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THE THEORY OF "ECONOMIC COMPLEXITY AND PRODUCT SPACE": WHAT IT MEANS FOR ECONOMIC DEVELOPMENT IN GENERAL, AND FOR BULGARIA IN SPECIFIC

Geert M.J. Termeer[1]

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Abstract

Ricardo Hausmann (Harvard University) and Cesar Hidalgo (MIT) developed the "Economic Complexity and Product Space" theory, which is based on their findings that the cumulative amount of knowledge in a country is central to the overall economic development of that country. They found that highly developed countries produce and export many different products and services, and in addition produce products and services of a high complexity. Their theory is made concrete and visualized in the "Atlas of Economic Complexity", also referred to as the "Observatory of Economic Complexity", which offers useful tools like: the Economic Complexity Index (ECI), which expresses the quantity of complexity of a country; the Product Complexity Index (PCI), which expresses the complexity of a product; the Product Space, which visualizes how many different products a country exports, and in what complexity; the Complexity Outlook Index, which expresses the value of the option to move into more and more complex products, given how far they are from a country's current position in the Product Space. The Atlas hence translates the theory in concrete tools, useful for countries, regions and companies, which want to speed up their economic development. In this article we present the theory; highlight the useful tools; mention some improvements the scholars still want to develop; and provide some recommendations based on the theory of Economic Complexity and Product Space in general, as well as for Bulgaria.

Keywords: *Economic Complexity (Index), Product Complexity (Index), Complexity Outlook (Index), Product Space, (tacit) knowledge, knowhow, capabilities, diversification, connectedness*

JEL Codes: *O20, O12, F61*

INTRODUCTION

Ricardo Hausmann, and Cesar Hidalgo developed the "**Economic Complexity and Product Space**" theory, which is based on their findings that

[1] MBA at IESE University, Barcelona; cum laude drs. (MA) at the University of Amsterdam in Slavic languages and literature; PhD student at South-West University, Blagoevgrad; career in organic consumer goods and trade, geerttermeer1@gmail.com

the cumulative amount of knowledge in a country, expressed in its production, and especially in its exports, is central to the overall economic development of that country. They found that highly developed countries produce and are able to export many different products and services, and do so in different product clusters. But highly developed countries also produce and export products of a high complexity. For the production of the many different and complex products and services, big amounts of specialized knowledge and increasingly complex webs of organizations, institutions and markets are needed. The development path of a country is hence determined by its capacity to accumulate the capabilities that are required to produce varied and, in particular, more sophisticated goods. Therefore, the overall complexity of a country's productive structure is the key variable in order to explain growth and development: countries' different abilities to accumulate capabilities explain differences in their performance. In this theory of capabilities, economic development is not only a process of continuously improving upon the production of the same set of goods, but also more importantly, a process that requires acquiring more complex sets of capabilities to move towards new activities associated with higher levels of productivity.

THE THEORY OF "ECONOMIC COMPLEXITY AND PRODUCT SPACE"

Ricardo Hausmann of the Center of International Development (CID), Harvard University; Cesar Hidalgo of the Massachusetts Institute of Technology (MIT); and key assistants (hereafter "Hausmann et al.") developed as from 2006 the theory of "Economic Complexity and Product Space", and publish the online "Atlas of Economic Complexity", also referred to as the "Observatory of Economic Complexity" (atlas.cid.harvard.edu; atlas.media.mit.edu (oec.world/en)) (hereafter "Atlas") (The official references for the Atlases, 2011). The theory is based on their findings that the cumulative amount of knowledge in a country is central to the overall economic development of that country. The theory develops the following logic:

1) Hausmann, Hwang and Rodrik (2006) conclude that two facts related to the structure of exports drive the policy literature on export diversification: 1) As income per person rises, the range of export activities becomes more diverse; 2) Countries that export more sophisticated products (primarily manufactured by countries at higher income levels) tend to grow faster (Hausmann, Hwang, Rodrik, 2006, pp. 1-25). Sutton (2012) notes that a reason may be that more

diverse economies are better able to take advantage of opportunities in global markets (Sutton, 2012, pp.1-128). UNIDO (2009) also finds that differences in diversification and sophistication are strongly related to differences in long-run growth in developing countries (United Nations Industrial Development Organization, UNIDO, 2009, pp.1-143).

