate in the literature over the "natural resource curse" has occurred over the past several decades, with the central question being: does it help or hurt economic growth when a country is "resource-rich" and decides to specialize rather than diversify its economic output? One path of research suggests economic growth is hurt by specialization when there is resource abundance that leads to economies largely driven by a single good. Lower growth explanations include Dutch disease (Corden & Neary, 1982) and (Krugman, 1987) who show that a country selling high levels of one commodity leads to the appreciation of the exchange rate and thus more expensive

[1] Richardson (2013) discussed this problem with Zimbabwe's rapid GDP growth, which was shown to be largely driven by government deficit spending, foreign grants and loans and high commodity prices.
[2] This data is available at http://www.atlas.cid.harvard.edu/ as well as http://atlas.media.mit.edu/ . Both websites generate useful and interactive visualizations of international trade data. Both call the project "The Atlas of Economic Complexity" although the websites differ slightly.

imports, thus leading to lower profitability in domestic firms. Sachs & Warner (1995) showed that resource abundance led to smaller levels of GDP growth per capita, even when controlling for institutional quality. However, other evidence also seems to counter the conventional findings of the resource curse literature, and argues that resource abundance has a positive effect on development and growth, as reported by Arezki & van der Ploeg (2007) although this research doesn't address the question of economic complexity directly.

Another research angle focuses on how revenues from commodities lead to lower quality institutions, and that is the channel by which economic growth slows (Mehlum, et. al. (2006) and Beland and Tiagi (2009). (Norman, 2009) distinguishes between stocks and flows when defining the resource curse, and finds that natural resource stocks are associated with lower levels of rules of law but the flows (measured by export intensity of commodities) are the primary driver in determining lower economic growth rates. Boschini, et. al (2007) fine tune this even further, suggesting that the resource curse is dependent on the type of natural resource.

The easy-come, easy go aspect of high quantities of natural resources may inhibit GDP growth since the hard work of developing value-added in manufacturing technology is less necessary. Crude oil, raw diamonds and gold nuggets can be easily exported for hard currency, while letting another country refine, polish and smelt these commodities. This can lead to political corruption among government officials, as seen in Mauro (1995). As indicated earlier, it also may contribute to higher volatility, since an "all eggs in one basket" strategy will be more prone to world price fluctuations.

As noted earlier, product specialization could lead to higher volatility caused by fluctuating commodity prices. With respect to volatility and GDP growth, Ramey & Ramey (1995) contributed an important paper that concluded volatility had a negative impact on economic growth, which led to much further research on this topic, including work by Le Leong & Mohaddes (2011), Gylfason (2001) and Cavalcanti, et. al. (2011). They all conclude that it is not the "resource curse" per se that lowers economic growth, but rather that it can lead to channels that lead to neglect of education, overconfidence, or volatility which then exerts the negative impact on economic growth. In sum, the lower accumulation of human and physical capital leads to lower economic growth, and offsets the positive impact of commodity booms.

Blattman, et. al. (2007) found in a historical investigation that commodity price fluctuations in countries with just a handful of primary products led to a different channel – it lowered foreign investment and this is what lowered economic growth for some nations. Van der Ploeg & Poelhekke (2010) also find that volatility and GDP growth is negatively related but give a more nuanced view that indicates it depends on a country's level of financial development, they suggest blaming it on the resource curse alone is a "red herring." Pindyck (1994) suggests that volatility of the prices of raw commodities is

likely to have a depressing effect on construction and production capacity while at the same time increasing the value of land needed to produce the commodity, but noted the lack of empirical evidence to make the case. Crain (2003) investigated the link in the United States, and found evidence of a risk-return tradeoff on a state by state basis. In other words, those states with higher volatility of state GDP growth also had higher GDP growth, suggesting investors needed a higher return to compensate for higher risk.

In summary, the interactions of economic complexity, volatility and GDP are complex ones and not likely to be resolved anytime soon, with clear endogeneity problems plaguing many of these studies. It is fair to say, summing up the literature in this area, that specialization leads a country to a greater vulnerability of commodity price swings, less economic and political stability, as well as less investment at a given rate of return. Whether that leads to higher or lower GDP growth is still an open question, however, since investors may move resources to countries that represent strategic bets with potentially huge payoffs, if the returns from one commodity can offset the risk of huge losses. But this also means these countries are likely to be stressful places to live, since the country's economic well-being will rise and fall with world-wide prices outside its control.

All this research is highly important, yet what remains undefined is exactly *how* to measure when a *particular* economy is advancing or declining in economic complexity, that can be used in conjunction with other measures of economic success such as GDP growth. This paper takes a viewpoint that creating such a variable allows us to examine and compare the texture of macroeconomic output, rather than boiling it down to a single number or two that does not differentiate complex economies from simple ones. An economy growing in economic complexity is an indication of an improving economic environment across the board. As a counter-example, the economy of Zimbabwe grew quite strongly in 2011 and 2012, but two-thirds of its growth was due to a massive increase in government spending, even as the private sector shrunk and hundreds of businesses failed (Richardson 2013). GDP growth figures do not take this into account, but an economic complexity measure would.[3]

This paper seeks to fill in that gap by creating a complexity index, and calculating the index for the countries of sub-Saharan Africa, which exhibit wide variation. (However, the methodology could just as easily be applied to other countries.) Thus the complexity index is given a chance to show how it can be used to widen and expand the typical stereotype of African countries as either 1) fast-growing based on a few valuable exports, or 2) shrinking due to chronic mismanagement. The notion here is that if an economy is

[3] Richardson (2013) also suggests that the standard way of measuring GDP, which equals C + I + G + NX, could be revised to only include the private sector, i.e. C + I + NX. He demonstrates how, in Zimbabwe's case, this leads to starkly different conclusions about the nature of its recent and high GDP growth.

developing across multiple sectors, this implies an improved business environment across the board.

