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How do taxes react to changes in prices and economic activity? A case study for the state of Ceará

Gabriel Dantas[1], Paulo Matos[2], Paulo da Costa[3]
[1](CAEN Graduate School of Economics, Federal University of Ceará, Brazil)
[2](CAEN Graduate School of Economics, Federal University of Ceará, Brazil)
[3](CAEN Graduate School of Economics, Federal University of Ceará, Brazil)

Abstract:. *Starting from the inquiry about the impact of economic activity and inflation on the revenue of different segments of the Tax on operations related to the circulation of goods and on the provision of interstate, intermunicipal and communication transport services (ICMS) in the State of Ceará, this study uses Bayesian VAR to investigate the relationship between these variables over a period of twenty years, from 2003 to 2023.*
Background*: Brazil is a federation with twenty-seven federative units. These units, called States, have a set of powers determined by the Federal Constitution regarding their revenues and expenses. The largest source of revenue for the States is the ICMS. Investigating the impacts of Economic Activity and Inflation on the various ICMS segments is extremely important to support government decisions.*
Methodology*: This article uses Bayesian VAR to analyze how inflation and economic activity affect the collection of different ICMS segments in the State of Ceará between 2003 and 2023.*
Data*: Used monthly collection data from the different ICMS, Inflation and Economic Activity segments, between 2003m1 and 2023m12.*
Results*: The results of the analyzes show that local and national inflation impacted the collection of different ICMS segments throughout the period. Economic activity presented significant results only in relation to the Retail Trade sector. Furthermore, using the impulse response, the Retail Trade sector was the only one capable of positively influencing the Wholesale Trade, Industry and Fuel sectors.*
Conclusion: *Understanding the dynamics between tax collection and other economic variables is crucial for policymakers to formulate the most effective strategies. A clearer grasp of how ICMS collection behaves in response to changes in inflation and economic activity can support the State of Ceará in improving its public revenue and expenditure planning.*
Key Word*: Taxes. State Collection. ICMS. Autoregressive Vectors.*

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I. Introduction

Brazil is a federation composed of twenty-seven federative units called States. In this form of State, there is a division of responsibilities among different levels of government. According to Abrucio and Franzese (2007), federation is an agreement that establishes a sharing of territorial sovereignty, where autonomous entities have contractual relationships. In Brazil, the autonomous entities are the Union, the States, and the Municipalities. The States, including Ceará, have rights and obligations related to the collection of their revenue and the composition of their expenses. In the Brazilian State, the Federal Constitution of 1988 established the general principles of Taxation and the Budget, in addition to regulating the competencies of each Entity. This system aims to guarantee federative autonomy and meet the specific needs of the different spheres of government.

Regarding revenues, following the premise of fiscal federalism, the authority for collecting taxes is divided among the Union, the States, and the Municipalities. In this division, the States are responsible for instituting and collecting three taxes: Tax on operations related to the circulation of goods and on the provision of interstate, intermunicipal and communication transport services (ICMS), motor vehicle ownership tax (IPVA), and death and donation transmission tax (ITCD). ICMS is the tax that accounts for the largest share of State revenues. Data from the Ministry of Finance show that in 2023, ICMS accounted for 82.4% of state tax revenue. According to Azevedo, Da Silva and Gatsios (2015), around 20% of total tax collection in Brazil comes from ICMS. Currently, the National Congress is discussing a tax reform that proposes to unify the ICMS and the tax on services levied by Municipalities, but this transition is not expected to be completed until 2033.

ICMS is an indirect tax charged on the circulation of goods and services. Given its relevance as a source of financial resources for the States, its collection is extremely important for state governments. According to Giambiagi and Além (2017), considering that government entities require resources to implement their policies,

tax revenue is the primary source of income for the public sector. The ICMS resources collected are used to finance the various services provided by the State, including health, education, public security, social security, among others.

Comparing state governments, data from the Brazilian Institute of Geography and Statistics (IBGE) reveals that Ceará ranks 17th in territorial extension, 10th in population, and 13th in GDP. The Ministry of Finance reports that Ceará's total tax collection in 2023 amounted to R$ 19.1 billion, with ICMS collection accounting for 89.43% of this total.

ICMS collection in Ceará is categorized into segments such as fuels, energy, wholesale trade, retail trade, industry, communication, and others. Analyzing data from the Ceará State Department of Revenue for the period between the third quarter of 2003 (2003Q3) and the third quarter of 2023 (2023Q3) reveals a shift in the revenue share of each segment.

In 2003, the fuel segment (26%) held the largest share, followed by ICMS industry (24.7%), while electricity generated the lowest revenue (7.2%). By 2023, wholesale trade (24.6%) emerged as the top contributor, followed by ICMS industry (22.4%). Communication, on the other hand, represented the smallest segment (2.8% of total revenue). This shift in the sectoral profile over the analyzed period reflects not only structural changes within Ceará, but also the impact of major events like the COVID-19 pandemic on productive structures.

Due to the relevance of collecting this tax to make public spending viable, studying its relationship with other economic variables is very important to determine the strategies that will be used to provide more efficient public policies. According to Castanho et al. (2011) the forecasting and control of tax revenues has seen great growth in the academic environment and has attracted the attention of the political class and Research Institutes. Marques and Uchôa (2006), Clemente and Clemente (2011), Scheffer, Souza, and Zanini (2014), and Pessoa, Coronel, and De Lima (2013) exemplify this trend by employing statistical models to predict ICMS collection in various Brazilian states.

Several economic variables are frequently examined in studies on ICMS, including inflation, economic activity, and tax rates. For instance, Silveira and Gadelha (2020) investigate the sensitivity of ICMS collection to economic activity and tax rates. Their study concludes that stimulating economic activity contributes more significantly to ICMS collection than increasing tax rates. Batista and Da Cruz (2019) analyze the influence of vulnerability factors and anticipation capacity on the coping ability of Brazilian states during the 2007-2016 period, encompassing the 2008 financial crisis and the recent Brazilian economic recession. Their findings regarding vulnerability indicate that states with greater budgetary rigidity and dependence on federal transfers experience a larger negative impact on their own revenues during economic crises. Conversely, the capacity to generate savings in pre-crisis periods showed a negative association with variations in own revenues, suggesting that states with higher savings capacity were less affected by economic downturns.

