EXECUTIVE BOARD MEETING

SM/21/10

January 28, 2021

To: Members of the Executive Board

From: The Secretary

Subject: **Paraguay—Selected Issues**

Board Action:	Provides background to SM/21/9—Staff Report for the 2020 Article IV Consultation
Tentative Board Date:	**Friday, February 12, 2021**
Publication:	Yes*
Questions:	Mr. Bakker, WHD (ext. 34649) Mr. Roy, WHD (ext. 35338)
Document Transmittal in the Absence of an Objection and in accordance with Board policy:	After Board Consideration—European Investment Bank, Food and Agriculture Organization, Inter-American Development Bank, United Nations Development Programme, World Trade Organization

***Unless an objection from the authorities is received prior to the conclusion of the Board's consideration, the document will be published.**

INTERNATIONAL MONETARY FUND

PARAGUAY

SELECTED ISSUES

January 27, 2021

Approved By
Western Hemisphere Department

Prepared by Natasha Che

CONTENTS

TABLES

MACROECONOMIC IMPACT OF THE ITAIPÚ TREATY RENEGOTIATION[1]

The Treaty of Itaipú, which governs the operation and revenue distribution of the Itaipú Dam, is up for renewal in 2023. The implications for Paraguay's export revenues and fiscal position are potentially significant. The paper reviews the current energy distribution and sales arrangements of Itaipú.

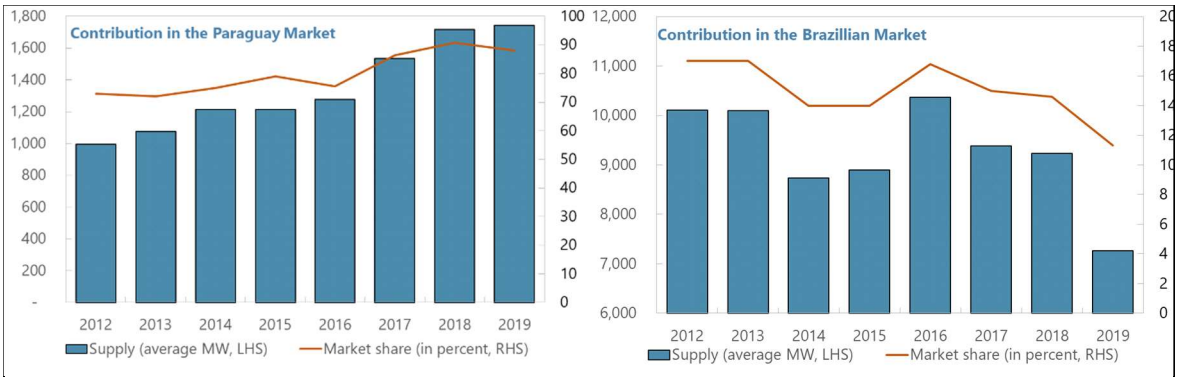
A. The Treaty of Itaipú

1. The Treaty of Itaipú was signed in April 1973 for a joint investment project of hydroelectricity between Paraguay and Brazil. Discussions first began between Paraguay and Brazil in the 1960s on a possible collaboration to explore the hydro resources of the commonly shared sections of the Paraná River between the two countries, resulting in the signing of the Act of Iguaçu. After that, on April 26, 1973, the countries signed the Treaty of Itaipú, which established the joint venture Binational Itaipú, with an initial capital of USD 100 million to carry out development projects including a dam construction. The entity was constituted by ELETROBRÁS (Centrais Elétricas Brasileiras S.A. of Brazil) and ANDE (Administración Nacional de Electricidad of Paraguay). And the Treaty gave equal rights and obligations to both parties within the entity.

2. The construction of the Itaipú Dam started in 1975. The initial power production by the first generator unit started in May 1984. But the construction of additional units continued for more than twenty years. Currently there are twenty power generating units in the dam, with the last unit completed in 2007. Each unit has a nominal capacity of 700 megawatts (MW), which brings the total installed capacity to 14 gigawatts (GW), one of the largest in the world.

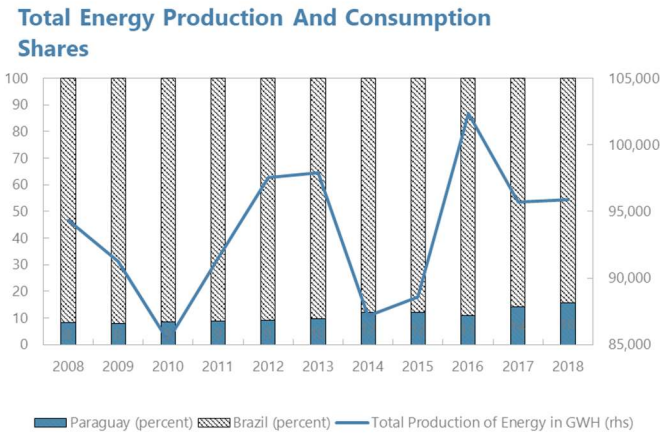
3. The Itaipú Dam supplies 17 percent and 90 percent of annual electricity needs of Brazil and Paraguay, respectively. Since 2007 to the present, average annual energy production of the dam has been around 94 million MWh. In 2016, the total energy production surpassed 103 million MWh, the world record of electricity produced by a single production plant.

[1] By Natasha Che.



Sources: Itaipú and IMF staff calculations.

4. The Treaty stipulates that each country is entitled to half of the energy produced by the dam. However, if one country does not consume all energy it is entitled to, the surplus can be sold only to the other country, at near-cost prices which are much lower than prevailing market prices. Lower demand for electricity in Paraguay relative to its share of energy produced by the dam, along with the weaknesses in transmission infrastructure, resulted in a large portion of its share being sold to Brazil. Although Paraguay's electricity consumption has been increasing over the past decade as the economy grows, still, in 2018 it only consumed with Brazil taking up the rest.



Sources: Itaipú and IMF staff calculations.

5. Itaipú's revenues from electricity sales to Paraguay and Brazil are used for three main purposes: 1) to service the debt incurred for building the dam, 2) to pay for operations and maintenance, and 3) to make payments to the two countries. Annex C of the Treaty stipulates the two main types of payments to Brazil and Paraguay, royalty payments and compensation payments.[2]

Royalty Payments

6. The royalty payments are paid to the two countries for the water used in electricity production, at a base price of USD 650 per GWh.[3] The payments are then updated

[2] There is a third type of payment, the administration payment, what mainly covers the cost of operating and managing the dam. This part is relatively small and not a material source of fiscal revenues from Itaipú. Thus the discussion of the paper will focus only on royalty payments and compensation payments.

[3] Lorenzon et al. (2017) provides a more detailed discussion on the royalty payments and revenue distributions of Binational Itaipú.

with the monthly growth rates of industrial production index (IP) and consumer price index (CPI) of the United States. In other words,

$$R_t = \$650 * E_t * K_t$$

where R_t is the royalty payment, E_t is the energy produced, measured in GWh at time t, and K_t is an adjustment factor determined by:

$$K_t = 1 + 0.5(\Delta IP)_t * 0.5(\Delta CPI)_t$$

where ΔIP and ΔCPI are growth rates of the industrial production index and consumer price index of the United States.

7. In accordance with the Treaty, the royalties have been paid monthly to both countries since May 1985. The amount of royalties paid vary with the total energy production in each month. According to Binational Itaipú, since the first installment of royalties in 1985, the royalty payments received by the two countries have amounted to over USD 11 billion in total (around 0.9 percent and 0.02 percent of the annual average GDP for Paraguay and Brazil respectively over this period).[4]

Compensation Payments

8. The compensation payments are for the sale of energy that is not domestically consumed. In practice, these are the payments for the energy that Paraguay sells to Brazil The compensation payment (C_t) is calculated as:

$$C_t = \$300 * ES_t * M_t * K_t$$

where ES_t is the total energy sold under the Treaty, M_t is an ad-hoc adjustment factor mutually decided by the two countries. Initially, M_t was set to 3.5. But it has been gradually increased over time. And on September 1, 2009, the Brazilian and Paraguayan authorities signed an agreement to triple the adjustment factor starting from 2011. Table 1 provides the historical evolution of the adjustment factors.[5]

[4] See https://www.itaipu.gov.br/en/social-responsibility/royalties.