III. Measuring Economic Complexity

Economists are typically better at recording and measuring the rules and policies of economies than finding out if those rules specifically paid dividends. For example, The World Bank's *Doing Business Indicators* is an excellent tool for discovering, along dozens of dimensions, the ease of opening a business. It includes the ease of registering the firm, getting basic utilities, obtaining necessary legal documents in a timely manner, and in general having a government which serves rather than thwarts the entrepreneur. The Heritage Freedom Index and Fraser Freedom Index also have multiple measures of institutional rules such as changes in property rights, sound currency, and government fiscal restraint.

Yet how do we measure if an improvement in those rules actually worked? The "go-to" measure is GDP growth. This is an extraordinarily crude measure. GDP can change substantially through an increase in government spending or world commodity price swings, just to name a few examples that have nothing to do with business indicators.

Rather than measuring just GDP or overall output, we can think of these various indices such as the World Bank *Doing Business* indicators as inputs for economic entrepreneurship and growth. Improvements in the ease of starting a business should generate a more complex economy as the output (along with economic growth). Thus, a complexity index can present a more textured and detailed look at how improvements in institutions directly affect numerous industries and can be a better barometer for a healthy and flourishing private economy.

The online Atlas of Economic Complexity

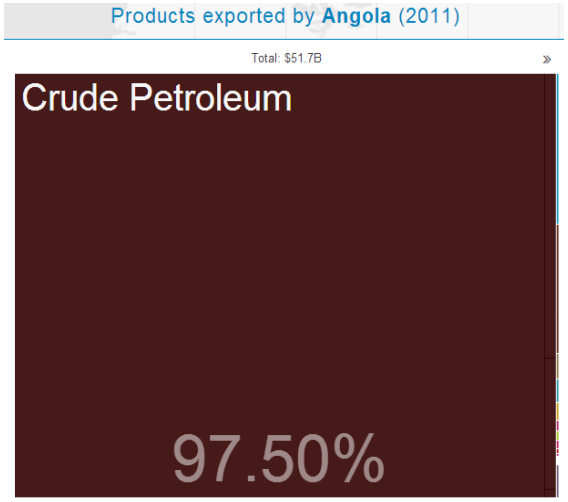
The Atlas of Economic Complexity (hereafter referred to as the Atlas) is a joint Harvard/MIT project that provides access to bilateral trade data for roughly 200 countries spanning 50 years and across 1000 different products, using the Standardized International Trade Code at the four-digit level (SITC-4) revision 2 classification. The Atlas also provides world trade data in the Harmonized System Classification (HS4) maintained by the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). The sources of the data come from Harvard University's Center for International Data and UN COMTRADE.[1]

Data begin in 1995 and end in 2012. For the purpose of this paper, yearly data on exports was used for nearly all the sub-Saharan African countries. Each product is reported in the Atlas as a four digit code. The share of the total exports is reported for each year, as well as in actual current dollar amounts. The Atlas website (see f.n. 1) creates highly visual and interactive representations of product linkage and diversity on a yearly basis, using

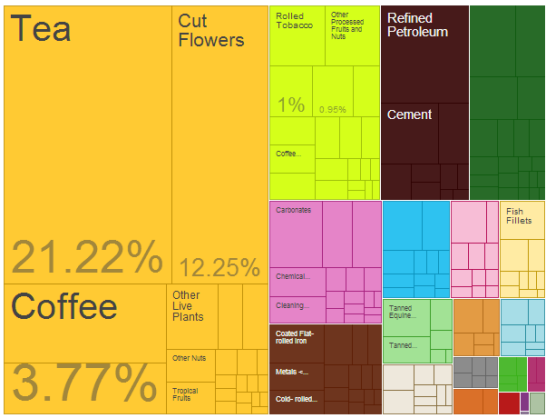
vivid colors and different rectangular areas that represent the economic share of each product. Products in related areas, such as tea and coffee, or gold and silver, have similar colors to make these relationships clearer. The work by the Harvard/MIT team is an excellent contribution to the understanding of economies, taking advantage of our brain's visual processing power to synthesize hundreds of statistics into readily understood graphics.

As an example of this, consider two African countries' exports: Angola and Kenya as seen in Figure 1. For Angola, oil makes up 97 percent of its exports, in contrast to the dozens of exports from Kenya. Figure 1 shows the vast differences in complexity of the respective economies, as measured by exports in 2011. This is where an index can play a role to complement the visual figures, especially in showing changes over time. First, I explain the idea behind the Harvard/MIT Economic Complexity index and then I give reasons and the methodology for computing a complexity index based on the Herfindahl index.

Figure 1.



Angola's exports, 2011



Kenya's exports, 2011

The Harvard/MIT Economic Complexity Index (ECI)

Hausmann et. al. (2011) used this data to calculate a type of ECI. Their aim is to calculate the degree of network effects *within* the economy and their inter-relation of different industries with each other. More networking equals more shared knowledge, which the authors argue is conducive to economic growth. This map, or network is used to illustrate a country's capabilities in making varied types of related and unrelated products, and use this increasing knowledge base to show how economies can thrive and grow.