2) Hausmann et al. show that (highly) **developed countries produce many different products and services**, and do so in different product clusters. They use the term "**diversity**" as being a measure of how many different types of products a country is able to make and export. The production of a product requires a specific set of knowhow, and its export expresses global competitiveness; therefore, a country's total diversity is another way of expressing the amount of collective knowhow held within that country in order to produce the diverse products it produces and exports. For the production of the diverse products, many different sorts of knowledge are needed.

3) **Highly developed countries** also **produce and export products of a high complexity**. For the production of complex products big amounts of specialized knowledge, and increasingly complex webs of organizations, institutions and markets are needed. **Complex economies** are those that can weave these vast quantities of relevant knowledge together, across large networks of people, to generate a diverse mix of knowledge-intensive products.

4) The cumulative amount (width and depth) of knowledge in a country (or e.g. region, cluster, city, company) is crucial for the overall **development** of a country (region, cluster, city, company). The "complexity literature" in effect implies that development is slow for countries with less developed (tacit) knowledge specialization, which hence have productive structures geared towards low-productivity and low-wage activities, producing mostly low valued commodities or agricultural products. But development is fast for countries with developed knowledge specialization, which hence can produce many, and complex products and form productive structures geared towards high-productivity and high-wage activities.

5) Individuals can only hold a limited amount of knowledge ("**personbyte**"). For an economy to develop through product diversity and complexity, it is hence crucial that many different individuals acquire a diversity of know-how (knowledge specialization), which then can be used and combined by companies to produce complex products (or e.g. for governments to create and manage complex institutions). The secret to **modernity** is that we collectively use large volumes of knowledge, while each one of us holds only a few bits of it. Societies function and develop because its members acquire that

knowledge (knowhow) and form webs that allow them to specialize and share their knowledge with others.

6) The crucial knowledge is **tacit knowledge**, which is acquired by a person by time-intensive processes of imitation and repetition, and hence only exists within brains. It is crucially needed knowledge within production, as it forms the base of the knowhow needed to produce a product or service. It requires costly and time-consuming efforts to be obtained, and is hard to transfer and hence normally constraints the process of growth and development. Ultimately differences in prosperity are related to the amount (depth and width) of tacit knowledge that societies hold, and to their ability to combine and share this knowledge. As obtaining tacit knowledge is a long and costly process, people (companies, clusters, regions, cities, or even countries) specialize. "Internally coherent" pieces of tacit knowledge, which can be put in productive practice, are referred to as "**capabilities**". Some of these capabilities have been modularized at the level of individuals, while others have been grouped into organizations and even into networks of organizations ("clusters").

7) The main way for a society to **maintain** (and expand) its **tacit knowledge** base and capabilities is in the productive setting: **by producing products**. When not used, tacit knowledge tends to disappear.

8) **Specialization** allows societies to store more knowledge (personbytes), but even more crucial is how to put the different chunks of specialized knowledge to use, and that is translated in the diversity and complexity of products and services produced. **Economic Complexity** is thus a measure of how elaborated and complex this network of interactions is, and of how much productive knowledge a society is able to mobilize, and is therefore expressed in the composition of a country's productive output, which reflects the structure that emerged to hold and combine knowledge.

9) Porter (1990) argues that productivity is the main factor for **international competitiveness**, and that the standard of living of a country's population can be improved as a direct result of increases in productivity. (Porter, 1990, pp.1-857), Sölvell (Sölvell, 2008, pp.1-137), and Porter (2011, 2012), state that innovativeness is stimulated by competitiveness. Companies play a crucial, but not exclusive, role in thriving innovativeness and are especially triggered to innovate, when they have to compete in international markets. Fujita, Krugman and Venables (1999), and Ketels, Lindqvist and Sölvell (2013) find that companies and clusters with international trading opportunities and global competitive exposure are the most dynamic and form the crucial key drivers for innovation, and the creation of more secure and higher paid jobs (Fujita,

Krugman, Venables, 1999; Ketels, Lindqvist, Sölvell, 2013, pp. 1-55). Although there are more jobs in the local economy, the traded economy is the real fundamental economic driver. It provides the longer term dynamic and growth opportunities. Obviously the world's export and import market, with a size of USD 16,3 trillion in 2017 (atlas.media.mit.edu), provides countries, regions and companies with a far bigger market than a local market can, even more so if a country has a small local market (Yuleva, 2019, pp. 25-35). Export markets give countries therefore enormous opportunities in scale, turnover and jobs. Hausmann, Rodriguez and Wagner (2006) also find that economical crises will last shorter (than can be expected as the result of business-cycle dynamics), and the recovery from a crisis is faster when export flexibility is higher (Hausmann, Rodriguez, Wagner, 2006, pp. 1-40). Because of these reasons, Hausmann et al. **measure complexity by looking at the mix of products that countries are able to produce and sell in the competitive global market**.