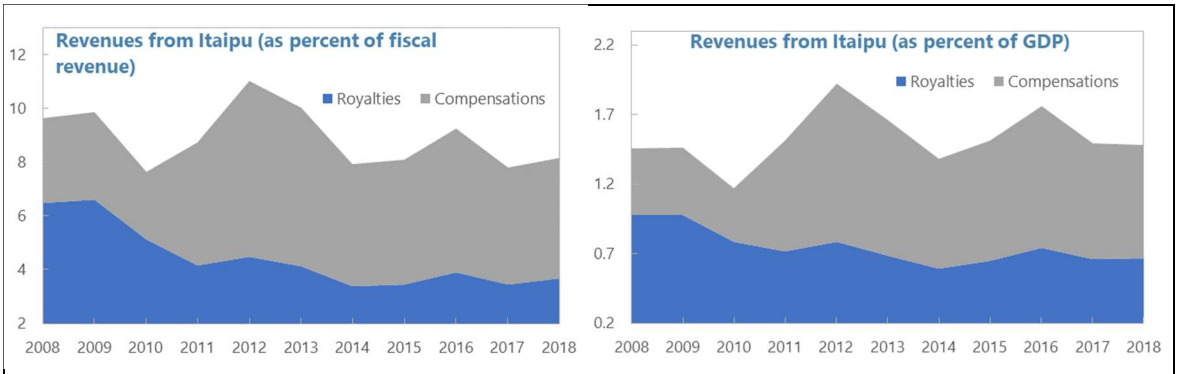
[5] Collected from Itaipú (2018).

Table 1. Paraguay: Historical Evolution of the Adjustment Factor

Year	(M_t)	(K_t)	$(M_t * K_t)$	Year	(M_t)	(K_t)	$(M_t * K_t)$
1985	3.50	NA	NA	**2002**	4.00	1.48	5.92
1986	3.58	NA	NA	**2003**	4.00	1.53	6.12
1987	3.66	1.03	3.77	**2004**	4.00	1.60	6.40
1988	3.74	1.07	4.00	**2005**	4.00	1.69	6.76
1989	3.82	1.12	4.28	**2006**	5.10	1.76	8.98
1990	3.90	1.17	4.56	**2007**	5.10	1.82	9.28
1991	4.00	1.20	4.80	**2008**	5.10	1.94	9.89
1992	4.00	1.23	4.92	**2009**	5.10	1.85	9.44
1993	4.00	1.25	5.00	**2010**	5.10	1.93	9.84
1994	4.00	1.28	5.12	**2011**	15.30	2.04	31.21
1995	4.00	1.32	5.28	**2012**	15.30	2.06	31.52
1996	4.00	1.35	5.40	**2013**	15.30	2.08	31.82
1997	4.00	1.37	5.48	**2014**	15.30	2.10	32.13
1998	4.00	1.37	5.48	**2015**	15.30	2.03	31.06
1999	4.00	1.39	5.56	**2016**	15.30	2.02	30.91
2000	4.00	1.46	5.84	**2017**	15.30	2.09	31.98
2001	4.00	1.49	5.96	**2018**	15.30	2.16	33.05

9. Over the past decade, fiscal revenues from Itaipu have averaged about 1.5 percent of GDP. The share of Itaipú royalties as percent of total fiscal revenues has been declining over the years, to 3.6 percent in 2018. The downward trend is mostly due to increases in the denominator, as the royalty payment amount has been stable over time, at an average of USD 245 million per year. On the other hand, the compensation payments had a sharp increase in 2011 due to the update in the adjustment factor discussed above. After the adjustment factor tripled, the compensation payments increased from USD 105 million in 2010 to USD 378 million two years after. Between 2012 and 2018, the average compensation payments received by Paraguay is around USD 345 million US per year (close to 1 percent of GDP).

10. The revenues from Itaipú averaged 9 percent of Paraguay's total fiscal revenue over the past decade. The share has declined over the years due to the country's strong economic performance that has increased the sizes of GDP and total fiscal revenues. But the importance of Itaipú revenue is expected to increase with the upcoming renegotiation of the Treaty.



Sources: Itaipú and IMF staff calculation

B. Macro Impact of the Itaipú Treaty Renegotiation

11. Annex C of the current Treaty will expire in 2023, the year when the debt incurred by Binational Itaipú for the dam construction will be paid off. According to Itaipú (2015), the debt service and amortization cost is over 60 percent of the total service cost of Itaipú. Thus, the completion of debt services would mean that the dam would be able to operate at a much lower cost after 2023. This can have significant implications for the revenues Paraguay receives from the dam.

12. Many Paraguayans have high hopes that the treaty renewal will deliver higher fiscal revenues for Paraguay. The sentiment is strengthened by the fact that it is a common perception in Paraguay that the country had gotten an unfair deal from the 1973 Treaty[6] that should be corrected with the new negotiation.[7]

13. Several components of the Treaty can be up for negotiation in the upcoming treaty renewal. These include, but are not limited to

a. the amount of royalty payments Binational Itaipú pays to Paraguay and Brazil;

[6] Several researchers have suggested that Paraguay has been significantly under-compensated for its Itaipú electricity exports. Toledano & Maennling (2013) argues that the "fair price" that Paraguay should have received for its energy exports should be based on the alternative cost to Brazil of electricity from non-Itaipú sources, which can be approximated by the wholesale electricity price in Sao Paulo. Under this assumption, the total revenue (royalty plus compensation payments) Paraguay should have received, in 2012, would be around USD 37,230 per GWh, which is much higher than the actual payment received, which, even in 2018, was only around USD 21,110 per GWh. Carter (2018)6 used five different sources to estimate the market value of the electricity sold to Brazil, and showed that from 1985 to 2016, the total market value of the energy sold by Paraguay to Brazil amounts to USD 37 billion at wholesale price (89 percent of 2018 GDP), and USD 54.5 billion at industrial-consumption price (130 percent of 2018 GDP). In contrast, the total compensation payment received by Paraguay during this period was only USD 4.3 billion (10 percent of 2018 GDP).

[7] The social expectation surrounding Itaipú-related negotiations was demonstrated by a public outrage in 2019, after the leak of an agreement concerning the power purchase agreement between the Paraguay and Brazil for the next three years until 2022. The agreement caused large public backlash as it was seen to be a sellout of Paraguayan interest.

b. the price of electricity at which Binational Itaipú sells to ELETROBRÁS and ANDE;

c. the amount of compensation payments received by Paraguay for selling its excess energy to Brazil;

d. whether Paraguay should be allowed to sell its excess Itaipú electricity to other countries in the region, such as Chile and Argentina, and whether it should be allowed to sell energy directly to the private sector of Brazil.

Components a) and b) are essentially about the different ways to distribute the windfall gains from Itaipú's cost reduction after 2023. Components c) and d) are about whether Paraguay should be able to earn more money from the electricity it is entitled to.

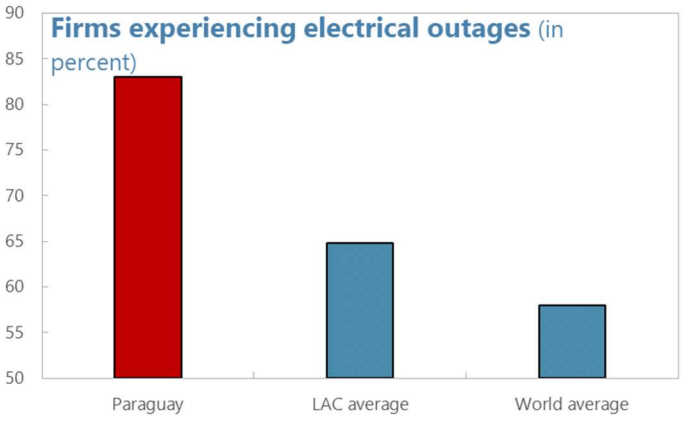
Higher Royalty Payments

14. Lower costs of Itaipú after 2023 could be translated into higher royalty payments for both countries. According to Itaipú (2015), the average annual debt amortization cost from 2016 to 2023 is around USD 1.4 billion. Assuming no other changes in the cost structure, that would lead to reduced cost / increased profit of the dam by a similar amount every year after 2023. If this gain were to be distributed solely as royalty payments, it would mean an additional USD 700 million in annual payments from Itaipú to Paraguay and Brazil, i.e. almost quadruple the current amount of royalty payments. This would translate into over 6 percent increase in Paraguay's projected fiscal revenue for 2024 (1.6 percent of projected 2024 GDP).

