Interregional capital flow tables for Brazil: A data-driven approach using electronic invoices

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Abstract

This study constructs interregional capital flow tables for Brazil by leveraging data from the country's electronic invoicing system (Nota Fiscal Eletrônica, NF-e), providing a highly detailed view of capital goods purchases by 67 economic activities (plus households) across the 27 Brazilian states. Using a novel, data-driven methodology aligned with the System of National Accounts, the research offers a granular representation of Gross Fixed Capital Formation (GFCF), enabling improved analysis of investment structure, regional disparities, and inter-industry relationships. This work addresses long-standing data limitations in the construction of capital flow tables and offers valuable input for future applications in economic modeling and policy analysis, with potential relevance for other countries with similar administrative data systems.

Keywords: Capital Flow Table, Input-Output Analysis, Electronic Invoices, Brazil, Nota Fiscal Eletrônica, Investment, System of National Accounts, Regional Analysis, Big Data.

1 Introduction

Investment dynamics is a cornerstone of economic activity and growth analysis. Capital flow tables, which detail purchases of capital goods by industry, provide crucial insights into the structure of investment, showing its sectoral patterns while allowing more accurate simulations of alternative policies to stimulate investment, promote sustainable growth, and improve the productive structure.

These tables, conceived by Wassily Leontief as an integral part of the input-output framework but not implemented by him (Meade et al., 2003), have often lagged behind standard input-output tables in development due to data constraints. The scarcity of prior studies estimating and analyzing capital flow tables for Brazil (Freitas, 2010; T. Miguez et al., 2014; T. Miguez & Freitas, 2021), which have relied on harmonizing diverse and often limited data sources, further confirms these data limitations.

This research addresses a significant gap by developing an interregional capital flow table for Brazil, disaggregated by Brazilian states and consistent with the System of National Accounts. It builds on a recent trend of producing estimates based on official administrative records,

which provide a more accurate representation of economic reality. The research pioneers a novel approach by using the comprehensive data from Brazil's electronic invoices (Nota Fiscal Eletrônica, NF-e) (Receita Federal, n.d.).

The NF-e system captures the majority of business-to-business transactions, offering unparalleled granularity. This allows us to address key research questions: How can NF-e data be used to construct a detailed and accurate capital flow table? What is the structure of industry capital flows in Brazil, as revealed by the NF-e data, and how does it differ from previous estimations? How can this table be integrated into the Brazilian SNA for a more complete picture of investment? And what is the distribution of capital goods in terms of sales and purchases among the 27 Brazilian states?

Our methodology involves cleaning and adapting a comprehensive extraction of the NF-e database for 2018. Although standardized, the NF-e requires some data cleaning and pre-processing to ensure data quality. We then used the Mercosur Common Nomenclature (NCM) product code, which is compatible with the International Harmonized System (HS), along with seller and buyer activity codes derived from the International Standard Industrial Classification (ISIC), and a tax code of the operation to classify transactions. A critical step is to use the Broad Economic Categories (BEC) classification to determine which products should be categorized as gross fixed capital formation and, in some cases, in what proportions. The data were then used to construct a capital flow matrix, which represents the flow of capital goods from producing to investment-consuming activities. This matrix is disaggregated by industry and by the 27 Brazilian states, providing a regional dimension. The resulting table is designed for seamless integration into the Brazilian System of National Accounts.

The primary data source is an extraction of the Brazilian NF-e database for the year 2018. Key variables include NCM/HS product codes, seller and buyer sector codes, legal classification (public and private), transaction values, product tax information, fiscal classification of the transaction, and geographic information (origin and destination states).

This research offers several key contributions. It provides an unprecedented level of granularity compared to previous studies, enabling a finer-grained analysis of capital flows. The NF-e system allows for potentially more frequent updates than survey-based methods, facilitating timely analysis. The regional disaggregation provides insights into regional disparities. Furthermore, this research develops a new methodology for constructing capital flow tables from electronic invoice data, potentially applicable to other countries with similar systems.