10) The production of complex products, and hence the economic development of a country, can thus be measured by analyzing the product mix a country can successfully export to the world market, reflecting its competitiveness in the specific fields. For countries this quantity of complexity is expressed in the **Economic Complexity Index** (ECI), and the complexity for products is expressed in the **Product Complexity Index** (PCI).

11) Hausmann et al. also state to be **able to predict how an economy will develop**, by expressing in a regression line the GDP per capita versus the overall complexity. Doing so per country concludes that complexity and income per capita are very closely related ("on average the income of a country tends to reflect their embedded knowledge"), but also that some countries have a lower (or higher) income than explained by their complexity. This means that these countries have a relative easy (or difficult) path to growth and economic development. If on the other hand a country is richer than the regression line of complexity explains, it might stagnate, or grow slower over time, until it nears its value on the regression line.

12) Hausmann, Hwang, and Rodrik (2006) show that **not all products have the same consequences for economic development**: there are products whose capabilities can be easily redeployed into the production and export of other products (which facilitates development), while there are other products that embody capabilities that can hardly be used for the production of other goods. Based on these findings Hausmann et al. developed the **Product Space**, which is a representation of all products exported and imported in the world, where products are linked based on the similarity of their required capabilities.

When products similar in capability requirements are defined in clusters ("communities"), a world, country, region or even city Product Space can be elaborated and depicted, which explains how many different products are produced, and in what complexity.

13) Hausmann et al. evaluate a country's overall position in the Product Space by calculating how far its products are from alternative products, and how complex these products are. This measure is called **the Complexity Outlook Index**, and it can be thought of as the value of the option to move into more and to more complex products, given how far they are from a country's current position in the Product Space. Hidalgo, Klinger, Barabasi and Hausmann (2008) show that the Product Space indicates in how far a country can easily grow ("jump") from one cluster community to another, where a product belongs to a product **community** if it is closer to the other members of the community than it is to products outside of the community, so: a product community consists of products, which are highly connected and use the same capabilities (Hidalgo, Klinger, Barabasi, Hausmann, 2008, pp.1-13).

The Product Space visualization shows that communities tend to have similar levels of complexity, but e.g. products in the Machinery, Electronics, or Health Related Chemicals communities tend to be much more complex than those in the peripheral communities such as Oil, or Tropical Agriculture. Hamidova (2012) e.g. finds that the simultaneous implementation of a policy of diversification of industry, and reducing the country's dependence on raw materials like oil, is a difficult task, also as e.g. the oil sector is very weakly linked to other export sectors in terms of technology and the skills used (Hamidova, 2018, pp. 2-13). Economic development in this theory is the growth path created by producing more complex products, and forming more complex communities "on the way" ("upgrading"; "climbing the ladder"). Countries are more likely to move into products that can make use of capabilities that the country already has, and will move into products that are similar in terms of the capabilities they already have available, which is influenced by the average proximity of a community's products to all other products, where **proximity** is the measure of distance between two products used to construct the Products Space. Poorly connected communities such as Oil, Cotton, Rice and Soybeans tend to be low in complexity. Machinery, by contrast, is very complex and that part of the Product Space is highly connected. Communities of products such as Garments, Textiles and Food Processing are, on the other hand, in an intermediate position, being connected to many, but not very sophisticated products. Electronics and Health Related Chemicals are very complex, but not as connected as Machinery. This

suggests they use specific capabilities relevant within their communities, but not outside of them. The probability that a country will **produce a new product** ("jump") is strongly related to how close that product is to other products the country already makes. So the location of a country in the Product Space captures information regarding both the productive knowledge that it possesses and the capacity to expand that knowledge by moving into other nearby products.

14) The ability of countries to diversify and to move into more complex products is crucially dependent on their **initial location** in the Product Space.