Lower Electricity Tariffs

15. The elimination of debt service cost could also be used to reduce prices at which Itaipú sells its electricity to the national electricity administrators of Paraguay and Brazil (ANDE and ELETROBRÁS). Since 2009, Itaipú has been supplying its energy to Paraguay and Brazil at a tariff of USD 22.6 per kW. The absence of the debt service cost, which would constitute around 40 percent of total cost in 2023, means that, all else equal, the tariff charged by Itaipú could theoretically be lowered by a similar percentage.

16. The tariff reduction may benefit a wide section of the domestic economy in the long run. The quality of electricity transmission and distribution infrastructure is low compared to other countries in the region. If ANDE would keep the prices its charges to its customers unchanged, high profits would boost the financial resources

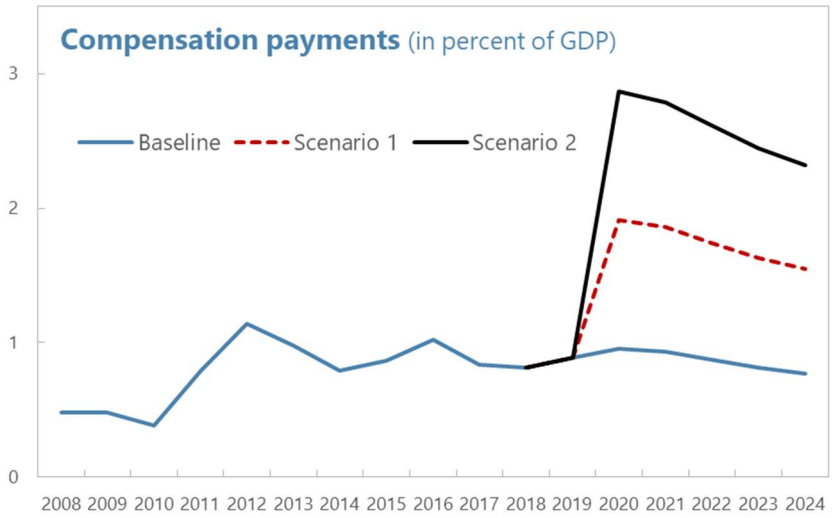


Sources: WB Enterprise Surveys

available for making the much-needed investments in electricity infrastructure. If the cost reduction is partially passed on to end users, it will also help reduce the operational cost of the domestic productive sector. Although Paraguay currently uses less than half of its energy share of Itaipú, the tariff reduction would still amount to sizeable savings for the domestic economy, of around USD 150 million a year (0.35 percent of 2019 GDP). As the domestic industrial sector continues to grow, the cost benefit would grow larger as well.

Compensation Payments

17. The treaty renegotiation can also result in higher compensation payments. Paraguay's excess electricity from Itaipú has long been sold to Brazil at well-below market prices. Even after the tripling of the adjustment factor in 2011, the tariff of energy sold to Brazil is around USD 10 / MWh, compared to the current average wholesale distribution price by Brazil's ANEEL (Agência Nacional de Energia Elétrica) of around USD 60 / MWh. The upcoming renegotiation may lead to changes to the compensation payment scheme that are more in line with the conditions of the regional electricity market. The chart below shows the projected compensation payments as percent of fiscal revenue, if the adjustment factor were to be doubled (scenario 1) and tripled (scenario 2), from its current level.



Sources: IMF staff estimates.

Alternative Selling Arrangements

18. The current exclusivity agreement, which stipulates that Paraguay's excess energy allotment from Itaipú can only be sold to Brazil, may be also up for renegotiation. Of course, selling electricity to other countries would require examining the feasibility of other export markets and exploring alternative export partnerships. In this regard, upfront investments may be needed in the transmission and distribution infrastructure to enable alternative export arrangements.

19. Domestic usage of Itaipú energy resources could be expanded. Paraguay currently uses only around 30 percent of its allotted share of energy from Itaipú. And electricity export constitutes over 20 percent of Paraguay's total exports. Though directly contributing to fiscal revenues and GDP, electricity exports generate little employment and have few linkages with the domestic productive sectors. In the long run, direct energy export is a suboptimal way to take advantage of Paraguay's natural abundance in cheap electricity generation. Efforts are needed to strengthen domestic transmission and distribution networks to better use the energy resources for the development of domestic industries that produce more diversified exports and generate more domestic employment.

C. Conclusion

20. The 2023 renewal of the Itaipú Treaty may have significant macroeconomic implications. The completion of the Itaipú dam's debt repayment will lead to a cost reduction for the Binational, of US$1.4 billion. This can either benefit Paraguay's and Brazil's fiscal position (the gain for Paraguay could be over 1.5 percent of GDP) or result in a cost reduction for both domestic economies Passing the cost reduction directly into the domestic economy through improved energy infrastructure and reduced energy tariff could be an efficient way to distribute the gain among the population and help support private sector development. On the other hand, the renegotiation of the Treaty can also result in changes in the agreements of compensation payments and energy export exclusivity, which could lead to more financial gains for Paraguay in addition to the cost reduction for the Binational. Additional investments in energy transmission and distribution infrastructure are likely needed to capture Paraguay's potential in energy exports and fulfilling domestic energy needs.

21. Windfall incomes from Itaipú should not be seen as a shortcut to solving the country's development challenges. Past researches have shown that, contrary to intuition, windfall gains from natural resources often do not improve a country's economic standing, without quality institutions and good public governance to ensure that the gains are wisely managed and spent. In the long run, exporting electricity is not an optimal way to take advantage of the country's abundant hydro resources. Sustainable growth demands a shift in Paraguay's export model, from direct energy exports to leveraging cheap energy for the development of domestic productive sectors.

22. The growth impact of the Itaipú revenue will depend on how exactly the money is spent. Without additional clarity about how the revenue is going to be used, it is difficult to estimate its growth impact on the economy. If the revenue is going to be a simple add-on to the total fiscal revenue, then there is no special growth effect to speak of—the multiplier of general fiscal spending applies. The consensus in the economic literature is that expenditures in public investment generally has a higher growth multiplier than other types of fiscal expenditures. As a benchmark, the IMF Regional Economic Report (2018) for the LAC region estimated that 1 percentage point of GDP increase in public investment expenditure might lead to 0.5 percent increase in total outputs in the short term, and up to 1.5 percent cumulative increase in total outputs after 2 years.

References

Carter, M. (2019). Itaipú: La Riqueza Energética Perdida de Paraguay.

Dabán-Sánchez, T and W. Zarate, (2010). Sustainable Management of Revenues from Itaipú. IMF Country Report No. 10/170, Paraguay: Selected Issues, pp. 3-12.

Itaipú, (2015-2018). "Financial Statements of Itaipú Binational."

Lorenzon, A. S., C.A.A.S. Ribeiro, A. R. dos Santos, G. E. Marcatti, G. F. Domingues, V. P. Soares, N. L. M de Castro, T. R. Teixeira, S. C. M. C. de Menezes, E. Silva, K. O Barros, G. M. A. D. A. dos Santos, S. F. da Silva, P. H. S. Mota, (2018). A New Methodology for Royalties Distribution of the Itaipú Hydroelectric Plant: The Hydrographic basin as the Unit of Analysis. Journal of Environment Management, Vol. 217, Iss. 1, pp. 710-17.

Toledano, P., & Maennling, N. W. (2013). Report on Leveraging Paraguay's Hydropower for Sustainable Economic Development.