The research will provide a comprehensive and detailed picture of capital flows in Brazil, revealing intricate inter-industry and inter-regional relationships. We will compare the findings with existing estimates to assess the impact of using the more granular NF-e data. The resulting capital flow table will be a valuable resource for researchers and policymakers, offering a powerful tool for analyzing investment, economic growth, and structural change, and supporting evidence-based decision-making in economic development, industrial policy, and the reduction of regional disparities. We will also discuss challenges, limitations, and potential future research directions.

2 Literature review: Capital Flow Tables and investment analysis

The study of investment processes holds a central role in the theories of economic development, particularly in analyses of structural change. However, the statistical systems has historically lacked harmonized and comprehensive data (T. Miguez & Freitas, 2021). This persistent data gap has constrained the understanding of investment structure at a disaggregated level.

Early efforts to compile capital flow tables for Brazil (Freitas & Dweck, 2009; Freitas, 2010; T. Miguez et al., 2014) laid foundational groundwork. These studies aimed to disaggregate Gross Fixed Capital Formation (GFCF) data by demand-side activities, identifying flows of capital goods from producers to investing economic activities. Miguez (2016) further updated this methodology and extended the data series to 2013. More recently, Miguez and Freitas (2021) updated the methodology to align with the new System of National Accounts (SNA) to Reference 2010. A consistent challenge across these prior works was their dependence on harmonizing a wide array of diverse and often limited statistical sources.

On the international front, capital flow table development has been undertaken by a few countries, although progress has often lagged behind that of standard input-output tables (Meade et al., 2003). The United States, through its Bureau of Economic Analysis (BEA), stands out as an example, having published a series of Capital Flow Tables for benchmark years (Meade et al., 2004). Canada also provides some sectoral disaggregation of GFCF, although to a more limited extent (T. de H. L. Miguez, 2016).

3 Data: Leveraging electronic invoices for interregional capital flows

The research pioneers an innovative approach, utilizing comprehensive data from Brazil's Electronic Invoices (NF-e) (Receita Federal, n.d.) Following a trend in Input-Output Table estimations, fiscal records are used for the first time to estimate Brazil's Capital Flow Table (CFT).

The Brazilian Electronic Invoice (NF-e) registration system was established in September 2006, replacing printed invoices. An agreement between the Brazilian Federal Revenue Service (RFB) and the Institute of Applied Economic Research (IPEA) granted access to this system from 2018 onwards

Issuing NF-e is mandatory for all commercial transactions that involve at least one of the following conditions: i) transactions involving the industrialized goods tax (IPI); ii) wholesale or merchandise distribution transactions; iii) interstate transactions; iv) transactions involving any public administration entity (including state-owned enterprises); and v) foreign trade transactions. Managed by a consortium of all federal units led by the RFB, all electronic invoices issued are stored in a database administered by the RFB.

Thus, the NF-e system captures most business-to-business transactions, providing unparalleled granularity, particularly for estimating the MAI at the Brazilian state level. This enables addressing key research questions: How can NF-e data be used to construct a detailed and accurate capital flow table? What is the structure of industry capital flows in Brazil as revealed by NF-e data, and how does it differ from previous estimates? How can this table be integrated into Brazil's National Accounts System (SCN) for a more comprehensive investment overview? Additionally, what is the distribution of capital goods in terms of sales and purchases among Brazil's 27 states? Ultimately, the proper use of NF-e facilitates a more precise evaluation of investment supply and demand in Brazil, with sectoral and regional details, enabling the evaluation and formulation of public policies that encourage economic growth through productive investment. For example, Oliveira (2020) uses data from the Brazilian interregional input-output table estimated using the NF-e to assess sectoral and regional impacts of tax reform on consumption taxes on goods and services.