In another study, Augusti, Rodinei et al (2021) measure the elasticity of ICMS collection in different sectors of the economy in the State of Rio de Janeiro (2nd largest GDP in Brazil among the States) between 1997 and 2019. The authors sought to identify which Investments in these sectors should be prioritized to optimize state tax collection. Collection data from the primary, secondary, tertiary, energy and oil sectors are used. The study shows that the secondary, tertiary, energy and oil sectors have positive elasticities, that is, the increase in revenue in the sector tends to increase total revenue, while the primary sector has negative elasticity.

Benson and Johnson (1986) examine the relationship between taxes and economic activity. The authors emphasize interstate tax competition and conclude that taxes negatively affect economic activity. Bartik (1992) discusses the relationship between state and local taxes and economic development. According to the author, local and state taxes have significant negative effects on economic growth.

In this sense, this article investigates how the level of economic activity and inflation impact the collection of different ICMS segments in the State of Ceará. Furthermore, understand the relationships between the collection segments and how they relate to each other.

The results obtained are extremely relevant for the State of Ceará as they offer support for governments to make more accurate predictions about ICMS collection over time. Furthermore, better understanding the dynamics of revenue allows governments to better plan their spending and thus implement more efficient and consistent public policies.

II. Methodology

In this paper, we apply Bayesian Time Varying Coefficient Vector Autoregression (BTVCVAR) model for the analysis. This framework arises from the combination of Time Varying Coefficient Vector Autoregression (TVCVAR) and the Bayesian approach. However, before this discussion it is important to quickly review the Vector Autoregression (VAR) model. First introduced by Sims (1980), the VAR captures the dynamic between time series. Precisely, the model considers its own data and lagged info in the process. One can also include exogenous variables, if that is the case. The model is denoted by

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_k y_{t-k} + u_t \quad (1)$$

where μ is a vector representing the constant terms, A_i are the coefficients matrix and u_t is error term following a normal distribution with zero mean and covariance matrix S. It seems hard to sustain the argument that VAR parameters hold constant over time. Instead, it is reasonable to believe that the parameters switch along the period analyzed. To solve this issue, the TVCVAR model allows the coefficients to vary enabling the relationships between variables dynamically change over different time periods. This approach is composed of two equations: observation and process. The observation equation is like VAR equation except by the time subscript attached to the coefficients

$$y_t = \mu + A_{1,t} y_{t-1} + \cdots + A_{k,t} y_{t-k} + u_t \quad (2)$$

As we make coefficients vary, another problem occurs: overparameterization. We can amend this situation by considering this random walk procedure:

$$A_{i,t} = A_{i,t-1} + e_t \quad (3)$$

where the $e_t \sim N(0, Q)$ is the error term. Equation (3) is the process equation. The first element of this procedure, $A_{i,0}$, is considered as part of the prior specification - which will be explained next.

The addition of the Bayesian inference to the VAR model was stablished by the seminal papers of Doan, Litterman and Sims (1984) and Litterman (1986). Some advantages of the Bayesian VAR are to deal with overparameterization and small sample sizes. The model shows to have great forecast performance even with many variables. The Bayesian background in these models comes from the Bayes' rule (see Woźniak, 2016). In short, given a set of parameters to be estimated θ and let Y represent the data used on the estimation, the Bayes' rule is given as

$$p(\theta|Y) = \frac{p(Y|\theta)p(\theta)}{p(Y)} \quad (4)$$

The LHS of the equation (2) is the Posterior Distribution. The numerator on the RHS is the product between the Likelihood Function and the Prior Distribution, which is the joint distribution of the data and parameters. On the denominator we have the marginal data density which is $p(Y) = \int p(Y|\theta)p(\theta)\, d\theta$. The specification of the prior distribution needs to represent previous information the researcher has about the parameters. The stronger the belief is the lesser is the chance the parameters to be the ones desired by the data and vice-versa. As explained before, the BTVCVAR combines the TVCVAR with a prior distribution. By setting the prior we shrink the model to a simpler version. Specifying a prior where the process error variance is zero turns the TVCVAR into a single VAR model, for example. Shrinking the model towards the basic VAR to some extent estimates parameters that vary smoothly. Knowing that A represents the coefficients vector and considering the initial state A_0 and the covariance matrices S and Q, the prior is defined as

$$p(A_0, S, Q) = p(A_0)\, p(S)\, p(Q) \quad (5)$$

Combining the prior distribution with the likelihood function forms the posterior distribution from where coefficients come from the following equation, which is an alternative representation of the Bayes' rule.

$$p(b,\, S,\, Q \mid y|) \;\propto\; p(b_0\,,\, S,\, Q) \prod_{t=1}^{T} f(y_t \mid b_t,\, S) f(b_t \mid b_{t-1},\, Q) \quad (6)$$

where $\propto$ denotes proportionality up to the normalizing constant, which means the marginal data density. The terms on the RHS of the proportionality symbol are, respectively, the prior distribution, the observation equation and the process equation. This derivation is possible thanks to Gibbs sampler method, which is a Markov Chain Monte Carlo (MCMC) method to draw samples from the posterior distribution. The Gibbs sampler iterates through sampling each parameter conditional on the current values of the other parameters[1].

[1] The BTVCVAR estimations were made on Eviews 13. The pre-setting of the prior hyper-parameters associated to A_0, S, and Q are: T0 = 0, tau0 = 5, tau1 = 1, tau2 = 0.01, nu1 = 7, nu2 = 5. The burn-in size is 5000.