EXPORT DIVERSIFICATION RECOMMENDATIONS FOR PARAGUAY WITH MACHINE LEARNING[1]

A. Introduction

1. A diversified export portfolio supports sustainable growth and economic stability. The relationship between export diversification and countries' economic performance has been extensively studied in the economic literature. Overall, existing research asserts that export diversification is a key element in the economic development process, particularly for developing and emerging market countries trying to catch up with their advanced peers. Various studies provide evidence of a positive association between export diversification and economic development (e.g. Imbs and Wacziarg, 2003; Klinger and Lederman 2004 and 2011; Cadot et al., 2011).

2. Diversification into new export categories often happens serendipitously, is often introduced by new foreign investments, and frequently involves knowledge transfer and capacity spillover from existing, adjacent export categories. In some cases, the *potential*, or *latent comparative advantage* in an export category may not materialize, until one foreign company, scouting the globe for new production bases, decides to invest in the country. Such decisions involve a multitude of considerations, and the country's comparative advantages in the pure economic sense are only part of them. In other cases, domestic exporters may manage to branch into a new export category related to their existing exports, once they have accumulated sufficient knowledge, e.g. in production scaling and logistics, and established distribution channels in importing countries, through learning by doing from their past export experiences. In other words, a country may have a latent comparative advantage in product X. But it is not observed until actual exports of product X happen with at least some success. The occurrence and timing of the such events are highly unpredictable. So it is reasonable to assume that at any given time, the set of products that a country has a latent comparative advantage in is almost always bigger than the set of actual product categories that the country has demonstrated competence in exporting**.**

3. However, not all types of diversification are created equal, and a country's diversification strategy needs to follow its comparative advantages. Diversification for its own sake is hardly a recipe for sustainable growth. A foundational idea of the classical international trade theory is that under free trade, countries will tend to export what they are relatively good at producing, i.e. products they have a comparative advantage in. "Diversifying" into industries that are misaligned with a country's current endowment fundamentals, as the former Soviet-block nations did after World War II through industrial policies that aimed to accelerate industrialization, has negative growth consequences (see e.g. Lin, 2009). On the other end of the spectrum, delayed industrialization also leads to negative growth outcomes,

[1] By Natasha Che.

as the experience of many resource-rich countries that are entrenched in their over-dependence on commodity exports has shown (e.g. Frankel, 2010). Relatedly, Hausmann et al. (2007) finds that countries that export more sophisticated, or knowledge-intensive products, tend to grow faster, controlling for initial income levels.

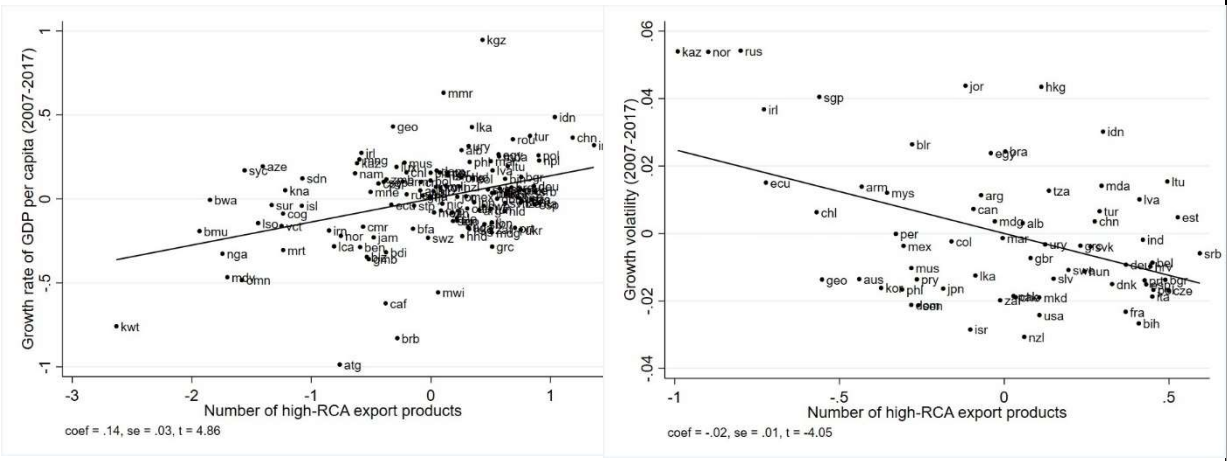
4. Throughout this paper, export diversification is measured by the number of export products a country has with high "revealed comparative advantage" (RCA). The RCA score, first introduced by Balassa & Noland (1965), is a popular measure in the economic literature for calculating the relative importance of a product in a country's export basket. Formally, the RCA score of country i in product j can be calculated as:

$$RCA_{ij} = \frac{E_{ij}/E_i}{E_j/\sum_{i' \in I} E_i}$$

where E_{ij} is the export value of product i from country j, E_i is the total export values of country i, E_j is the total exports of product j from all countries around the world, and $\sum_{i' \in I} E_{i'}$ is the total world exports.

5. A high-RCA export product for country i is defined as a product with its $RCA_{ij} > 1$. Mathematically, it means that the product's share in the country's export portfolio is greater than its share in the total world exports, which is an indication that the country has a comparative advantage in the product. The interest of the paper is not in recommending products that a country can export a little of, but rather in recommending products that the country can potentially have a high RCA in, in other words, to discover a country's *latent comparative advantages*. Using data for 2007–17, Figure 1 shows that controlling for country size, GDP growth rate is positively related to the number of high-RCA exports a country has, and growth volatility is negatively related to the number of high-RCA exports.

Figure 1. Paraguay: Number of High-RCA Exports vs GDP Growth and Growth Volatility



Sources: UN Comtrade and staff estimates.

6. The paper's approach to studying export diversification comes from two key observations. First, as mentioned above, products that share production resources and knowledge tend to show up in the export basket together. A country that has successfully exported beef can, with some effort, branch into exporting dairy. A country that has mastered the trade of exporting desktop computer hardware is in a better position to produce and export cellphones than otherwise. Therefore, the products in a country's existing export basket contains valuable information regarding what other products the country can become good at producing. Secondly, countries with similar comparative advantages tend to export similar products. Bangladesh and Vietnam are both successful in exporting garments because of the countries' shared abundance in low cost labor. New Zealand and Uruguay both specialize in cattle exports partly because of the high availability of pasture land. In other words, the export baskets of similar countries contain information about the comparative advantages the countries share.

7. The paper quantifies these insights to characterize Paraguay's latent comparative advantages and produce export diversification recommendations for the country,[2] using machine learning algorithms that implement collaborative filtering, an approach used widely by online commercial applications for their recommender systems. A recommender system based on collaborative filtering uses the revealed preferences of a group of users to make predictions about the preferences of a user similar to the group. There are numerous applications of this approach in the e-commerce space. For example, Amazon.com recommends new products to a customer by looking at the customer's purchase history and the purchase records of other customers of a similar taste. After a user watches one movie, Netflix recommends to the user similar movies, using a "people who have watched this movie also watched..." approach.

8. The paper is organized as follows. Section B offers an overview of Paraguay's export composition and diversification evaluation. Section C explains the methodology for diversification recommendations. Section D presents the recommendations for Paraguay. Section E concludes.

B. Is Paraguay Diversified Enough?

9. The economic literature suggests that an export structure dominated by natural-resource-enabled commodity exports may have negative consequences for long term growth and stability. A vast number of papers has studied the impact of natural endowments, e.g. oil and gas, precious metal, and abundant agricultural land, on economic growth. The general sentiment of the literature is that, contrary to intuition, natural endowments, though providing economic advantages in the short term, are not necessarily a blessing to long-run growth. See for example, Frankel (2010), Bahar & Santos (2018), Bacha & Fishlow (2011).

[2] For more country examples, see Che (2020).