Hausmann et. al (2011: 18) note it this way:

"Said differently, countries do not simply make the products and services they need. They make the ones they can. To do so, they need people and organizations that possess relevant knowledge. Some goods, like medical imaging devices or jet engines, embed large amounts of knowledge and are the results of very large networks of people and organizations. By contrast, wood logs or coffee, embed much less knowledge, and the networks required to support these operations do not need to be as large.

Hausmann et. al. (2011:23) also note the following caveats about representing an entire economy through the lens of exports: "Countries may be able to make things that they do not export. The fact that they do not export them, however, suggests that they may not be very good at them." They also point out that their measure of economic complexity, or ECI, accounts for 15.1 percent of the variance in economic growth during the 1996-2008 period. In contrast, the six Worldwide Governance Indicators (or WGIs, a measure of quality of institutions and rule of law by the World Bank) combined account only for 1.0 percent of the variance. Hausmann et. al (2011:33) concluded that, "as far as future economic growth is concerned, the Economic Complexity Index captures significantly more growth-relevant information than the six Worldwide Governance Indicators, either individually or combined." This does not mean that governance is not important for the economy- rather it suggests that the WGIs and appear to be more strongly reflected in

the economic activities that thrive in each country. As a result, patterns of economic growth may be more effectively captured by the Economic Complexity Index (p. 33).

One thing to note is that WGIs are really the preconditions for economic growth, but not the ultimate drivers, which may explain why they are a poor predictor of economic growth. On the other hand, economic complexity, as explained by Hausman et. al. is seen as an input into GDP growth, but it doesn't explain how that complexity arose in the first place. An alternative explanation would be to see economic complexity as an output, not an input, which occurs *as a result* of improved business conditions. Thus the idea that one measurement- the ECI- is a better predictor of economic growth than WGIs may not be a fair comparison since they are really at different ends of the economic production line.

However sophisticated a measure, the MIT/Harvard index is highly mathematical and as a result, 1 unit changes in the index are difficult, if not impossible, to interpret for those not well-schooled in higher order mathematics, as seen in Appendix 1. The advantage of the index developed in this paper is that it is far simpler and easier to interpret, based on the well-known Herfindahl index. The Herfindahl index is typically used to assess the concentration of industries in a particular sector in order to assess market power. It is well known by economists and not difficult to interpret one unit changes. What both indexes have in common is the shared use of country export data from *The Atlas of Economic Complexity.*

> Transforming the Atlas of Economic Complexity data: a new Export Complexity Index (EXCI).

Although the visual and interactive display of information is one of the key contributions of *The Atlas of Economic Complexity*, I downloaded the export share data for all sub-Saharan African countries, for the years 1995 and 2012, the earliest and latest years available. The data were compiled in Microsoft Excel. The rationale is that while the visualization of the exports is extremely useful, tracking changes in export complexity over time is visually difficult in countries with many products, since the visualization produces mosaic-like illustrations, of varying colors and hues. While these visuals (as seen in Figure 1) are excellent at quick comparisons between countries, it is far more difficult to compare one country's changes over time, especially when there are hundreds of products with small changes in export shares. There is thus a need to develop an index number that summarizes export complexity, so that this number can be tracked over time and compared far more easily than a mosaic of color-coded squares. This methodology is explained in the next section.

Note that *The Atlas* only tracks international trade and thus information on domestic diversification in manufacturing is not available. This paper assumes that there is a strong correlation between export complexity and overall economic complexity of the particular

country's economy, for the same reasons as mentioned earlier by Hausman, et. al (2011).

A common way to measure economic complexity in the field of industrial organization is the use of a Herfindahl index, seen in equation (1). The index is defined by taking the shares of the market held by each company in an industry:

Herfindahl Index = $s_1^2 + s_2^2 + s_3^2 + \ldots + s_n^2$ (1)

where s_n = market share of company n in an industry, for up to the 50 largest industries.

Summing the squared values of each market share and adding them means that as an industry becomes increasingly concentrated, the Herfindahl index gets smaller. In a monopoly, there would be only one market share, at 1.0, thus the Herfindahl index would also equal 1.0. On the other hand, an industry with 50 companies with an equal market share would generate a Herfindahl index equal to $(.02)^2 * 50$ firms = 0.02.

A similar methodology can be employed, using export shares of each product instead of company shares of the industry, to obtain a measure of export complexity. However, emulating the Herfindahl index would mean a smaller number would indicate more diversification in the economy. This could be confusing to remember. It makes more intuitive sense to follow Anand et. al. (2015), who show how to estimate a diversity score for financial portfolios, by using the same method as a Herfindahl index, but inverting the result. As the authors point out, this makes more intuitive sense, since larger values denote greater diversification, whereas smaller values denote less. I do the same when calculating the diversification of exports, and define the EXCI, or export complexity index, which is defined in equation (2) as:

EXCI = $1/ (s_1^2 + s_2^2 + s_3^2 + \ldots + s_n^2)$, where: (2)

s_i = export share of product i, for up to n =50 of the largest export shares in the economy.