15) One implication of the Product Space is that the **lack of connectedness** between the products in the periphery (low-productivity products), and in the core (high-productivity products) **explains the difficulty of poor countries to converge** to the income level of the rich countries.

16) **What limits the speed of the complexity process**? There is a chicken and egg problem: On the one hand countries cannot create and produce products that require capabilities they do not have. On the other hand, there are little incentives to accumulate capabilities in places where the industries that demand them do not exist. Moreover, since capabilities are chunks of tacit knowledge, accumulating them in countries with few industries is difficult even when there is demand for them, because the country does not have many examples to copy. A country's historical and actual position in the Product Space determines hence its opportunities to expand its productive knowledge and increase its level of economic complexity.

17) **The Atlas data base**: The Atlas contains trade data for 250 countries and territories, classified into 20 categories of goods and 5 categories of services (tourism, transport, ICT, finance and insurance, and others), resulting in a coverage of over 6000 products worldwide. The raw trade data on goods are derived from countries' reporting to the United Nations Statistical Division (COMTRADE), and cleaned for CIF and FOB difference. The trade data on services are from the International Monetary Fund (IMF) Direction of Trade Statistics database, via the World Development Indicators.

FUTURE IMPROVEMENTS OF THE ATLAS

Harvard and MIT are both **publishing** and **updating** their complexity and Product Space information regularly (online), and plan to **improve their data bases further** e.g. by: - Adding numbers on a regional, and when possible also city level, in order to conclude how regions and cities developed, and can develop further in know how and (complex) product producing capabilities; - Adding

existing “skills and capabilities”, so that it can be concluded which skills are missing and what additions would contribute to diversity, ubiquity and complexity; - Including the Growth Diagnostic logic of Hausmann, Rodrik and Velasco (2005), in order to identify the binding constraints for growth of countries (regions, cities), in order for them to conclude on what to focus, where to invest, and be able to act more effectively; (Hausmann, Rodrik, Velasco, 2005, pp.1-31) - Including data on transfer of knowhow between countries (regions, cities), assisting them to understand what they can do in order to accelerate knowledge accumulation; - Elaborating a Product Gini Index (PGI) and improving a version of the Product Space, where products are colored according to their PGI, being the level of income inequality that is expected for the countries that export that product (see: atlas.media.mit.edu). Hartmann, Guevara, Jara-Figueroa, Aristaran and Hidalgo (2017) show that countries exporting complex products, as measured by the ECI, have lower levels of income inequality than countries exporting simpler products, and that a country’s productive structure thus may limit (or increase) its range of income inequality (Hartmann, Guevara, Jara-Figueroa, Aristaran, Hidalgo, 2017, pp. 75-93). Economic complexity is a significant (negative) predictor of income inequality, and that relationship is robust to controlling for aggregate measures of income, institutions, export concentration, and human capital.

SOME RECOMMENDATIONS FOR COUNTRIES, REGIONS AND COMPANIES, BASED ON THE THEORY OF ECONOMIC COMPLEXITY AND PRODUCT SPACE:

a) **Increase knowledge and knowhow** (capabilities): In this theory of capabilities, economic development is not only a process of continuously improving upon the production of the same set of goods, but even more importantly, a process that requires acquiring more complex sets of capabilities to move towards new and more complex activities associated with higher levels of productivity. Cheston (2017) finds that what faster growing countries share is a focus on expanding the capabilities of their workforce that leaves them well positioned to diversify into new products, and products of increasingly greater complexity (Cheston, Timothy, 2017);

b) **Increase the procurement, dissemination and optimal use of tacit knowledge**: As we saw Hausmann et al. believe that the slow transfer of tacit knowledge and know-how explains the slow, incomplete diffusion of technology and production around the world. Procurement, dissemination and making

optimal use of accumulated tacit knowledge, therefore stands at the heart of the economic growth process, and policies that aim to speed this up are important for the pace of economic growth, and development (e.g. by FDI, brain gain, educational programs, vocational education, exchange programs);

c) **Increase and smoothen (commercial and production) interactions and connectedness**: Most products require more knowledge than can be mastered by any individual. Those products require that individuals with different capabilities interact. Stimulating and improving this interaction is a crucial element in economic development (e.g. cluster policies, international exchanges, international student programs, infrastructural improvements);