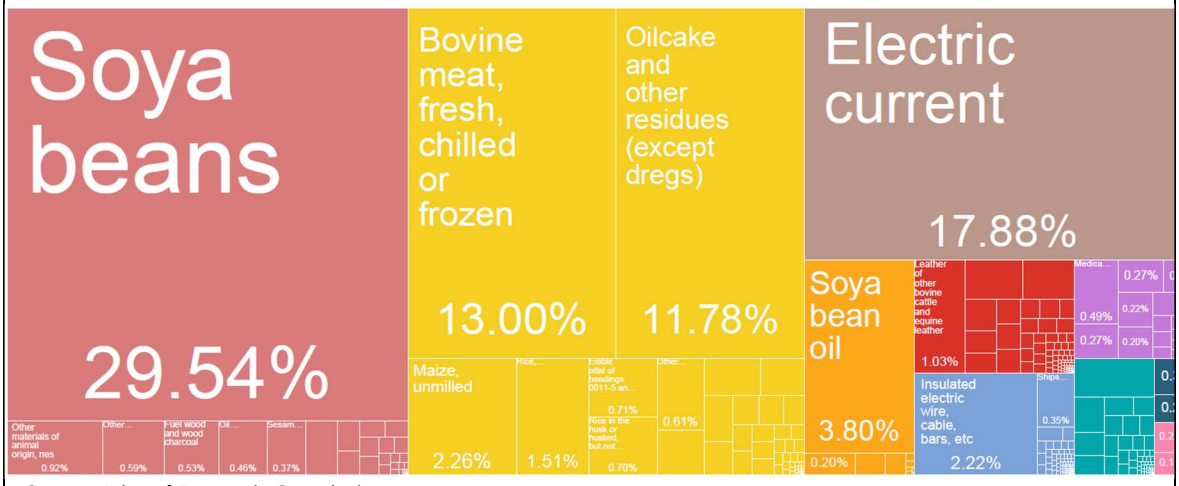
10. There are multiple reasons why a dominance of commodity exports may not be ideal for long run growth. Specifically:

- There is empirical evidence suggesting that agricultural commodity prices, despite large cyclical swings, are on a trend decline over the long run.
- Countries with a history of dependence on commodity exports tend to have a more concentrated export structure and a less developed industrial sector.
- The excess volatility that come with agricultural commodity exports, due to both the high volatility of world prices and the volatility of weather shocks, usually translates into macroeconomic instability, and pose substantial challenges on the execution of monetary and fiscal policies.
- High reliance on commodity exports often correlates with under investments in human capital and institutional reforms.

For these reasons, the economy of commodity exporters is often plagued by high macro volatility, undiversified export structure, slow developing industrial sector, high fiscal deficit and weak public governance.

11. Data suggests that some of these predicaments of commodity exporters apply to Paraguay. Paraguay's export basket is dominated by agricultural commodities and electricity. The agricultural commodity price boom during the 2000s was a major cause of the growth acceleration in Paraguay. The price boom not only boosted income growth in the short term, but also stimulated agricultural investment and increased production concentration in select crops that had seen large price increases, primarily soybeans. In contrast, non-agriculture, non-energy exports, though growing in recent years, are very small, while the commodity sector and the non-tradable sector attract most of the capital, labor, and entrepreneurial resources.

Figure 2. Paraguay: Composition of Goods Exports, 2018



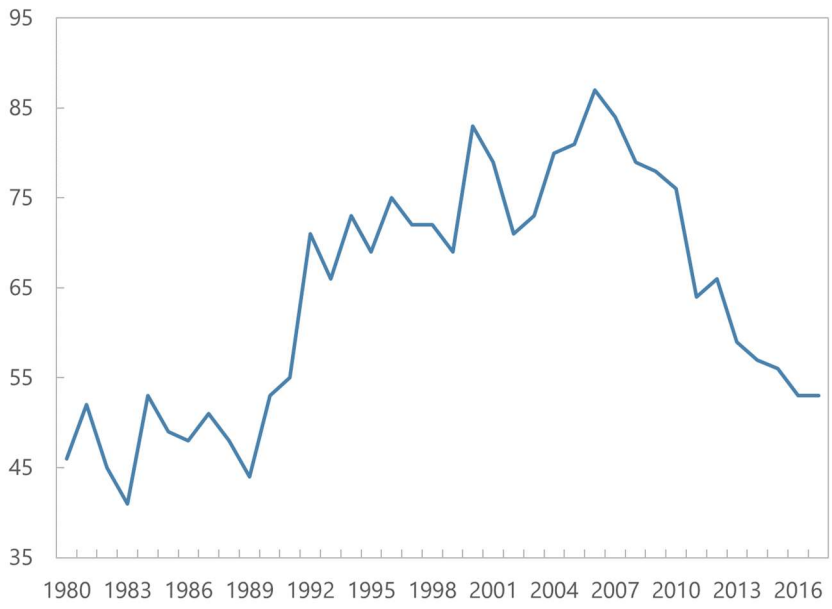
Source: Atlas of Economic Complexity.

12. Export diversity has declined during the commodity price boom period. From 2000 to 2017, the number of high RCA exports dropped by over 35 percent, from 83 to 53. In 2018, close to 35 percent of goods exports from Paraguay are soybean related. And another 25 percent of total exports consists of electrical energy primarily produced by the two large hydroelectric dams, respectively co-owned with Brazil and Argentina. The electricity exports, though a major source of fiscal revenue, have little connection with the rest of domestic production sectors.

13. In general, the number of high-RCA exports is positively correlated with country income level and country size. Rich countries tend to have more sophisticated industrial structure and export more types of products than poor countries. In addition, many industries need a minimum scale to be sustainable. Therefore, smaller countries, with less capital, labor, and other production endowments, tend to produce in fewer product categories than larger countries.

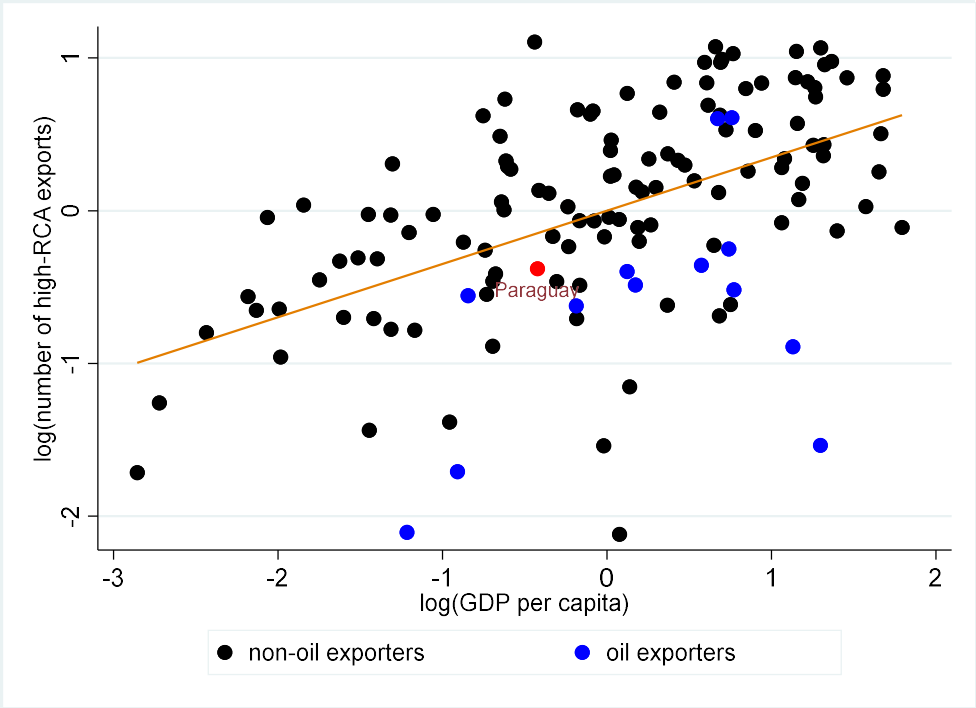
14. But Paraguay's export concentration is high even compared to countries of similar income level and size. As Figure 4 shows, controlling for the country population size, there is a positive relationship between the number of high-RCA exports and a country's GDP per capita. And yet Paraguay's export diversification level is lower than what would be predicted by its income level. The under-diversification would be more striking if the comparison is done among non-oil exporting countries, given the fact that many of the countries below the regression line are oil exporters. Comparing Paraguay with other countries in its size group shows a similar pattern.

Figure 3. Paraguay: Number of High-RCA Exports



Sources: UN Comtrade and staff calculations.