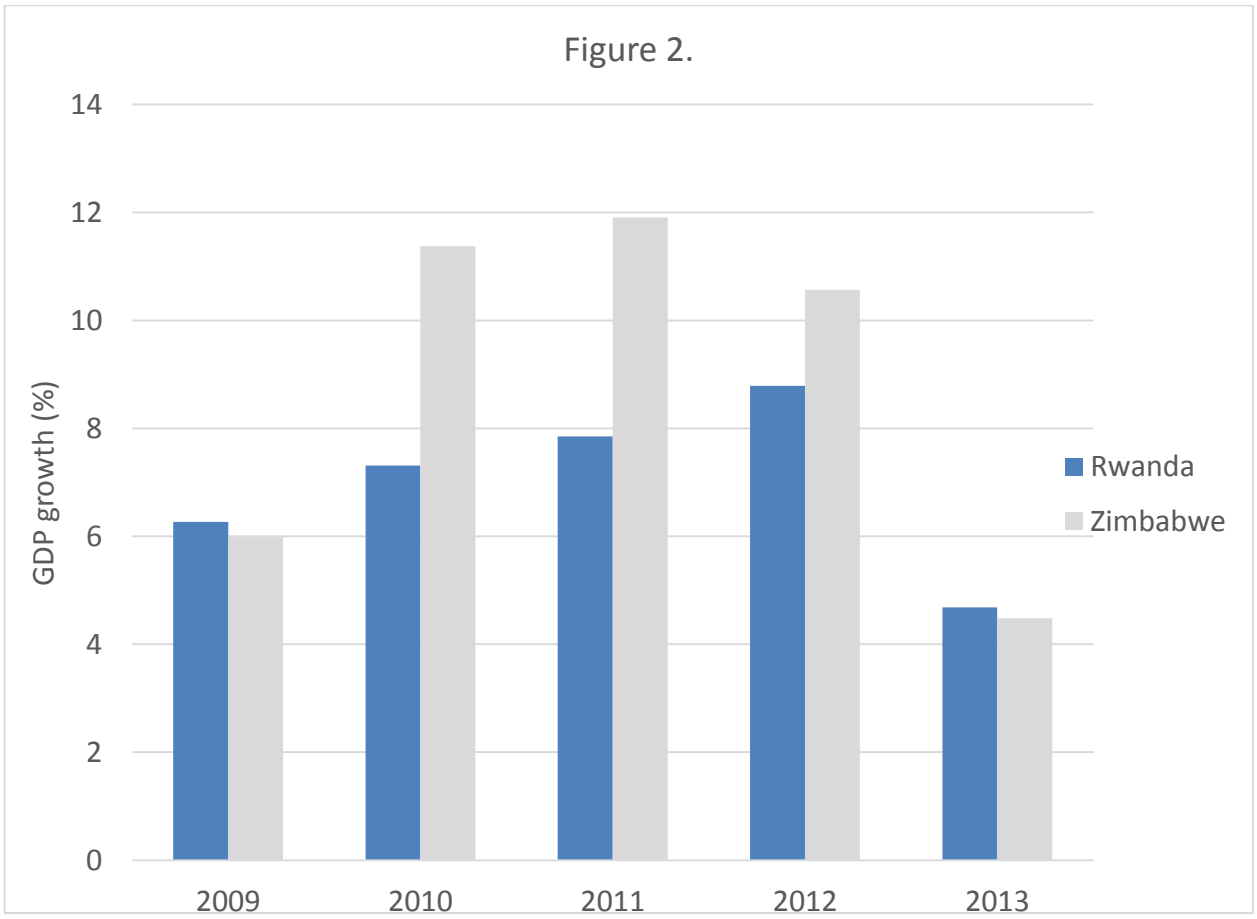
Consider how we can now interpret the EXCI with respect to movements from one value to another. If a country moved from only having one export to equally split in two products, the EXCI would change from 1.0 to $(1/(.5^2 + .5^2)) = 1/.5 = 2$. If the country moved from two export products to an equal split of four, having a 25% share of the total exports, then the EXCI would be 4. However, in reality export shares are rarely, if ever, exactly the same. Suppose we have one export that has an 80% share, and four other export products that have an equal share of 5%. This would lead to a EXCI = $1/ (0.8^2 + .05^2 + .05^2 + .05^2 + .05^2) = 1.56$. If the larger industry broke up into two equal sized different industries with a 40% share each, the CI would increase to $1/ (0.4^2 + 0.4^2 + .05^2 + .05^2 + .05^2 + .05^2) = 3.03$. Using the export data for each sub-Saharan country from the Atlas of Economic Complexity, the data were downloaded to Excel for the years 1995 and 2010. EXCI indices were then created for each country within a separate spreadsheet.

One problem with using a complexity index based on the Herfindahl index is that it assumes the sectors are uncorrelated, which may not be realistic if many industries are within the same grouping, e.g. agriculture for example. However, a more sophisticated measure that takes this into account is beyond the scope of this paper. Nonetheless, one may posit that even within agriculture, commodities such as coffee and wheat have little correlation to each other with regard to world commodity prices.