d) **Explore different development paths**: The Product Space is highly heterogeneous, and therefore confronts countries with radically different opportunities to develop their productive knowledge, and their capabilities as embedded in society. Based on the theory there are **countries with different opportunities**: 1) Countries with too few productive capabilities to easily diversify into related products (e.g. Bangladesh, Ecuador, and Guinea). Countries with low levels of complexity tend to have few opportunities available. This is because the products they make tend to have few interesting connections; 2) Advanced countries that already produce nearly all existing products, so that "easy remaining opportunities" are basically lacking, and progress will require pushing "the world's technological frontier" by inventing new products; a process that implies slower growth and higher innovation investments and efforts (e.g. Japan, Germany, and the United States);(Stanishev, 2018, pp. 111-119) 3) Countries with an intermediate level of complexity. This group differs greatly in their Complexity Outlook: a) Countries like Saudi Arabia, Jamaica and Chile are located in sparse parts of the Product Space, which implies that they have few easy diversification opportunities; b) Others like India, Turkey, Brazil, and Indonesia are located in parts of the product space, where opportunities are plentiful; c) Still other countries have acquired capabilities, but still have many and bigger jumps to make (e.g. Bulgaria). It shows that countries, often with similar incomes, face dramatically different opportunities and choices.

In their Atlas, Hausmann et al. visualize **how countries can move through the Product Space** and explore different development paths, by highlighting the products that each of these countries was exporting and importing with comparative advantages, at different points in time; by noting their actual situation; by showing interconnectedness in the Product Space; and show feasibility of (future) production diversification opportunities. As tools they offer: **A) Product Tree Maps**, displaying the breakdown of exports, or

imports by country, or by product in a given year (for product classes HS4 or SITC4, and with gross and net (exports minus imports) numbers); **B) Geo Maps**, displaying the shares of country trade with other countries, or by product, in a given year; **C) Stacked Charts**, displaying the breakdown of exports or imports, by country or product over time; **D) Product Spaces**, depicting the connectedness between products, based on the similarities of knowhow required to produce them; **E) Feasibility Charts**, displaying a country's opportunities for diversification based on what it currently exports (its current capabilities); **F) Rings Charts**, displaying selected product's nearby or related exports, or those products that are often co-exported by the same country. Products are co-exported based on their technological similarity, by relying on similar productive knowhow to produce them; **G) International Growth** Projections and rankings for the coming decade; **H) Country Complexity Rankings** (ECIs); **I) Product Complexity Rankings** (PCIs). In addition the MIT atlas provides: **J) PGI Spaces**, or Complexity and Income inequality Spaces, visualizing products according to their Product Gini Index (PGI), reflecting the level of income inequality that can be expected for the countries that export a product, and; **K) Overall Country Data** (e.g. GDP, and GDP per capita; top exports and imports products and destination rankings; and bordering);

e) **Define and implement a development path of diversification and complexity, based on the theory and data**: Diversification into more and more sophisticated products provides several advantages, like e.g. increasing employment, with higher salaries and bigger job security; entrance to the global economy, with higher export potential; positive spinoff effects; all supporting an overall upgrade of society. In addition the ability of companies in (lower-income) countries to export such goods indicates that they have mastered both the technology and the management practices required to be globally competitive in price and quality on that product, or in that sector. These are "high capability" companies, and economies with large numbers of high capability companies have a stronger base for productivity increase;

f) **Role for government and the public sector**: In general scholars see a stimulating and coordinating task for the public sector, but also indicate that there will always be a major role for "self-discovery" by the private sector in lifting an economy to a higher level of (export) diversification, sophistication and level of complexity.