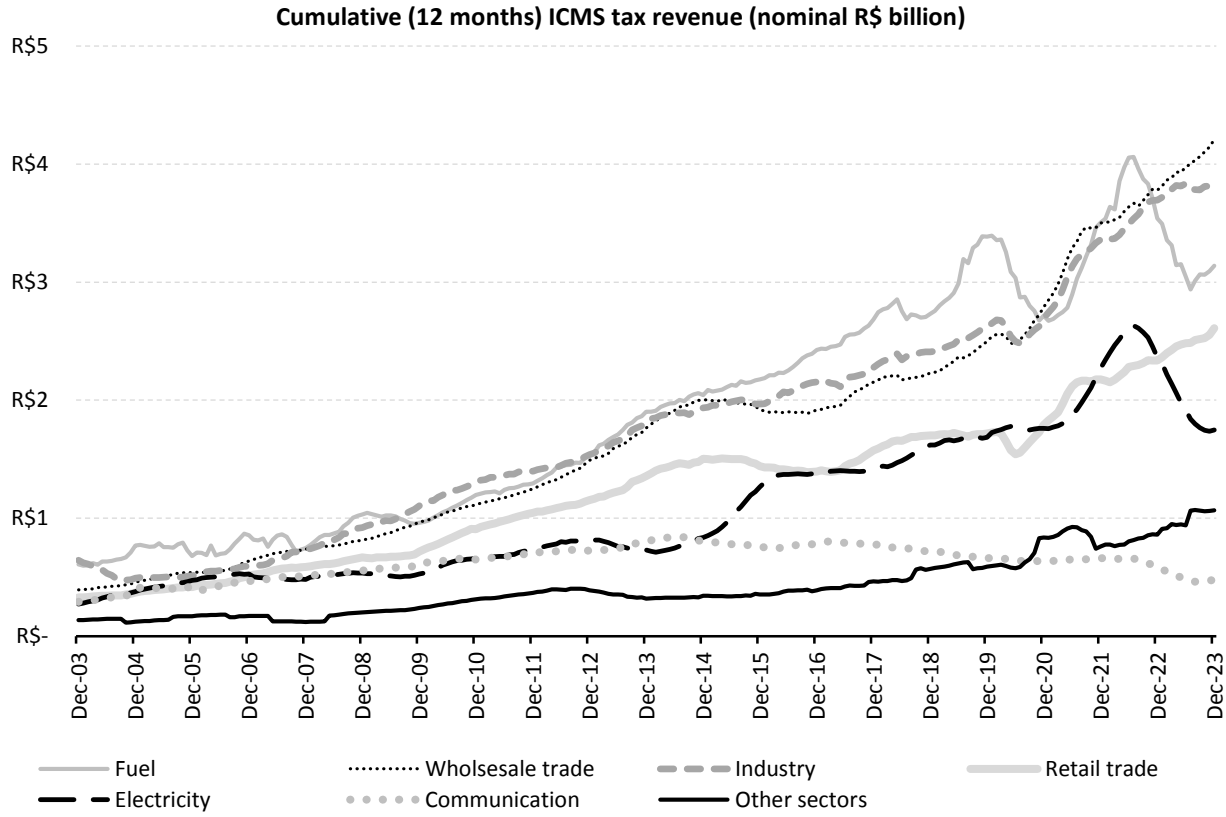
III. Result

Summary statistics

In Brazil, ICMS is the main tax, the main source of tax revenue for the 27 state governments, including the Federal District. In 2023, for example, governments have collected R$703 billion from ICMS. As it is the main state tax, managing its collection is fundamental to the state government's revenue autonomy.

In Ceará, looking at data from the last two decades, we can see that the ICMS in 2003 was R$2.7 billion, while the collection in 2023 was almost R$17.1 billion. In nominal terms, without considering inflation, we have an average annual growth of 9.7%. In real terms, deflated by official inflation (IPCA), we have an average annual growth of 3.8% over these 20 years.

Figure 1 shows the evolution of accumulated ICMS (12 months, moving window), by sector, in current values, without correction for inflation. We considered the 6 most relevant economic sectors in revenue and the residual sectors were aggregated under the heading "other sectors".



Based on the coefficient of variation of the accumulated monthly series, the sectors with the most volatile revenue were Other sectors (0.61), Wholesale trade (0.59), and Electricity (0.58). The least volatile was the Communication sector (0.22).

Among these sectors, only communication showed nominal growth below the accumulated inflation in the period, i.e., negative real growth (-3.1%). The average annual real growth rates were: Wholesale trade (6.5%), Retail trade (4.9%), Other sectors (4.8%), Electricity (3.8%), Industry (3.4%) and Fuel (2.7%).

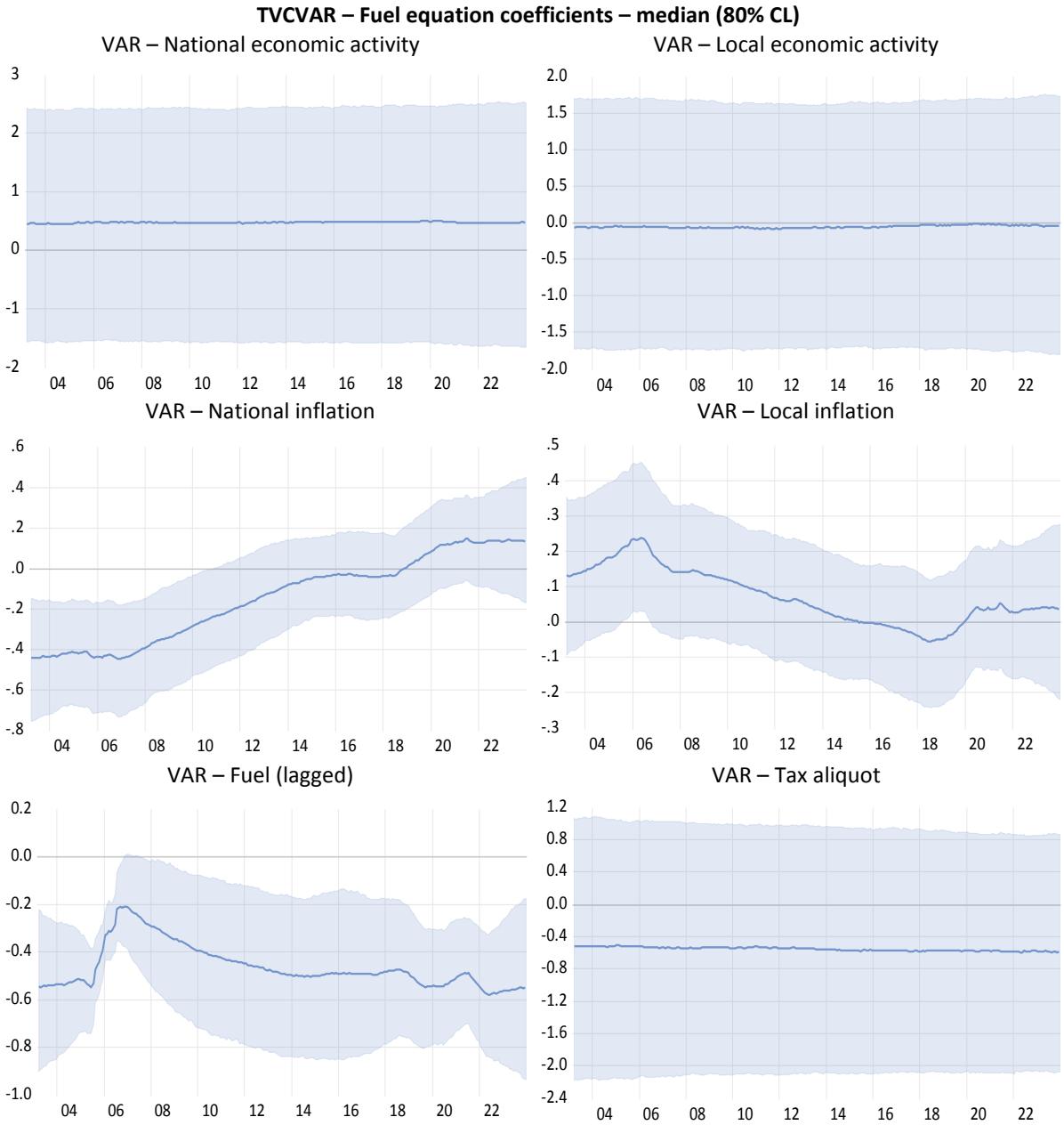
It is noteworthy that since July 2022, the collection of the fuels and energy segments has declined due to new national legislation that capped the tax rate for these segments, negatively impacting revenue across all states.