Figure 4. Paraguay: Diversification vs Income Level



Sources: UN Comtrade and staff estimates.

C. Empirical Methodology

15. The paper constructs a recommendation system for export categories based on three algorithms widely used in online collaborative filtering recommender systems: product-based and country-based K-nearest neighbors (KNN), and Singular Value Decomposition (SVD). All methods used in the paper produce the so-called "top-N recommendations"- the goal of the exercise is to generate a list of N product categories that a country should export the most of. The algorithms produce the list by predicting the RCA scores of different products for the underling country, using the training dataset of export values by country and SITC 4-digit product, and recommending the N products with the highest predicted RCA scores.

16. The underlining data used in the recommendation system can be represented as a m x n matrix R, where m is the number of countries in the database, and n is the total number of SITC 4-digit products. The content of R, i.e. r_{ij} , is country i's RCA score in product j. R is a sparse matrix due to the fact that each country only exports a subset of the products in the SITC universe. In the case that country i does not export any product j, r_{ij} = 0. If an implementation uses multiple years of export data, then each country-year is a row in R, i.e. $m = c$ x y, where c = the number of countries in the dataset, and y = the number of years

included. In most versions of implementations discussed below, y = 1, i.e. if the task is to generate export recommendations for country i in 2017, only the cross-country export data for 2017 is included in the training set.[3]

Neighborhood-Based Algorithms

Product-Based KNN

17. KNN is one of the most frequently used methods in solving classification and pattern recognition problems and is a popular approach in constructing recommender systems. The basic idea of KNN is learning by analogy- classifying the test sample by comparing it to the set of training samples most similar to it. Different KNN implementations vary in terms of their choices of how the similarity between input vectors is calculated. In the present paper, the cosine similarity score is used as the similarity measure.

18. The intuition behind the current paper's product-based KNN implementation is simple. First look at what products a country already has a revealed comparative advantage in, and then recommend other products that are similar to those products. To explain the approach in more details, let's first rewrite the RCA score matrix R as:

$$R = [\boldsymbol{p}_1, \boldsymbol{p}_2, \dots, \boldsymbol{p}_n]$$

where $\boldsymbol{p}_j$ is a vector of length m that represents the RCA scores of product j for all the m countries in the sample:

$$\boldsymbol{p}_j = \begin{bmatrix} r_{1j} \\ r_{2j} \\ \cdot \\ \cdot \\ r_{mj} \end{bmatrix}$$

19. In machine learning terminology, each product in the sample has *m* features. The cosine similarity between products i and j is equal to $(\boldsymbol{p}_i \cdot \boldsymbol{p}_l) / \left(\left\|\boldsymbol{p}_j\right\| \|\boldsymbol{p}_l\|\right)$, which ranges from -1, when the two vectors are the exact opposite, to 1, when the two are exactly the same. The intuition behind this is that by comparing the two sets of countries that export i and j, and how important the products are in the countries' export baskets, information can be inferred regarding how closely related the two products are.

20. The implementation of the product-based KNN recommender for country i involves the following steps:

a. Represent each product in the SITC 4-digit product space as a vector of RCA scores, $\boldsymbol{p}_j$

[3] The paper experimented with including multiple years of data in the training set, but found no significant improvement in the evaluation metrics, while the model took longer to compute as the size of m increases.

b. Select the set of K products in which country i has a revealed comparative advantage, i.e. $r_{ij} > 1$. Let's call it the high-RCA product set of country i.

c. For each $j \in [1, n]$, calculate the predicted value of r_{ij} as the weighted average RCA score of the high-RCA product set, weighted by the cosine similarity between product j and the products in the country's high-RCA set.

The recommended products for country i are the N products with the highest predicted r_{ij} values.

Country-Based KNN

21. Instead of recommending product categories related to a countries' existing export products, the problem at hand can also be thought of as "recommending" other countries similar to the country in question. In other words, finding a group of countries that are similar to country i. And because these countries have similar comparative advantages, the products they export, beyond the ones country i is already exporting, can be good candidates for diversification for country i. More specifically, the RCA score matrix R can be represented as:

$$\boldsymbol{p}_j = \begin{bmatrix} q_1 \\ q_2 \\ \cdot \\ \cdot \\ q_m \end{bmatrix}$$

where qi is a vector of length n that represent country i 's RCA scores for the n product categories in the SITC 4-digit product space.

22. The execution of the country-based KNN algorithm for country i can then be broadly described as follows:

a. Calculate the cosine similarity score between $\boldsymbol{q}_i$ and $\boldsymbol{q}_j$, where $1 \leq j \leq m$, and $j \neq i$.

b. Select a set of K countries with the highest similarity scores to country i.

c. For each $l \in [l, n]$, calculate the predicted value of r_{il} as the weighted average RCA score of product l across the K countries, weighted by the similarity score between each country and country i.

d. The recommended products for country i are the N products with the highest predicted r_{ij} values.

23. It is important to note that although the product-based and country-based KNN recommenders apply similar algorithmic logic, the differences in the perspectives of the

two methods lead to different recommendation results, as will be demonstrated in the next section. Generally speaking, in the data sample $n > m$[4] it may be easier to identify the relatedness between products with more accuracy than to identify similar countries, which make the product-based KNN a superior approach. The results presented in the next section seem to confirm this hypothesis.

Matrix Factorization Algorithm

24. The KNN algorithms, though intuitive and easy to implement, suffer from some significant drawbacks. First of all, these algorithms have limited scalability. As the sizes of m and n increase, the amount of computation required to calculate the similarity scores increases at $O(n)$ time, reducing the performance of the algorithm on larger data sets. Another disadvantage of the KNN algorithms is their problem with sparse data. Since the KNN algorithms require explicitly calculating similarities among vectors, the calculation becomes increasingly inaccurate when there's a lot of missing data in matrix R. This problem is exacerbated by the fact that the algorithm essentially treats each row of the product vector (or the country vector) as independent features of equal importance, which is not the most efficient use of information in the data, and also makes missing rows generally more damaging, compared to algorithms that impose some discretion on the relative importance of different data points. For the current use case, the first drawback is not a big concern, as the m and n of the country-product space are relatively small, especially when we do not include multiple years in the calculation. The second drawback is more problematic, as it implies that the KNN algorithms would perform worse on countries that are significantly under-diversified, i.e. lots of missing entries in R for these countries. This would potentially defeat the purpose of the exercise, as under-diversified countries are arguably the ones that are most in need of diversification recommendations.

25. The Singular Value Decomposition (SVD) algorithm provides a possible remedy to the problem. SVD is a matrix factorization technique widely used in dimensionality reduction and principal component analysis. The basic idea is that matrix R can be decomposed into three matrices:

$$R = USV'$$

where U and V are two orthogonal matrices of size m x r and n x r respectively. r is the rank of R. And S is a r x r diagonal matrix, with the singular values of R as its diagonal elements, sorted in the order of decreasing magnitude.

26. The main purpose of the decomposition is to represent the products and countries as combinations of the latent factors in the data, which are implicit, orthogonal features that can be used to characterize the entire country-product space. U represents the

[4] There are close to 800 product categories in the SITC 4-digit product space, while there are just over 250 countries in the sample.

relationship between countries and the latent factors, while V' represents the similarity between products and latent factors. The diagonal elements of S can be thought of as the relative scaling values assigned to various latent factors.

27. To illustrate the intuition behind the algorithm, here is an extremely simplified example. Suppose the matrix R can be summarized by three independent latent factors: labor, land, and knowledge. Row i of matrix U represents the comparative advantage of country i as a combination of the latent factors. $\boldsymbol{u}_i = [.55, .4, .05]$ would mean that country i's profile can be described as 50% labor, 40% land, and 5% knowledge- a resource-rich, developing country. Column j of matrix V' represents the characteristics of product j as a combination of latent factors. Thus $\boldsymbol{v}_j = [.15, .05, .80]'$ means that the production of product j can be characterized as 15% labor, 5% land, and 80% knowledge- a technology-product that requires mostly intangible inputs. $r_{ij} = \boldsymbol{u}_i \cdot \boldsymbol{v}_j$, scaled by the appropriate diagonal element in S. It's not difficult to see that r_{ij} would be relatively small, i.e. country i does not have a comparative advantage in producing product j. This is, of course, a very hypothetical example. In practice, the latent factors computed by the optimization algorithm are not human-interpretable, and only serve as features that more efficiently characterize data.