The access to NF-e database includes all invoices issued in 2018, de-identified but containing sufficient information to estimate the CFT. Each invoice includes: i) transaction participant information, seller and buyer sector codes derived from the International Standard Industrial Classification (ISIC), as well as their respective states and legal nature, allowing identification as public or private entities or even individuals; ii) transaction scope information: intrastate, interstate, import, and export; iii) tax characterization of the transaction: sale, purchase, cancellation, return, transfer, and fiscal operation; iv) product information detailed according to the Mercosur Common Nomenclature (NCM) product code, compatible with the International Harmonized System (HS); v) details on quantity, unit, unit price, freight value, and discounts per product; vi) detailed information on each product's associated taxes: tax base, rate, deductions, etc.; and vii) general invoice details, such as payment method and amounts paid.

This extensive volume of information necessitates specific treatment and adaptation for each type of information contained in the invoice. Although standardized, the NF-e requires adjustments in aggregation processes, particularly in transaction and product/activity classifications. For compatibility, the most disaggregated level of the Brazilian National Accounts System was used, encompassing 68 activities and 128 products. As the research aims to present the inter-regional Brazilian CFT, it covers all 27 federation units, including 26 states and the Federal District. All referred to in the research as states.

Beyond handling tax-related issues through classifications and the Brazilian tax legislation legal framework, it was also necessary to use the Broadcast Economic Classification (BEC) version 5.0 to determine which products should be categorized as gross fixed capital formation and, in some cases, in what proportions.

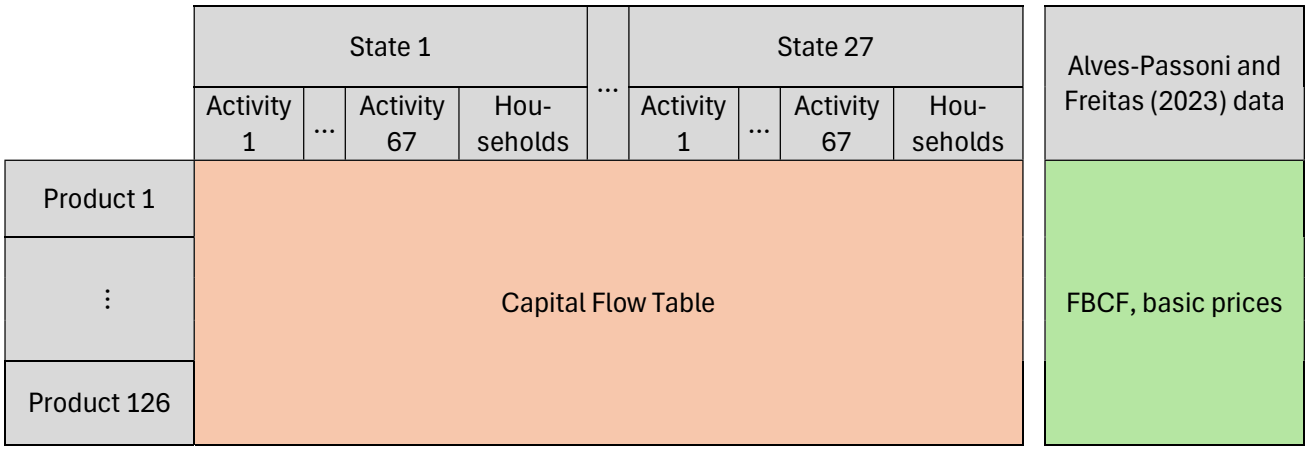
Therefore, from the necessary aggregations and value adjustments based on transaction types (sales, cancellations, returns, transfers), the following information was extracted from the NF-e for national and import transactions: i) seller's economic activity, legal nature, and federation unit of sale; ii) the same for the buyer; iii) traded products, limited to those classified according to BEC 5.0; iv) transaction value net of discounts; v) specific freight value per product; and vi) total value of all taxes.