Looking at last year's market share, the Wholesale trade sector collected 24.6% of the total ICMS. Next, Industry (22.4%), Fuel (18.4%), Retail Trade (15.3%), Electricity (10.2%), Communication (2.8%). Other sectors raised 6.2% of the R$17.1 billion in 2023.

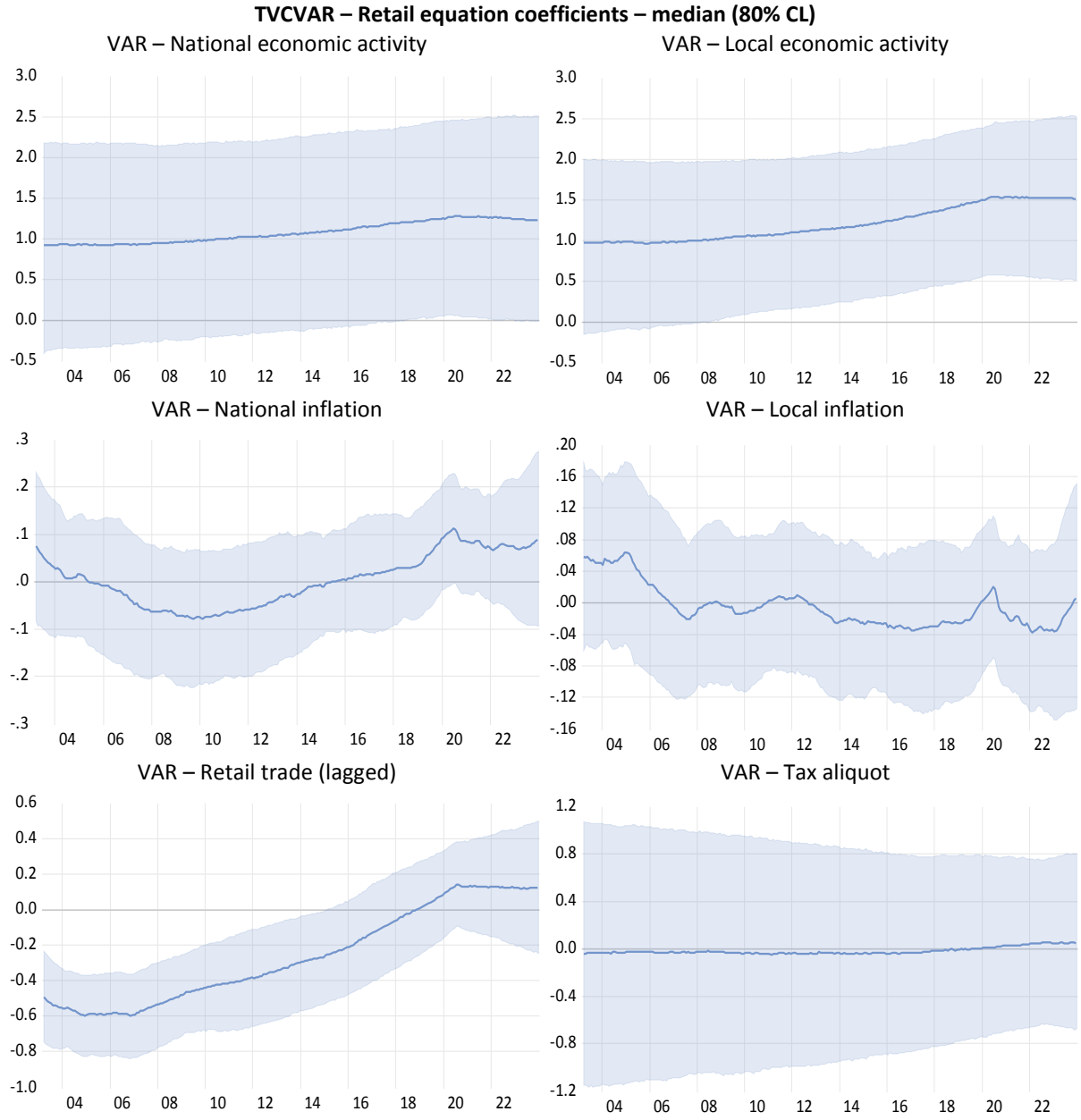
Main VAR Results by Sector

In this section, we report our main results, i.e., the equation coefficients for each sectoral ICMS from the beginning of 2004 to the end of 2023. For each sector of the economy, we will report the results in the same way. In each graph, the blue line represents the coefficient associated with the explanatory variable, varying over time,

estimated via Bayesian VAR. The light blue area represents the confidence interval, based on a 10% significance. The explanatory variables are the seasonally adjusted monthly variations of: national (IPCA) and local (IPCA For) prices, national (IBC BR) and local (IBCR CE) economic activity, and aggregate variation in ICMS rates. In Figure 2, we report the results for the Fuel sector. We find that variations in economic activity, both national and local, do not affect the variation in tax collected. National inflation (IPCA) negatively affects revenue until 2012, with an elasticity of up to -0.4, while local inflation affects positively between 2005 and 2006, with an elasticity of up to 0.25. The endogenous lag affects negatively during the 20 years with elasticity between -0.2 and -0.55.