28. The goal of the SVD algorithm is essentially to find the best estimations of U and V', and then produce recommendations based on estimated $\widehat{r_{ij}} = \widehat{\boldsymbol{u}_i} \cdot \widehat{\boldsymbol{v}_j}$. In practice, because R is already sparse, observing orthogonality constraints for U and V' becomes computationally untenable. The execution of the algorithm thus centers on solving the following optimization problem:

$$\min_{\boldsymbol{u}_i, \boldsymbol{v}_j} \sum_{r_{ij} \in R} \left(r_{ij} - \boldsymbol{u}_i \cdot \boldsymbol{v}_j\right)^2 + \lambda \left(\|\boldsymbol{u}_i\|^2 + \|\boldsymbol{v}_j\|^2\right)$$

where λ is a regularization factor. The minimization is performed with stochastic gradient descent, using python Surprise library for building recommender systems. The recommended products for country i are the products with the highest predicted $\widehat{r_{ij}}$ value.

D. Export Diversification Recommendations for Paraguay

29. The recommendation algorithms are run on the SITC 4-digit export data for 2016 and 2017 to generate diversification recommendations for Paraguay. Table 1 shows the number of recommended high RCA exports and the hit rates from each algorithm.[5]

30. Test results from other countries show that the product-based KNN performs the best among the three algorithms. Che (2020) applied the algorithms to the historical data of several high-growth countries, including China, India, Chile and Poland. The results showed

[5] The hit rate measures the percentage of recommendations that has an actual RCA score > 1, i.e. the ones Uruguay is already exporting a lot of. The top-N hit rate measures the percentage of the top 100 recommendations from each algorithm with an actual RCA score > 1. In the current specification, N = 100.

that the product-based KNN is the apparent best among the three algorithms in providing guidance on the

Table 1. Paraguay: Summary Stats of the Recommendations

	Product-based KNN	Country-based KNN	SVD
Number of recommendations	105	164	214
Hit rate (in percent)	34.3	22.6	18.2
Top-N Hit rate (in percent)	34.3	20.1	7.0

Sources: IMF staff estimates.

structural change of a country's export portfolio. Although the product-based KNN results are not always well aligned with the test countries' historical export composition, they are able to predict the changes in the export structure of the test countries over a 20-year span. Thus, a conclusion from the paper is that the product based KNN appear to produce recommendations that are forward-looking and can better support the sustainable growth of the test countries. Still, diversifying into higher-value added categories that support long-term growth does not have to be in conflict with diversifying into the categories that fit more into the country's current comparative advantages. The latter is often easier in the short-to-medium term, and can still provide benefits in, for example, reducing growth volatility. So, in analyzing the recommendation results, the present paper will give more weights to the product-based KNN recommendations, while still referencing the results from other algorithms.

31. Table 2 and Figure 5 compare the existing sectoral structure of actual high RCA exports in 2017 and the recommendations from the models, by SITC 1-digit category. Table 2 shows the numbers of 4-digit high RCA exports contained in each 1-digit category, for actual exports and for recommended exports. The shares are the numbers of 4-digit products in each category as percent of the total count of high RCA exports. The orange column in Figure 5 are weighted averages across the three models.[6]

32. Consistent with the observations at the beginning of the section, Columns 2 and 3 of Table 2 shows that Paraguay's exports are heavily concentrated in agricultural commodities (row 1) and primary materials also related to agriculture (row 3). The industrial exports are mostly concentrated in chemical products (row 6) and basic manufacturing mostly concerning the processing of raw materials (row 7).

33. Overall, the recommender algorithms concur with the current export structure. For example, the product-based KNN, the most forward-looking algorithm among the three according to the results of the test cases, suggests that the dominance of food and crude

[6] The weights are .6, .2, and .2, for product-based KNN, country-based KNN, and SVD respectively.

materials in the export basket should be maintained, with diversification focusing on expanding into more products within these categories. At the same time, the algorithm suggests moderate expansion in the machinery & transport equipment category, which would reduce the relative importance of some other sectors, such as energy, in the export basket.

34. The other two algorithms agree in the ballpark with the recommendations from the product-based KNN. The weighted average recommendations from the three algorithms can be broadly described as follows: an export diversification strategy for Paraguay should focus on expanding varieties within the categories of agricultural products and primary materials, which the country is already very strong in. Meanwhile, the country should create conditions to continue expanding basic manufacturing exports that involve the processing of primary materials, and more aggressively expand the manufacturing of machinery and equipment. The growth of the latter categories can serve to reduce the country's reliance on electricity exports.

Table 2. Paraguay: Actual vs Recommended Export Structure

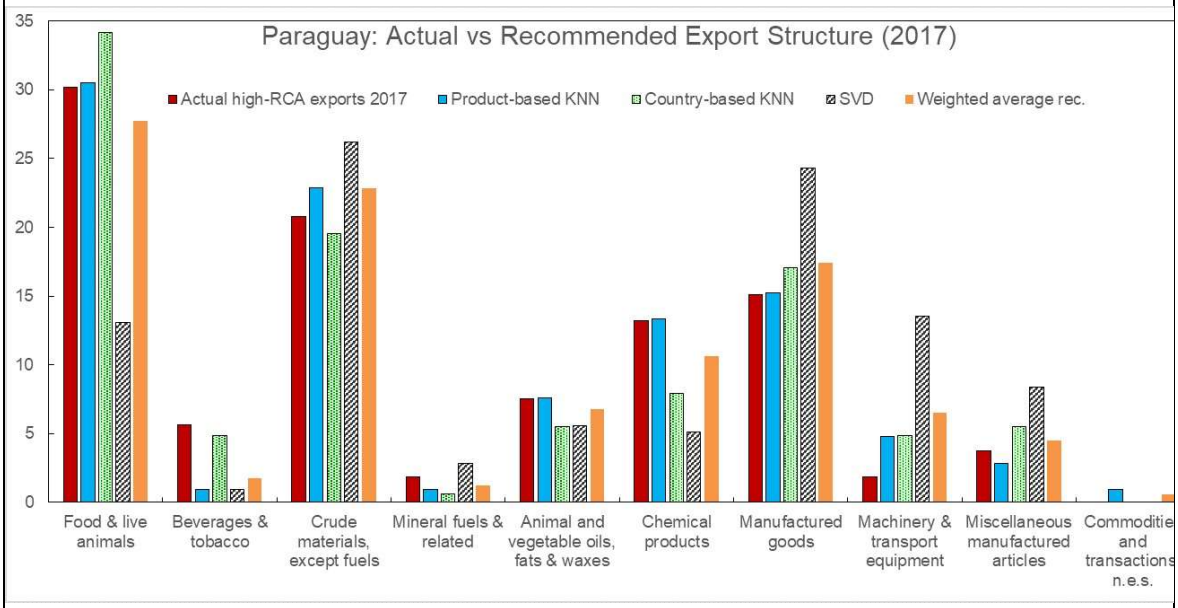
Categories	Actual high-RCA exports 2017		Product-based KNN		Country-based KNN		SVD	
	Number	Share (in %)	Number	Share (in %)	Number	Share (in %)	Number	Share (in %)
Food & live animals	16	30.2	32	30.5	56	34.1	28	13.1
Beverages & tobacco	3	5.7	1	1.0	8	4.9	2	0.9
Crude materials, except fuels	11	20.8	24	22.9	32	19.5	56	26.2
Mineral fuels & related	1	1.9	1	1.0	1	0.6	6	2.8
Animal and vegetable oils, fats & waxes	4	7.5	8	7.6	9	5.5	12	5.6
Chemical products	7	13.2	14	13.3	13	7.9	11	5.1
Manufactured goods	8	15.1	16	15.2	28	17.1	52	24.3
Machinery & transport equipment	1	1.9	5	4.8	8	4.9	29	13.6
Miscellaneous manufactured articles	2	3.8	3	2.9	9	5.5	18	8.4
Commodities and transactions, n.e.s.		0.0	1	1.0		0.0		0.0
Total	53		105		164		214	

Sources: IMF staff estimates.