4 Methodology: Constructing an Interregional Capital Flow Table from NF-e data

The NF-e data detailed in the previous section can now be used to disaggregate the GFCF by economic activity/institutional sector and Brazilian state. While the official data published by the Brazilian Institute of Geography and Statistics (IBGE) only provide total investment (GFCF) disaggregated by 128 products, the maximum level of disaggregation that IBGE publishes in its reports. Our work estimates the economic activities (and households) that demanded these products and in which states, informing the data in a way that is compatible with the 2018 input-output table for Brazil estimated by Alves-Passoni and Freitas (2023), also based on IBGE reports. Although two tables were constructed, one for national FBCF and the other for imports, the procedure for building both tables was fairly similar.

The main goal is to create composition tables that, when multiplied by the aggregated vector of GFCF, produce matrices compatible with the original data presented in Alves-Passoni and Freitas (2023), which were based on official sources. Figure 1 provides a simplified representation of the capital flow table. Alves-Passoni and Freitas (2023) present the total GFCF vectors for 126 products, both national and imported. Our work disaggregates these vectors into matrices of 126 products for 67 economic activities (plus households) in 27 states.

Figure 1: simplified representation of the capital flow table



Source: own elaboration.

Of the 126 products listed by Alves-Passoni and Freitas (2023), only 34 are considered GFCF. Sixteen of those can be found in the electronic invoice data. The remaining 18 products were classified as unitary (11), since they are characterized as being exclusively demanded by a specific sector, or general allocation (7)[1], which should be distributed among the demanding activities according to the demand share. The methodology employs specific procedures for each case.

[1] The list of products for each case is in Annex 1.

First, we estimate the composition table directly from the NF-e data. Second, we focus on estimating the composition tables of products that are used as capital goods by only one activity. Third, we estimate the demand for products used as capital goods by a wider range of activities. The total composition table is the sum of the previous three tables.

4.1 Products available in the NF-e

Of the 34 GFCF products considered, we have detailed administrative records of transactions for 16 products available in the NF-e, most of which are *industrial* capital goods. We can determine whether these products were purchased by firms or households, and in which state the transaction occurred. Based on this information and by subtracting the freight and tax values from the invoice informed totals to correspond to the basic prices, we construct a table with a structure similar to Figure 1. All the data in this table is based on the nominal values reported on the invoices.

To transform this matrix into a composition table, we divide each element in a row by its respective row total. This ensures that the sum of the elements in each row equals 1. The resulting matrix is referred to as the $\boldsymbol{N}$ matrix.

This is the most important and simplest step in the methodology because, once the adjustment and pre-processing described in the previous section are complete, fewer simplifying assumptions are required than in the other stages. Additionally, the composition table based on invoices does not require other data sources, such as sectoral surveys.

Estimating the sectoral and regional demand for the remaining 18 products depends on external data and simplifying hypotheses, which will be explained below.

4.2 Unitary allocation

Demand could not be estimated for 18 products using the electronic invoice. Eleven of these products have specific sectoral demand, and the remaining seven have broader use. Although these product sets were treated differently, a common question remains: How can we establish broad distribution of GFCF demand between households and other institutional sectors (which are distributed among economic activities)?

To address this issue, a simplifying hypothesis was adopted for products under general and unitary allocation, assuming that institutional sectors' relative demand for investment is proportional to their respective relative production by economic activity (For example, if households produce 41.8% of the agricultural output, as shown in Table 1, then they will account for 41.8% of total activity investment).

Additionally, in the case of unitary allocation, products were considered to be demanded by only one activity. Thus, the distribution of products could be inferred by the activity's demand. For example, if households produced 41.8% of agricultural output and responded with 41.8% of the activity's investment, as previously hypothesized, then they would demand 41.8% of orange products *as capital goods*. Thus, the distribution of production among institutional sectors and activity groups determines the demand for specific capital goods.