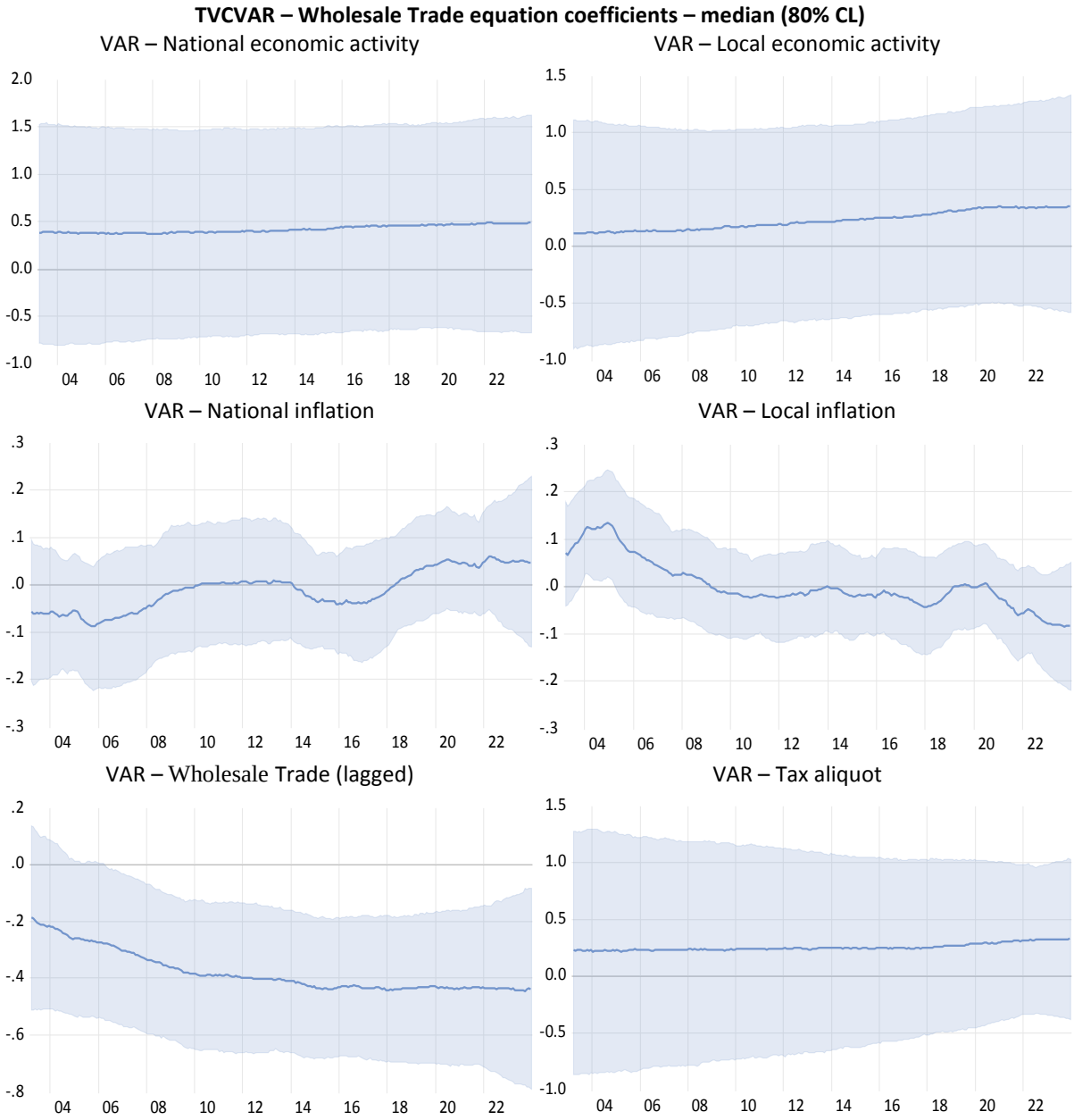


In Figure 3, we report the results for the Retail trade sector.



We find that variations in national economic activity affect positively the variation in tax collected during the period between 2017 and 2023, with elasticity up to 1.2. The variations in local economic also activity affect positively the variation in tax collected in the Retail trade sector during the same period, with elasticity up to 1.4. National and local price changes are not able to drive tax change. The endogenous lag affects negatively from 2004 to 2015, with elasticity between -0.2 and -0.6.

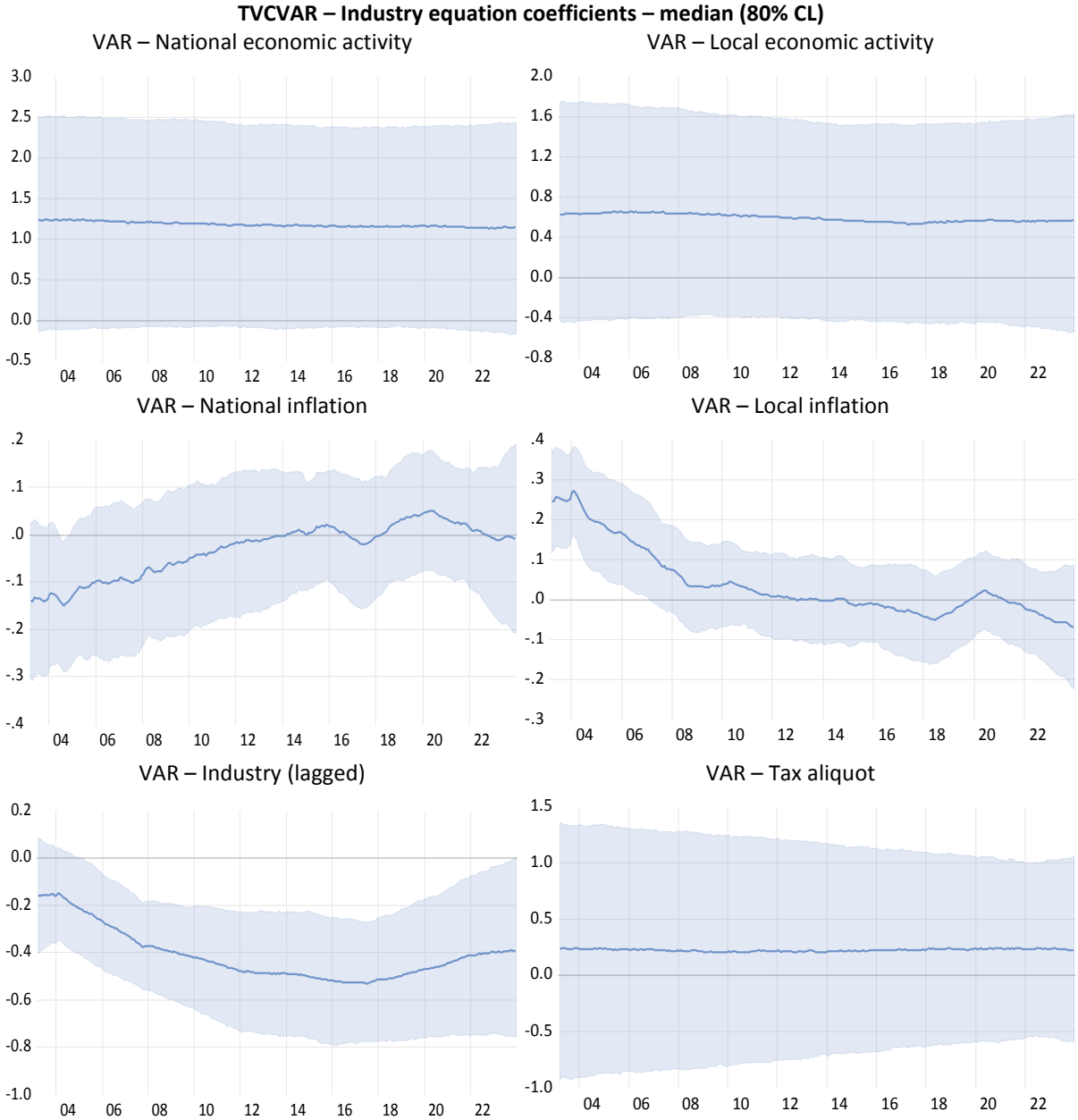
In Figure 4, we report the results for the Wholesale trade sector.