IV. Case study: Rwanda vs. Zimbabwe

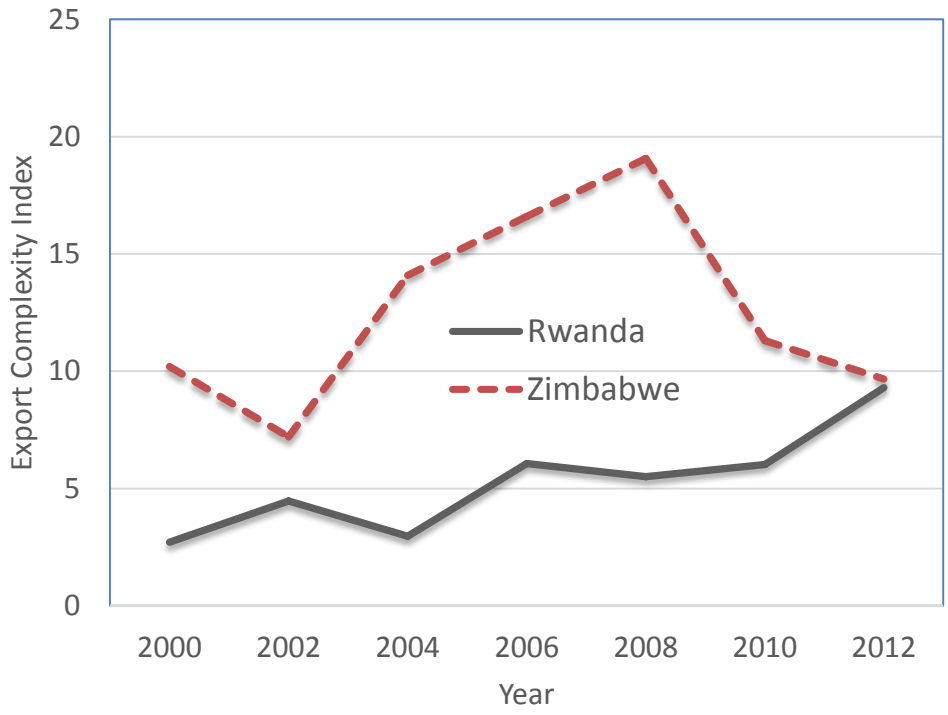
Both Rwanda and Zimbabwe provide an interesting glimpse into the diversity among sub-Saharan African countries, as both have had stunning rises and economic success as well extreme economic collapse during the 2000s. Since 2009, both have had strong economic growth, with Zimbabwe ending hyperinflation in that year and adopting the U.S. dollar and the South African rand, while Rwanda has rapidly improved the business environment, as measured by the World Bank's Doing Business Indicators. GDP growth for both countries went nearly as high as 12 percent for Zimbabwe in 2011, compared to nearly 8 percent for Rwanda.

Figure 2.



But what is interesting is the change in export complexity, which is a proxy for the entire domestic economy. Zimbabwe's economy has moved towards less complexity since 2008, as it has focused more on raw diamond and gold exports. Zimbabwe's complexity index has some improvements through the mid 2000s, but declined overall from 13.4 in 1995 to 9.7 in 2011. Meanwhile, Rwanda's favorable business environment has likely led to sharply increased economic complexity, from 1.7 in 1995 to 9.3 in 2012. Even though Zimbabwe had one of the fastest growing economies in the world in 2011, its stagnant economic complexity over the past 15 years suggests that its high GDP growth during the 2009-2013 period has not led to growth across many industrial sectors. Figure 3 shows the changes in economic complexity for the two countries since 2000.

Figure 3.



Differences in starting a business in Zimbabwe vs. Rwanda

Economic complexity is a function of the ease of opening a business in a given country. Take for example, the World Bank's *Doing Business* indicators, which monitor the ease of registering property, getting electricity, dealing with construction permits and so on. Rwanda has only 2 procedures needed to start a business in 2014, compared with 8 on average for sub-Saharan Africa, and 5 on average for OECD nations. Impressively, the

average amount of time for a Rwandan businessperson to start a business takes just 2 days, compared with 29.7 days for the average country in sub-Saharan Africa, and 11.1 days for OECD nations. This puts Rwanda in the worlds' top ten group that includes New Zealand, Canada, Australia and Hong Kong (but not the United States). Rwanda's rank across the board has moved from 54th in the world overall (out of 189 economies) in 2013 to 32nd in 2014, a net change of 22 places upward in just one year. For registering property it showed the most significant improvements, moving from 64th in the world in 2013 to 8th in the entire world in 2014, a remarkable improvement by any standard. Going back to 2004, the earliest date available, Rwanda had 9 procedures to start a business, and it took 18 days to complete, on average. That sharply changed in 2010, when it dropped to 2 procedures and 3 days.

Now compare Rwanda's business environment to Zimbabwe, which was ranked 168th (out of 189 economies) in the world in 2013 for doing business, and fell another two places to 170th in the world in 2014. Compared to Rwanda, which had 2 procedures for starting a business, Zimbabwe requires 9 procedures in 2014, and following all of them takes an average of 90 days instead of 2 days for Rwanda. Zimbabwe's 9 procedures have been in place since 2004, which is when the World Bank began collecting information on this. The number of days to start a business was even higher at that time in 2004, at 97 days. For these two countries at least, complexity has been steadily increasing for Rwanda and stagnating or decreasing for Zimbabwe in recent years, which is not surprising given the differences in their ease of starting a business.