Table 1: Institutional sector production by economic activity, 2018, BRL millions

Economic activity groups	Households	Relative production	Other institutional sectors	Relative production	Total
01 Agriculture	245,791	41.8%	342,075	58.2%	587,866
02 Extractive industries	570	0.2%	355,978	99.8%	356,548
03 Manufacturing industries	69,066	2.1%	3,253,133	97.9%	3,322,199
04 Electricity and gas, water, sewage, waste management activities	1,734	0.4%	403,625	99.6%	405,359
05 Construction	218,100	39.5%	333,973	60.5%	552,073
06 Commerce	171,376	13.2%	1,124,296	86.8%	1,295,672
07 Transport, storage and mailing	85,365	14.1%	520,141	85.9%	605,506
08 Information and communication	17,074	4.3%	378,992	95.7%	396,066
09 Financial, insurance and related services activities	4,085	0.6%	644,924	99.4%	649,009
10 Real estate activities	580,630	90.8%	59,122	9.2%	639,752
11 Other service activities	423,260	23.7%	1,364,125	76.3%	1,787,385
12 Public administration, defense, health and education, and social security	0	0%	1,412,575	100%	1,412,575

Source: own elaboration based on data from Synoptic Table 17 of the National Accounts, published by IBGE.

Table 1 is derived from Synoptic Table 17, published by IBGE. This source provides data on production by institutional sectors, organized into broad groups of economic activities. Based on this information, the proportional contribution of households and other institutional sectors to total production was calculated for 12 economic activity groups. The 67 activities identified in the work of Alves-Passoni and Freitas were then mapped to these 12 groups. Finally, the products in the unitary allocation were classified according to the 67 activities, establishing a correspondence between the 11 products of the unitary allocation and the 12-group activity classification.

The next step is to allocate the value attributed to institutional sectors other than households across the 67 activities. To do this, the first hypothesis presented in this section was applied once again: investment demand is distributed among activities in proportion to their gross production value.

Finally, to distribute these products in each activity among the states, data from the IBGE regional accounts system were used, which discloses the gross production value, intermediate consumption and value added for 18 activities at the state level. This information was used as market share to calculate the proportion of each activity in each state, expanding the 18 activities from the regional accounts to the 67 activities estimated through a translator, applying it at the national level.

This results in a structure similar to that shown in Figure 1, but applied to the eleven products of interest. We can then divide each element in the rows by its respective row total, yielding the composition table for the unitary allocation products.

4.3 General allocation

Although only seven products are allocated more broadly, they play a crucial role in GFCF. In particular, the three construction-related products have a significant impact on the overall value of the GFCF and should be analyzed separately.

As a simplifying assumption, it is considered that the construction activity produces only the construction product, a reasonable assumption based on Brazilian data. Conversely, it is also assumed that the construction product is produced exclusively by the construction activity, which is likewise consistent with the Brazilian context. These assumptions allow us to infer a close relationship between the characteristics of the construction activity and those of the construction product.

As shown in Table 1, households account for a significant share of total construction activity production. Here, we assume that households demand all the construction they produce, that is, they do not sell construction to other institutional sectors. Instead, they build exclusively for their own use or for sale to other households.

However, households do not produce all three construction-related products. Among these (buildings, infrastructure, and specialized construction services) we assume that households produce only buildings. Infrastructure projects and specialized construction services are assumed to be produced and demanded exclusively by other institutional sectors.

Similarly, the development of systems and other information services, as well as research and development, are assumed to be produced and demanded only by institutional sectors other than households.

Finally, the sectoral distribution between households and the rest for wholesale and retail trade, as well as for cargo transport (land and water), follows the distribution of the commerce and transport, storage, and mailing activities, respectively, as presented in Table 1.

Unlike the unitary allocation, the investment corresponding to institutional sectors other than households must be distributed across multiple economic activities. This distribution is based on the gross production value of each activity, which is used as a weight for allocating investment demand.

However, as in the unitary allocation, data from the regional accounting system with 18 products were used to weight the participation of these activities in each of the states. In a manner analogous to that explained in the previous section, the number of activities was expanded from 18 to 67 and this weighting was applied to the states

This results in a structure similar to that shown in Figure 1, but applied to the seven products of general allocation. By dividing each element in the rows by its respective row total, we obtain the composition table for the general allocation products.