We find that only variations in local prices (IPCA For) seem to be able to drive changes in tax revenue, from 2004 to 2005, in the same direction, with elasticity up to 0.15. We do not find a significant role played by economic activity, national nor local.

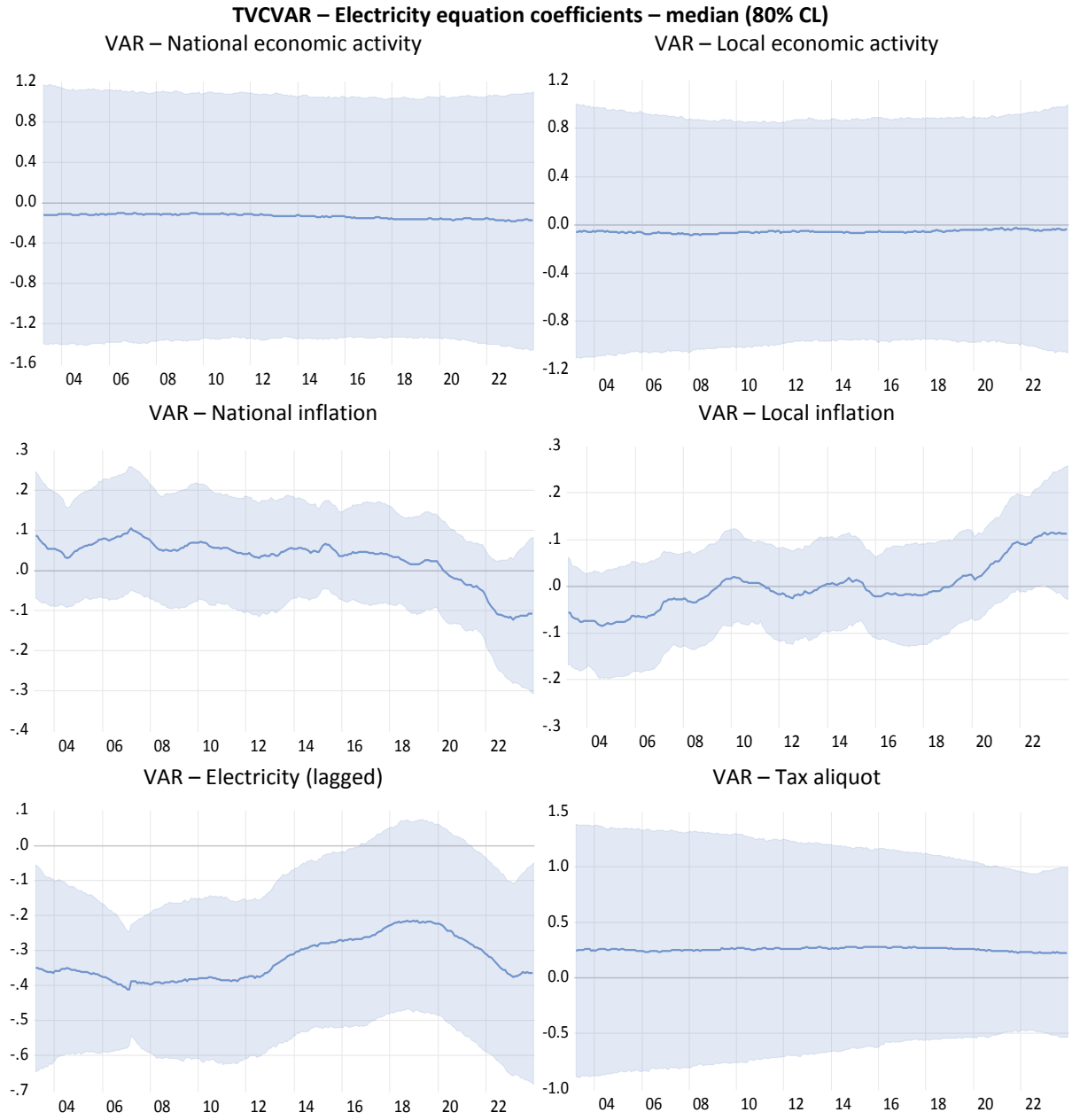
The endogenous lag affects negatively from 2006 to 2023, with elasticity between -0.25 and -0.5.

In Figure 5, we report the results for the Industry sector.