SOME CONCLUSIONS AND RECOMMENDATIONS FOR BULGARIA, BASED ON THE ECONOMIC COMPLEXITY AND PRODUCT SPACE THEORY

1) **Bulgaria has not been very successful in improving its Economic Complexity Index (ECI) in between 1995-2017.** Its ECI went up from 0,368 in 1995, which also was its lowest point during the 22 years analyzed (e.g. in 1996 the ECI was 0,568), to 0,623 in 2017, with its highest point in 2011 (0,655). This is an improvement of 0,255, but from a low level (e.g. compared to 1996 the improvement is only 0,055). In the ECI ranking Bulgaria went up from country number 45 (1995) to 40 (2017). The **ECI of Slovakia** for instance went up from 1,32 in 1995 to 1,41 in 2017, an improvement of 0,09, but on an already relative high level. In the ECI ranking Slovakia went up from country number 16 (1995) to 15 (2017). The **ECI of Poland** went up from 0,758 in 1995 to 1,19 in 2017, or an improvement of 0,432. In the ECI ranking Poland went up from country number 27 (1995) to 21 (2017). And the **ECI of Romania** went up from 0,58 in 1995 to 1,16 in 2017, or doubling, with an improvement of 0,58. In the ECI ranking Romania went up from country number 32 (1995) to 24 (2017). Overall we can observe an improvement in complexity for all these Eastern European countries, but the progress of Bulgaria is lagging behind countries like Poland and Romania, and in absolute terms Bulgaria lags in 2017 quite significantly behind the 3 other Eastern European countries. As a reference: Japan is number one in ECI (2017), with 2,28; and Guinea is last (country number 133), with an ECI of -2,13.

2) **This lack of improvement in ECI results in a low growth projection for Bulgaria for the years 2017-2027** based on the single measure of Economic Complexity, **with a projected average yearly growth of 1,96%.** International growth projections were given during the press release by researchers of Harvard's Growth Lab at Harvard's Center for International Development (CID) in Cambridge, Massachusetts, on June 3rd 2019. The Bulgarian growth is the second lowest in Europe, with only Italy projected to grow at a slower rate during this decade (1,88%). To compare: Romania is projected to grow on average with a yearly 3,92%, Slovakia with 3,34%, and Poland with 3,14%.

3) **Bulgaria can follow the (6) practical recommendations mentioned above**, **making use of the Economic Complexity and Product Space theory and the Atlas data and tools, to develop a "faster path ahead" for the country, its regions, cities, and companies**.

CONCLUSION

The Economic Complexity and Product Space theory is based on findings that the cumulative amount of knowledge and capabilities in a country is central to the overall economic development of that country, and that highly developed countries produce and export many different products and services, and in addition produce and export products and services of a high complexity. These developed countries produce and export many and complex products, because of their possession and application of big amounts of specialized knowledge, and their ability to organize increasingly complex webs of organizations, institutions and markets. The level of accumulated knowledge (and especially tacit knowledge), and organizational power explains the complexity of a country's productive structure, which is the key variable in order to explain growth and development. Countries' different abilities to accumulate capabilities explain differences in their development performance, which is above all a process that requires acquiring more complex sets of capabilities to move towards more diverse, and new (more complex) activities associated with higher levels of productivity.

The traded economy is found to be the real fundamental economic driver of an economy. It had a size of USD 16.3 trillion in 2017. The production and export of complex products, and hence the economic development of a country, can thus be measured by analyzing the product mix a country can successfully export to the world market, reflecting its competitiveness in the specific fields.

The theory is made concrete and visualized in the "Atlas of Economic Complexity", which offers useful tools like: the Economic Complexity Index (ECI), expressing the quantity of complexity of a country; the Product Complexity Index (PCI), expressing the complexity of a product; the Product Space, visualizing how many different products a country exports, and in what complexity; the Complexity Outlook Index, expressing the value of the option to move into more and to more complex products, given how far they are from a country's current position in the Product Space. The Atlas hence translates the theory in concrete tools, useful for countries, regions, cities and companies, which want to speed up their economic development. The plan is that in future the Atlas will be extended with: regional data; existing and missing skills and capabilities; Growth Diagnostics binding constraints analyses; and a Product Gini Index (PGI), reflecting the level of income inequality that is expected for the countries that export certain products.

Bulgaria was not very successful in improving its Economic Complexity Index (ECI) in between 1995-2017, also when compared to other Eastern

European countries. This results, based on the theory, in a low projected average yearly growth of 1.96% for Bulgaria for the years 2017-2027, which is the second lowest growth in Europe, after Italy.

Bulgaria, and other countries (regions, cities and companies) can benefit from the tools, as well as the recommendations as drawn from the theory, being to: a) Increase knowledge and knowhow (capabilities); b) Increase the procurement, dissemination and optimal use of tacit knowledge; c) Increase and smoothen (commercial and production) interactions and connectedness; d) Explore different development paths, using the Atlas data (and hence the Product Space and Feasibility and Rings Charts); e) Define and implement a development path of diversification and complexity, based on the theory and data, in order to increase overall Economic Complexity and speed up economic development, with a government and public sector taking a stimulating and coordinating role.

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