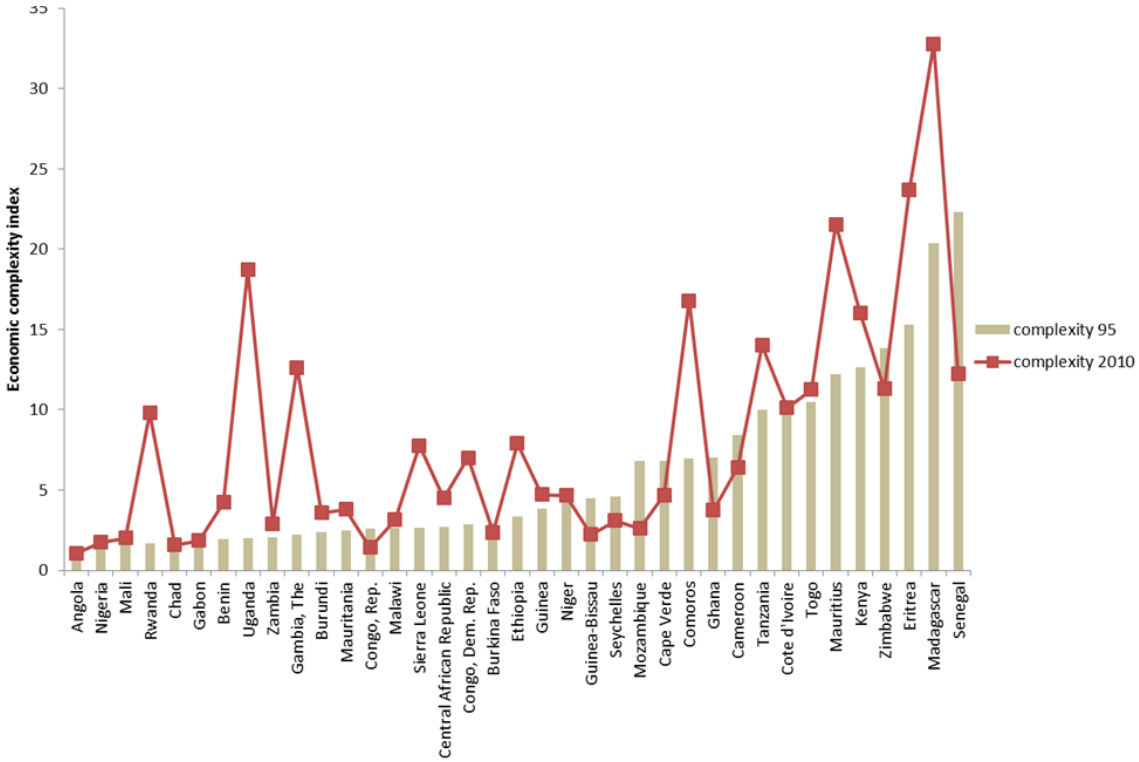
Relationships between complexity and GDP growth

Taking a broader view, Table 1 takes the dataset of 38 sub-Saharan African economies and sorts them by the EXCI, into two categories: the ten least complex and the ten most complex as of 2010. As one can see, the growth rate for the least complex economies exceeded the most complex economies, at GDP growth at 5.4 percent vs. 3.5 percent between 1995-2010. What is also notable is the least complex economies have a higher volatility than the most complex (4.7% vs. 3.1%) as measured by the standard deviation of GDP growth over this time frame, using a 5 year rolling average. Also notable is that the ten least complex economies are growing even less complex over time. The average EXCI for this group moved from 2.7 to 2.0, a net change of -0.7. Meanwhile the most complex economies are getting more complex, by a significant amount- the average EXCI for the group increased from 11.8 to 18.0, a net increase of 6.2.

Figure 4 presents data on 38 sub-Saharan African countries for which data was available, as a means to compare how the various countries are faring from 1995 to 2010 in terms of changes in economic complexity. Figure 4 shows that there are strong trends towards increasing economic complexity for many of the 38 listed nations, and only a few, such as Ghana, Zimbabwe and Senegal showing dramatic declines in economic complexity. These trends are perhaps even more important than recent strong GDP growth across

the sub-continent, as this is an indication of improving business environments in a continent typically characterized by corruption, mismanagement and chaotic political and business environments.

Figure 4.



Note: Botswana, Lesotho, Namibia, South Africa, Sudan and Swaziland had no data available.

So what this implies is that good governance that allows a multiplicity of businesses to thrive and grow may result in a number of different “bets” in different areas of the countries’ respective economies, that mean GDP growth is slower but more stable. In addition, good business begets good business, so the rise in economic complexity continues.

For the least complex economies, the bets on raw commodities have been good bets, at least for now, in terms of GDP growth. But the high volatility and likelihood of experiencing a sudden crash in industry and government revenue mean a more challenging environment both to work and live. A complete listing of nearly all sub-Saharan countries’ GDP growth, standard deviation of GDP growth and the calculated complexity index are available in Appendix B and Appendix C. Appendix C sorts the countries from largest changes in complexity to the smallest, while Appendix B sorts the countries alphabetically.

V. Conclusion

Measuring GDP growth has traditionally been one of the primary ways to assess the underlying health of an economy, as well a measure of standard of living. This paper noted that previous research has shown that specialization in single product, combined with large quantities of domestic natural resources, can lead to high volatility and unstable business environments, particularly in the case of developing countries. This paper constructed a new type of complexity index based on the well-known Herfindahl index, which is used for industry concentration measures, and adapted it to study changes in economic complexity for nations. This complexity index can be seen as a useful first step towards better assessing the nature of GDP growth and the changes in the business environment that lead to wide scale flourishing of free markets. In this way, the perils of the natural resource curse can be better monitored. Countries deemed as successful can be tracked not only with GDP growth, but also with this economic complexity variable, to show the underlying changes in the country's diversification of economic outputs.