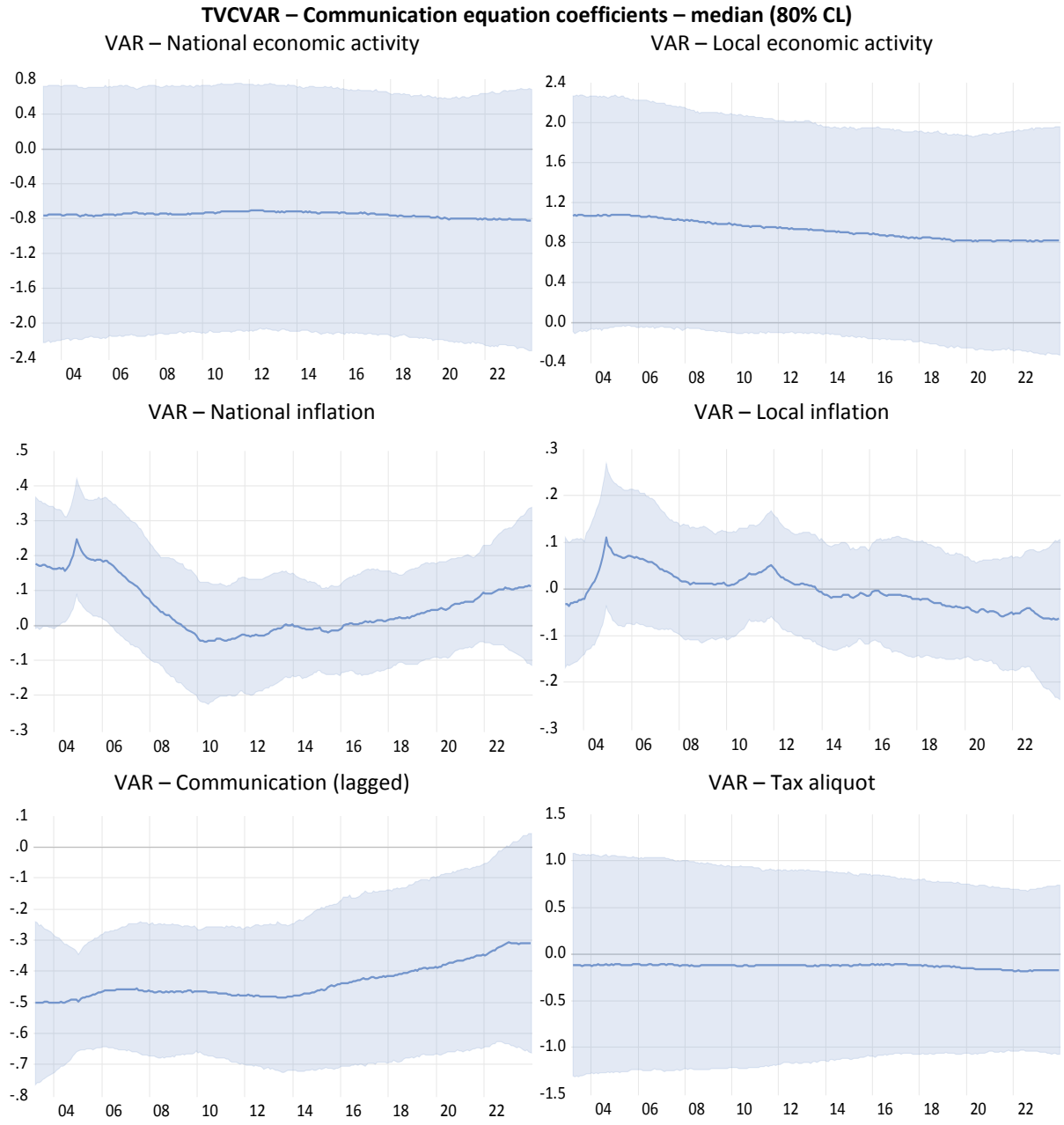
We find that variations in economic activity, both national and local, do not affect the variation in tax collected. National inflation (IPCA) negatively affects revenue from 2004 to 2005, with an elasticity close to -0.15, while local inflation affects positively between 2004 and 2006, with an elasticity ranging between 0.1 e almost 0.4. Once more, the endogenous lag affects negatively from 2005 to 2023 with elasticity between -0.2 and -0.55.

In Figure 6, we report the results for the Electricity trade sector.



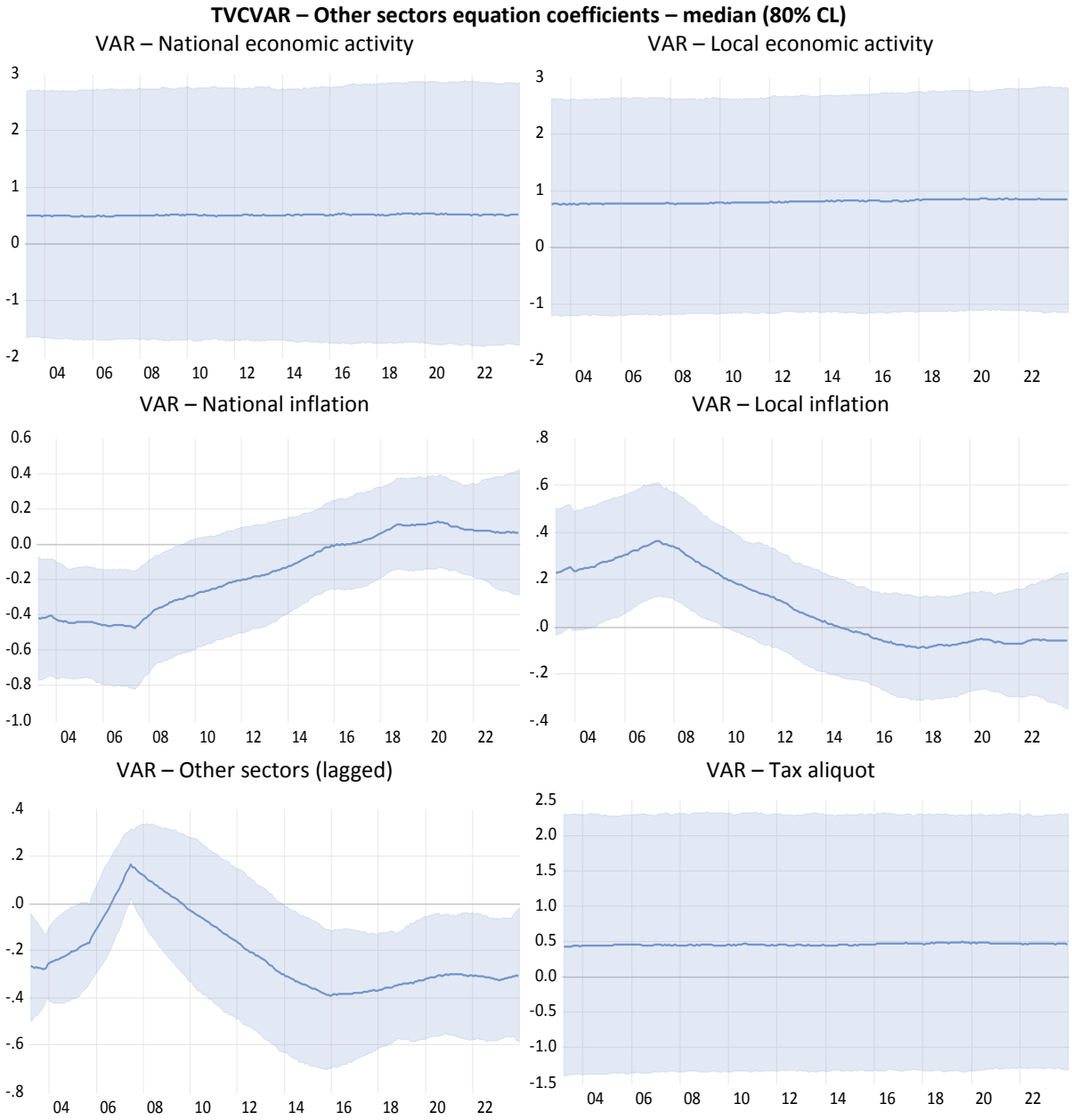
We find that variations in economic activity, both national and local, do not affect the variation in tax collected. Local inflation affects positively in the last years of the sample, with an elasticity close to 0.1. Once more, the endogenous lag affects negatively, but now over two different periods, from 2004 to 2016 and after 2021, with elasticity between -0.25 and -0.4.