4.4 Capital flow table

The total composition table is therefore the result of the sum of the three tables: i) the table obtained directly from the NF-e data; ii) the composition table of products that are used as

capital goods by only one sector of activity; and iii) the table containing the estimated demand for products used as capital goods by a wider range of sectors of activity.

Two total composition tables were obtained, one for imported goods and another for national goods. Each of them was multiplied by the vectors estimated by Alves-Passoni and Freitas (2023). In this way, the two matrices that represent the demand of each activity in each state for each product were obtained. Although two tables were constructed, one for the national GFCF and another for imports

5 Results: The structure of Brazilian interregional capital flows in 2018

The resulting capital flow table is a detailed matrix comprising 34 products used for GFCF, with demand disaggregated by 67 economic activities (plus households) and 27 states. This data enables in-depth analysis of Brazil's investment patterns. However, given the scope of this work, such analyses will not be undertaken here and are left for future studies. To illustrate the richness of the data, Figure 2 and Figure 3 present the demand for domestically produced and imported capital goods by state, respectively.

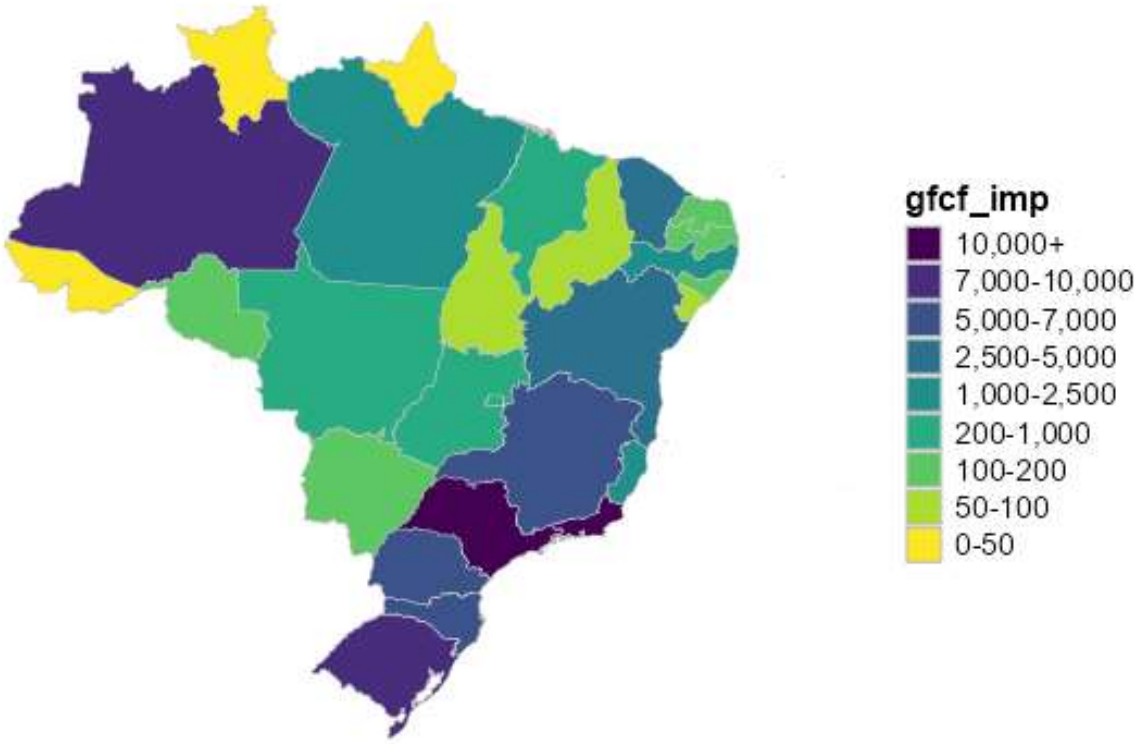
Figure 2: Demand for domestically produced capital goods by state, 2018, BRL billions

Source: Own elaboration based on Brazilian electronic invoice (NF-e) and Brazilian national and regional accounts data.