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Table 1. Sub-Saharan Africa- Complexity and GDP growth				
Ten least complex economies				
GDP (1995-2012)		Complexity Index		
growth rate (%)	Average st. deviation	1995	2010	Net change
5.4	4.7	2.7	2.0	-0.7
Ten most complex economies				
GDP (1995-2012)		Complexity Index		
Average growth rate	Average st. deviation	1995	2010	Net change
3.5	3.1	11.8	18.0	6.2

Endnotes.

[1] From the website: “Research into Economic Complexity was led by Ricardo Hausmann, Professor of the Practice of Economic Development at the Harvard Kennedy School and CID Director, and Cesar A. Hidalgo, Asahi Broadcast Corporation Career Development Professor at MIT. CID published this research in *The Atlas of Economic Complexity: Mapping Paths to Prosperity*, a comprehensive study of national growth trajectories and analyses. The Atlas online was originally built as part of lead developer Alexander Simoes’ masters thesis at the MIT Media Lab, with Cesar A. Hidalgo as his thesis advisor.”According to the website, “The Atlas online is the result of the contribution and hard work of many individuals. Additional help in the development of the platform was provided by Ali Almossawi, Crystal Noel, David Landry, Sarah Chung and Eric Franco. Original versions of the datasets were provided by Muhammed Yildirim, Sebastian Bustos, Michele Coscia and Juan Jimenez. Robert Feenstra provided the 1962-2000 data. The Atlas online is currently being managed at the Center for International Development, at Harvard University.” "The Atlas of Economic Complexity," Center for International Development at Harvard University, http://www.atlas.cid.harvard.edu

Appendix A.

TECHNICAL BOX 2.1: MEASURING ECONOMIC COMPLEXITY:

If we define M_{cp} as a matrix that is 1 if country c produces product p, and 0 otherwise, we can measure diversity and ubiquity simply by summing over the rows or columns of that matrix. Formally, we define:

$$Diversity = k_{c,0} = \sum_{p} M_{cp} \quad (1)$$

$$Ubiquity = k_{p,0} = \sum_{c} M_{cp} \quad (2)$$

To generate a more accurate measure of the number of capabilities available in a country, or required by a product, we need to correct the information that diversity and ubiquity carry by using each one to correct the other. For countries, this requires us to calculate the average ubiquity of the products that it exports, the average diversity of the countries that make those products and so forth. For products, this requires us to calculate the average diversity of the countries that make them and the average ubiquity of the other products that these countries make. This can be expressed by the recursion:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} \cdot k_{p,N-1} \quad (3)$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} \cdot k_{c,N-1} \quad (4)$$

We then insert (4) into (3) to obtain

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} \frac{1}{k_{p,0}} \sum_{c'} M_{c'p} \cdot k_{c',N-2} \quad (5)$$

$$k_{c,N} = \sum_{c'} k_{c',N-2} \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \quad (6)$$

and rewrite this as:

$$k_{c,N} = \sum_{c'} \widetilde{M}_{cc'} \cdot k_{c',N-2} \quad (7)$$

where

$$\widetilde{M}_{cc'} = \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \quad (8)$$

We note (7) is satisfied when $k_{c,N} = k_{c,N-2} = 1$. This is the eigenvector of $\widetilde{M}_{cc'}$ which is associated with the largest eigenvalue. Since this eigenvector is a vector of ones, it is not informative. We look, instead, for the eigenvector associated with the second largest eigenvalue. This is the eigenvector that captures the largest amount of variance in the system and is our measure of economic complexity. Hence, we define the Economic Complexity Index (ECI) as:

$$ECI = \frac{\vec{K} - \langle \vec{K} \rangle}{\text{stdev}(\vec{K})} \quad (9)$$

where < > represents an average, stdev stands for the standard deviation and

$$\vec{K} = Eigenvector\ of\ \widetilde{M}_{cc'}\ associated\ with\ second\ largest\ eigenvalue. \quad (10)$$

Analogously, we define a Product Complexity Index (PCI). Because of the symmetry of the problem, this can be done simply by exchanging the index of countries (c) with that for products (p) in the definitions above. Hence, we define PCI as:

$$PCI = \frac{\vec{Q} - \langle \vec{Q} \rangle}{\text{stdev}(\vec{Q})} \quad (11)$$

where

$$\vec{Q} = Eigenvector\ of\ \widetilde{M}_{pp'}\ associated\ with\ second\ largest\ eigenvalue. \quad (12)$$

Appendix B. Sub-Saharan African Countries, Average and Standard Deviation of GDP growth and Export Complexity, sorted by Export Complexity Index (2010) and selected years.