In Figure 7, we report the results for the Communication trade sector.



We find that variations in economic activity, both national and local, do not affect the variation in tax collected. Communication is the unique sector in which national inflation is able to affect positively. It happens in 2004 and 2005, with elasticity ranging between 0.2 and 0.25. Once more, the endogenous lag affects negatively from 2004 to 2022, with elasticity between -0.5 and -0.5.

In Figure 8, we report the results for the Other sectors.



We find that variations in economic activity, both national and local, do not affect the variation in tax collected. Local inflation affects positively over the period between 2005 to 2009 with an elasticity ranging between 0.20 and 0.4. National inflation also drives tax variation from 2004 to 2008, with elasticity ranging between -0.25 and -0.45. Once more, the endogenous lag affects negatively, but now over two different periods, from 2004 to 2005 and after 2014, with elasticity between -0.15 and -0.4.

Intra Sectoral Results:

The Time-varying coefficients Bayesian Vector Autoregressive enables us to measure the intra sectoral lagged effects, which is relevant based on a general equilibrium approach. Depending on the pass-through involving the sectors, it is intuitive and even expected a negative or a positive intra sectoral relationship.

In Table 1, we summarize only the statistical (10%) significative effects. The forty-two figures with all cross relationships are not reported here, aiming to save space but they are available upon request. Considering that there are forty-two possible bilateral relationships, we showed significant effects in fourteen of them, that is, 1/3. Most of the effects suggest a pass-through in the direction table, that is, a positive variation in one sector also

implying a positive variation in another sector in the following month. Only the electricity sector is not affected, and only the wholesale trade sector does not affect any others.

Table no 1: Intra-sectoral effects

	Affected sectors (t)						
Sector (t-1)	Fuel	Retail trade	Wholesale trade	Electricity	Industry	Communic.	Other sectors
Fuel						(2004-2005) Elasticity: 0.1 to 0.85	(2004-2005) Elasticity: 0.1 to 0.55
Retail trade	(2018-2023) Elasticity: 0.45 to 0.6		(2012-2023) Elasticity: 0.2 to 0.55		(2015-2023) Elasticity: 0.25 to 0.65		
Wholesale trade							
Electricity	(2004-2007) Elasticity: 0.35 to 0.45		(2004) Elasticity: -0.2 to -0.3				
Industry		(2004-2009) Elasticity: 0.2 to 0.55	(2004-2005) Elasticity: 0.2 to 0.25				
Communic.	(2005-2007) Elasticity: 0.05 to 0.3	(2004-2008) Elasticity: -0.15 to -0.25	(2005-2007) Elasticity: -0.1 to -0.15				(2004-2007) Elasticity: -0.35 to -0.5
Other sectors	(2005-2006) Elasticity: 0.1 to 0.2						

Impulse Response Results:

Finally, this technique also enables us to measure the accumulated response (Cholesky factor – one standard deviation) given an own or cross impulse. We find a significant positive effect in all analyzes considering own shocks, lasting between 6 and 12 two months, with an order of magnitude up to 0.15, except for other sectors, whose response was up to 0.3. Impulses in the Retail trade ICMS variation are capable of generating positive responses (below 0.1) of short duration (up to 4 bimonths) in taxes collected in the Wholesale trade, Industry and Fuel sectors.

IV. Discussion

To summarize, we find that national and local inflation are able to affect tax variation in some economic sectors, with significant and opposite effects at different periods of time and intensity. Regarding economic activity, variation in IBC-BR and IBCR-CE can positively influence only the variation of ICMS in Retail trade in the last years of the sample. Concerning the own lagged effects, in all sectors, we find that there is a mean reversion property of sectoral tax monthly variation. However, own response (accumulated) impulses are all significant positive and persistent for up to a year. There is evidence of several intra-sectoral lagged effects, with a predominance in the first years of the sample, with both signs, but with a positive effect in greater numbers. The Retail sector is the only one capable of influencing some of the other sectors via impulse response.

V. Conclusion

Public revenue and expenditure are extremely relevant topics in the economy. Efficient and effective collection allows more resources to be used for investments and the provision of public services. Therefore, revenue is crucial because, according to Ahuja and Pandit (2020), investment has a significant impact and positively influences economic growth. In this context, ICMS stands as the most important tax for Brazilian states. Due to its importance, the analysis of its relationships with other economic variables is very important for crafting public policies.

This paper employs Bayesian VAR to investigate the relationship between local and national inflation, in addition to local and national economic activity, with the collection of different types of ICMS, the most important tax for the States of Brazil.

Our findings indicate that during the initial sample years, National Inflation and Local Inflation exhibited opposing effects on ICMS collection. While National Inflation negatively impacted revenue, Local Inflation had a positive effect. Additionally, the results revealed that National and Local Economic Activity only exerted significant impacts on the collection of the Retail Trade segment.

The Impulse-Response test revealed that the retail sector was the only one capable of influencing other sectors. The test demonstrated that shocks in this sector can generate positive responses in the wholesale trade, fuels, and industrial sectors.

Data analysis allowed us to verify that throughout the period we have numerous behavioral profiles between the variables, varying according to the segment and period. Consequently, disaggregating the ICMS collection data by segment is considered a key methodological strength, enabling the acquisition of novel and insightful results. These findings provide valuable information regarding the sensitivity of ICMS collection to both inflation and economic activity. From the results obtained, detailed analyzes can be carried out for each period to verify the economic aspects that led to some revenue segments being more affected than others by inflation and economic activity, in addition to how they affected each other. Furthermore, the results constitute a useful database so that public policy makers can better plan their policies based on ICMS collection.

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