35. Tables 3 and 4 compare the recommended export structure from the product-based KNN and the actual exports and list the top 10 product categories with the largest increases and decreases in overall export shares, by SITC 2-digit category. Examining Table 3, it is interesting to note that the top recommendations cover multiple broader sectors. Paraguay currently exports little in most of these categories, even though some of them belong to the commodity and primary material sectors that Paraguay specializes in. On the other hand, of a couple categories in this list Paraguay already exports a lot, such as 01: meat

and preparation, but the recommender system suggests there is still significant room to increase the export varieties in these categories.

Figure 5. Paraguay: Actual vs Recommended Export Shares by Industry



Sources: IMF staff estimates.

36. For the top categories with reduced export shares in the recommendations (Table 4), it is important to note that, with a couple of exceptions, the system is not suggesting that export quantities from these categories should be reduced. But rather, more diversification should happen in other categories that lead to a reduction of *export shares* for the categories in the list.

Table 3. Paraguay: Top 10 Categories with Increased Product Shares

Product code	Product name	Share (actual)	Share (rec.)	Difference (rec. - actual)
72	Machinery specialized for particular industries	0.0	3.8	3.8
02	Dairy products and birds' eggs	0.0	2.9	2.9
21	Hides	0.0	2.9	2.9
26	Textile fibers and their wastes	0.0	2.9	2.9
58	Artificial resins and plastic materials	0.0	2.9	2.9
01	Meat and preparations	3.8	5.7	1.9
28	Metalliferous ores and metal scrap	3.8	5.7	1.9
09	Miscellaneous edible products	0.0	1.9	1.9
53	Dyeing	0.0	1.9	1.9
66	Non-metallic mineral manufactures	0.0	1.9	1.9

Sources: IMF staff estimates.

Table 4. Paraguay: Top 10 Categories with Reduced Product Shares

Product code	Product name	Share (actual)	Share (rec.)	Difference (rec. - actual)
06	Sugar	5.7	1.0	-4.7
12	Tobacco and tobacco manufactures	5.7	1.0	-4.7
61	Leather	5.7	2.9	-2.8
59	Chemical materials and products	7.5	4.8	-2.8
27	Crude fertilizer and crude minerals	1.9	0.0	-1.9
77	Electric machinery	1.9	0.0	-1.9
29	Crude animal and vegetable materials	3.8	1.9	-1.9
55	Oils and perfume materials	3.8	1.9	-1.9
08	Feeding stuff for animals	5.7	3.8	-1.9
22	Oil seeds and oleaginous fruit	7.5	5.7	-1.8

Sources: IMF staff estimates.

E. Conclusion

37. A strategic vision for export diversification that aligns with a country's comparative advantages and development aspirations can usefully inform the design of growth-enabling policies. Yet there is no overarching empirical framework in economic research for creating such a vision that takes into account the diverse and often complicated fundamentals of individual countries. The paper aims to fill this gap by designing a machine-learning based recommendation system for export diversification, taking inspiration from the recommender systems by collaborative filtering, popularized by online media and e-commerce platforms.

38. The recommendation results suggest that Paraguay should expand on its comparative advantages in agricultural commodities. The diversification strategy suggested by the algorithms is to focus on expanding varieties within the categories of agricultural products and primary materials, while creating conditions to expand on basic manufacturing exports that involve the processing of primary materials, and more aggressively expand on the manufacturing of machinery and equipment, to reduce the reliance on energy exports.

References

Adeniyi, David Adedayo, Zhaoqiang Wei, and Y Yongquan. "Automated web usage data mining and recommendation system using K-Nearest Neighbor (KNN) classification method". In: Applied Computing and Informatics 12.1 (2016), pp. 90-108.

Aiginger, Karl and Dani Rodrik. "Rebirth of Industrial Policy and an Agenda for the Twenty First Century". In: Journal of Industry, Competition and Trade (2019), pp. 1-19.

Bacha, Edmar L and Albert Fishlow. "The recent commodity price boom and Latin American growth: More than new bottles for an old wine?" In: The Oxford Handbook of Latin American Economics. 2011.

Balaguer, Jacint and Manuel Cantavella-Jorda. "Structural change in exports and economic growth: cointegration and causality analysis for Spain (1961-2000)". In: Applied Economics 36.5 (2004), pp. 473-477.

Cadot, Olivier, C'eline Carr'ere, and Vanessa Strauss-Kahn. "Export diversification: what's behind the hump?" In: Review of Economics and Statistics 93.2 (2011), pp. 590-605.

Che, Natasha. "Intelligent Export Diversification: An Export Recommendation System with Machine Learning". IMF Working Paper 20/xx, 2020.

Clickstreams, Multi-faceted Web. "Workshop Notes", 2005.

Feenstra, Robert and Hiau Looi Kee. "Export variety and country productivity: Estimating the monopolistic competition model with endogenous productivity". In: Journal of international Economics 74.2 (2008), pp. 500-518.

Frankel, Jeffrey A. The Natural Resource Curse: A Survey. Tech. rep. National Bureau of Economic Research, 2010.

Giri, Rahul, Mr Saad N Quayyum, and Rujun Yin. Understanding Export Diversification: Key Drivers and Policy Implications. International Monetary Fund, 2019.

Hausmann, Ricardo, Jason Hwang, and Dani Rodrik. "What you export matters". In: Journal of economic growth 12.1 (2007), pp. 1-25.

Hausmann, Ricardo and Bailey Klinger. "The structure of the product space and the evolution of comparative advantage". In: CID Working Paper Series (2007).

Herzer, Dierk and Felicitas Nowak-Lehnmann D. "What does export diversification do for growth? An econometric analysis". In: Applied economics 38.15 (2006), pp. 1825-1838.

Hidalgo, Cesar A and Ricardo Hausmann. "The building blocks of economic complexity". In: Proceedings of the national academy of sciences 106.26 (2009), pp. 10570{10575.

Imbs, Jean and Romain Wacziarg. "Stages of diversification". In: American Economic Review 93.1 (2003), pp. 63-86.

IMF. "Sustaining Long-Run Growth and Macroeconomic Stability in Low-Income Countries-The Role of Structural Transformation and Diversification". In: IMF Policy Paper (2014).

Klinger, Bailey and Daniel Lederman. Discovery and development: An empirical exploration of "new" products. The World Bank, 2004.

——— "Export discoveries, diversification and barriers to entry". In: Economic Systems 35.1 (2011), pp. 64-83.

Koren, Yehuda, Robert Bell, and Chris Volinsky. "Matrix factorization techniques for recommender systems". In: Computer 42.8 (2009), pp. 30-37.

Lathia, Neal, Stephen Hailes, and Licia Capra. "kNN CF: a temporal social network". In: Proceedings of the 2008 ACM conference on Recommender systems. 2008, pp. 227-234. Lin, Justin Yifu and Feiyue Li. Development strategy, viability, and economic distortions in developing countries. The World Bank, 2009.

Al-Marhubi, Fahim. "Export diversification and growth: an empirical investigation". In: Applied economics letters 7.9 (2000), pp. 559-562.

Paterek, Arkadiusz. "Improving regularized singular value decomposition for collaborative filtering". In: Proceedings of KDD cup and workshop. Vol. 2007. 2007, pp. 5-8.

Prebisch, Raul. "The economic development of Latin America and its principal problems". In: Economic Bulletin for Latin America (1962).

Sarwar, Badrul et al. Application of dimensionality reduction in recommender system-a case study. Tech. rep. Minnesota Univ Minneapolis Dept of Computer Science, 2000.

——— "Incremental singular value decomposition algorithms for highly scalable recommender systems". In: Citeseer.

Singer, Hans W. "The distribution of gains between investing and borrowing countries". In: The Strategy of International Development. Springer, 1975, pp. 43-57.

——— "The Distribution of Gains between Investing and Borrowing Countries". In: The American Economic Review 40.2 (1950), pp. 473-485.