Country Name	Average GDP growth (%), 1995-2012	St. deviation of GDP growth, 1995-2012	Export complexity index, 1995	Export complexity index, 2010	Export complexity net change 95-10
Angola	9.37	6.15	1.25	1.06	-0.19
Congo, Rep.	3.92	3.13	2.60	1.41	-1.19
Chad	7.45	8.32	1.79	1.57	-0.22
Nigeria	6.73	7.06	1.37	1.75	0.38
Gabon	2.22	3.86	1.86	1.86	0.00
Mali	5.21	2.77	1.64	2.01	0.37

Guinea-Bissau	1.27	8.49	4.48	2.24	-2.24
Burkina Faso	6.31	2.32	2.91	2.38	-0.53
Mozambique	7.39	2.50	6.80	2.62	-4.18
Zambia	4.54	2.84	2.07	2.92	0.85
Seychelles	3.50	5.16	4.57	3.09	-1.48
Malawi	3.99	5.46	2.63	3.16	0.53
Burundi	1.50	4.08	2.40	3.57	1.17
Ghana	5.95	2.63	7.00	3.75	-3.25
Mauritania	4.79	4.94	2.49	3.81	1.32
Benin	4.35	1.12	1.97	4.24	2.27
Central African Republic	3.96	4.03	2.73	4.49	1.76
Niger	4.25	3.71	4.43	4.67	0.24
Cape Verde	8.12	4.34	6.83	4.70	-2.13
Guinea	3.24	1.44	3.85	4.72	0.87
Cameroon	3.84	0.89	8.43	6.43	-2.00
Congo, Dem. Rep.	2.49	4.78	2.86	7.00	4.14
Sierra Leone	4.59	7.81	2.65	7.78	5.13
Ethiopia	7.23	4.73	3.35	7.90	4.55
Rwanda	10.18	6.68	1.70	9.80	8.10
Cote d'Ivoire	2.16	3.71	10.14	10.11	-0.03
Togo	3.48	3.97	10.48	11.26	0.78
Zimbabwe	-1.00	7.99	13.86	11.30	-2.56
Senegal	4.04	1.69	22.32	12.23	-10.09
Gambia, The	3.56	3.44	2.21	12.62	10.41
Tanzania	6.00	1.40	10.01	14.01	4.00
Kenya	3.66	1.96	12.66	16.04	3.38
Comoros	2.04	1.49	6.98	16.78	9.80
Uganda	7.02	2.23	2.01	18.71	16.70
Mauritius	4.34	1.81	12.21	21.55	9.34
Eritrea	2.46	4.75	15.29	23.70	8.41
South Africa	3.26	1.69	39.23	29.20	-10.03
Madagascar	2.98	4.76	20.40	32.80	12.40
Botswana	4.61	4.03	n/a	n/a	n/a
Lesotho	3.72	1.82	n/a	n/a	n/a
Namibia	4.35	2.64	n/a	n/a	n/a
Sudan	4.79	4.90	n/a	n/a	n/a
Swaziland	2.26	1.38	n/a	n/a	n/a

Appendix C. Sub-Saharan African Countries, Average and Standard Deviation of GDP growth and Export Complexity, in alphabetic order by selected years

Country Name	Average GDP growth (%), 1995-2012	St. deviation of GDP growth, 1995-2012	Export complexity index, 1995	Export complexity index, 2010	Export complexity net change 95-10
Angola	9.37	6.15	1.25	1.06	-0.19
Benin	4.35	1.12	1.97	4.24	2.27
Botswana	4.61	4.03	n/a	n/a	n/a
Burkina Faso	6.31	2.32	2.91	2.38	-0.53
Burundi	1.50	4.08	2.40	3.57	1.17
Cameroon	3.84	0.89	8.43	6.43	-2.00
Cape Verde	8.12	4.34	6.83	4.70	-2.13
Central African Republic	3.96	4.03	2.73	4.49	1.76
Chad	7.45	8.32	1.79	1.57	-0.22
Comoros	2.04	1.49	6.98	16.78	9.80
Congo, Dem. Rep.	2.49	4.78	2.86	7.00	4.14
Congo, Rep.	3.92	3.13	2.60	1.41	-1.19
Cote d'Ivoire	2.16	3.71	10.14	10.11	-0.03
Eritrea	2.46	4.75	15.29	23.70	8.41

Ethiopia	7.23	4.73	3.35	7.90	4.55
Gabon	2.22	3.86	1.86	1.86	0.00
Gambia, The	3.56	3.44	2.21	12.62	10.41
Ghana	5.95	2.63	7.00	3.75	-3.25
Guinea	3.24	1.44	3.85	4.72	0.87
Guinea-Bissau	1.27	8.49	4.48	2.24	-2.24
Kenya	3.66	1.96	12.66	16.04	3.38
Lesotho	3.72	1.82	n/a	n/a	n/a
Madagascar	2.98	4.76	20.40	32.80	12.40
Malawi	3.99	5.46	2.63	3.16	0.53
Mali	5.21	2.77	1.64	2.01	0.37
Mauritania	4.79	4.94	2.49	3.81	1.32
Mauritius	4.34	1.81	12.21	21.55	9.34
Mozambique	7.39	2.50	6.80	2.62	-4.18
Namibia	4.35	2.64	n/a	n/a	n/a
Niger	4.25	3.71	4.43	4.67	0.24
Nigeria	6.73	7.06	1.37	1.75	0.38
Rwanda	10.18	6.68	1.70	9.80	8.10
Senegal	4.04	1.69	22.32	12.23	-10.09
Seychelles	3.50	5.16	4.57	3.09	-1.48
Sierra Leone	4.59	7.81	2.65	7.78	5.13
South Africa	3.26	1.69	39.23	29.20	-10.03
Sudan	4.79	4.90	n/a	n/a	n/a
Swaziland	2.26	1.38	n/a	n/a	n/a
Tanzania	6.00	1.40	10.01	14.01	4.00
Togo	3.48	3.97	10.48	11.26	0.78
Uganda	7.02	2.23	2.01	18.71	16.70
Zambia	4.54	2.84	2.07	2.92	0.85
Zimbabwe	-1.00	7.99	13.86	11.30	-2.56