Figure 2 shows that demand for domestically produced capital goods is concentrated in Brazil's southeastern region, which includes the country's wealthiest states: São Paulo, Rio de

Janeiro, and Minas Gerais. The southern region follows, also composed of relatively affluent states. Notably, parts of the Midwest, such as Goiás, with its strong presence in agribusiness, are gaining prominence. In the Northeast, the state of Ceará stands out, followed by Bahia due to its role in the expanding agribusiness frontier and its importance in tourism. The lowest levels of investment are observed in the North, with the exception of the state of Pará.

Figure 3: Demand for imported capital goods by state, 2018, BRL millions



Source: Own elaboration based on Brazilian electronic invoice (NF-e) and Brazilian national and regional accounts data.

Figure 3 presents the demand for imported capital goods by state, which generally follows a pattern similar to that observed in Figure 2 for domestically produced capital goods. The main exception is the state of Amazonas, which stands out for its significant demand for imported capital goods despite playing a relatively minor role in the demand for domestic capital goods.

This divergence is largely explained by the Zona Franca de Manaus (Manaus Free Trade Zone), an industrial hub located in the capital of Amazonas. Established in the 1960s, the Zona Franca offers tax incentives and other benefits to attract manufacturing companies, particularly those in electronics, motorcycles, and other high value-added sectors. These industries rely heavily on imported machinery and equipment, which explains the state's outsized share in the demand for imported capital goods.

The data shown in the previous figures refer to overall investment in Brazil in 2018. However, the detailed information provided by this study allows for a more refined analysis, disaggregated by 34 products and by 67 economic activities plus households, offering a highly granular view of investment structure across the country.

6 Conclusion

This study developed regional capital flow tables for both domestically produced and imported capital goods, using data from Brazil's electronic invoicing system (NF-e) as its primary source. The use of NF-e data simplifies the estimation methodology while significantly enhancing the level of detail and accuracy, representing a meaningful contribution to previous efforts in this field.

Despite its richness and relevance, the NF-e system presents some limitations for estimating GFCF. The most notable is the absence of certain key capital goods, particularly those related to construction activities, which are not well captured in the invoicing data.

Future research will aim to address this gap by exploring the possibility of development of proxies for the demand for capital goods related to construction, using indirect indicators available in the NF-e, such as the purchase of construction-related inputs.

Additionally, subsequent studies building on this line of research will explore the application of these detailed capital flow data in dynamic economic models, enabling more nuanced analyses of investment behavior and its macroeconomic implications across regions and sectors in Brazil.

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Annex

Annex 1: GFCF products classified according to the methodology

Classification	Code	Description
Available in NF-e	01921	Cattle and other live animals, animal products, hunting and services
	01923	Pigs
	25001	Metal products, excluding machinery and equipment
	26002	Office machines and computer equipment
	26003	Electronic material and communications equipment
	26004	Optical and electromedical measuring, testing and control equipment
	27001	Electrical machines, devices and materials
	27002	Home appliances
	28001	Tractors and other agricultural machinery
	28002	Machines for mineral extraction and construction
	28003	Other mechanical machinery and equipment
	29911	Cars, vans and utility vehicles
	29912	Trucks and buses, including cabins, bodies and trailers
	30001	Aircraft, vessels and other transport equipment
	31801	Furniture
	31802	Products from various industries
Unitary allocation	01917	Orange
	01918	Coffee beans
	01919	Other permanent crop products
	01924	Birds and eggs
	02801	Products from forestry and silviculture
	06801	Oil, natural gas and support services
	16001	Wooden products, excluding furniture
	24912	Semi-finished, flat rolled, long and steel tubes
	26001	Electronic components
	33001	Maintenance, repair and installation of machinery and equipment
	71802	Architectural and engineering services
General allocation	41801	Buildings
	41802	Infrastructure works
	41803	Specialized services for construction
	45801	Wholesale and retail trade
	49001+50001	Cargo transport (land and water)
	62801	Development of systems and other information services
	71801	Research and development

Source: own elaboration.