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# An Analysis for New Institutionality in Science, Technology and Innovation in Colombia Using a Structural Vector Autoregression Model

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***Abstract:***

***Purpose:*** *The purpose of this article is to analyze the strengths and the institutionality of the Ministry of Science Technology and Innovation (MSTI) in increasing investments in research and development as well as promoting the generation of knowledge.*
***Design/Methodology/Approach:*** *We use structural vector autoregression (SVAR) and structural vector error correction (SVEC) to examine the effects of institutionality in science, technology and innovation in the Ministry of Science, Technology and Innovation (MSTI) using three variables (i.e., investments in activities of science, technology and innovation (STIA), investments in research and development (R&D) and independence index).*
***Findings:*** *The results indicate that increasing the independence and transparency of the MSTI leads to higher investments in STIA and R&D over time. SVAR and SVEC models were used to assess the robustness and reliability of the results.*
***Practical Implications:*** *The results are important for assessing the effective governance and functionality of the new MSTI and its mission to adopt new policies and instruments that may strengthen science, technology and innovation in Colombia as the country migrates to a knowledge-based society.*
***Originality/Value:*** *In this context, Colombia opted to implement this model; using law 1951 of 2019, the country created this ministry. It is important to analyse the implications and key elements that allow the ministry to operate and achieve better investments to promote research, innovation, and the application of new technologies.*

***Keywords:*** *Science, technology, innovation, institutionality, structural vector autoregression model, Colombia.*

***JEL codes:*** *O30, O32, O38, C32.*
***Paper type:*** *Research article.*

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## 1. Introduction

Science, technology and innovation are recognized as the main pillars of development and economic growth. Countries that have increased investments in research and development and science, technology and innovation activities (STIA) have achieved higher development levels and higher levels of well-being among their populations. Thus, emerging economies should increase research and development as a strategy to strength their economies and sustainability.

In this context, governments should aim to harness and potentiate the benefits of science, technology and innovation (STI) as well as address, correct and prevent market failures by endeavouring to increase investments in STIA and research and development (R&D), which are key elements for promoting development, growth and effective solutions for the country's problems. Governments can achieve this goal by developing a national STI policy and adequate governance that integrates the overall national strategic plan and coordinates different stakeholders, such as the Ministry of Agriculture, Ministry of Education, and Ministry of Health (UNESCO, 2012).

The formulation of systematic STI policy changes the focus towards an emphasis on the interplay among institutions and their interactive processes at work in the generation of knowledge and its diffusion and application. Measurements are taken by using the indicators, which are fundamental for assessing potential changes to achieve more growth and development, as described in new version of Frascati Manual 2015 and Oslo Manual 2018 shown by OECD.

Structural vector autoregression (SVAR) has been applied in different studies, such as in the analysis of monetary policy shocks without restricting the response of output in United States; this analysis revealed that monetary policy shocks induce a decline in output with high posterior probability (Arias *et al.*, 2019), and the comparative evaluation of the policy mix in the United States and Europe revealed that these two cases are different and that the policies seem to act as complements (Afonso and Goncalves, 2019).

In the case of structural vector error correction (SVEC) research related to the influence of monetary aggregate shocks in the U.S., China and Europe on Japan, researchers determined that China's monetary growth has significant effects on Japan's economy that are quite dissimilar from those of the U.S. and Europe (Vespignani and Ratti, 2016). Researchers examining the effects of shocks on the labour market in Ukraine determined that various structural and cyclical shocks explicate unemployment in this country (Lukianenko and Oliskevych, 2015).

These studies demonstrated that SVAR and SVEC models are appropriate for analysing different policies in several countries (Thalassinos and Politis, 2011; 2012). However, little research has examined STI policies, especially for developing countries. To address this gap, the current study employs these models to examine the new STI institutionality in the Colombian case.

In this study, we develop an empirical study using the structural vector autoregressions (SVAR) and the structural vector error correction (SVEC) approaches to determine new institutionality in science, technology and innovation through new Ministry of Science, Technology and Innovation (MSTI), which was recently created in Colombia. We also use historical data trends to assess transparency and investments as an input to determine adequate governance and structure within this new institutionality.

The SVAR and SVEC approaches have been widely used methods to evaluate the diffusion of macroeconomic policies to macroeconomic variables in several studies, as these methods specify useful tools (e.g., impulse response functions) to analyse relationships between variables across time (van Aarle *et al.*, 2003; Galariotis *et al.*, 2016). The main objective in this study is to perform an analysis of the effects of new institutionality in science, technology and innovation considering investments and transparency. For evaluating such topics, we implemented SVAR and SVEC models with investments and transparency variables.

In terms of changing science, technology and innovation institutionality, it is very important to investigate the structural and cyclical factors of science, technology and innovation (STI) and to characterize shocks that lead to permanent changes in STIA and R&D investments in Colombia. The aim of this study is to conduct an empirical analysis and econometric modelling of the dynamic relationship between investments in STI, independence and transparency in a new institutionality through a MSTI in Colombia based on SVAR and SVEC. The conducted analysis will allow for the characterization of impacts of investments and new institutionality, as well as a determination which of investments will have long-term or short-term effects on the functionality of MSTI. Our results show that to improve and increase independence and transparency conditions within the Ministry of Science, Technology and Innovation, the ministry generates higher investments in STIA and R&D over time.

In section two, we analyse the data and underline important patterns in order to anticipate important relations for future policy. The econometric framework used in the study, as well as the empirical analyses of the results, are described. The robustness is assessed via different statistical tests. Finally, section five concludes.

## 2. Methodology and Results

Independence is, of course, an essential component for the functioning of institutions. To establish the comparability with previous works, the construction of an independence index is required. The design of the index followed two fundamental principles. First, it categorized a series of variables with limited but relatively precise characteristics in terms of the following: i. policy maker in STI; ii. formulation of STI policy and its priorities; iii. institutional objectives; and iv. government restrictions for budget allocation. Second, the design uses only past evidence and some results from these perspectives. Additional information on how the regulations would apply for a later exercise was deliberately omitted. These principles allow institutions to be classified according to their degree of independence in several dimensions with relatively few value judgements along with a focus on concrete and intuitive details, instead of a broader but vaguer vision of reality. The classification according to each criterion indicates the degree of independence of the entity. The closer the indicator is to 1, the more independent the entity will be. Therefore, independence and transparency are essential factors for the proper functioning of institutions. The main data sources for this study are databases and reports of the Colombian Observatory of Science and Technology (OCyT).

In this section, we seek to establish the historical relationship between the political independence index of the Ministry of Science, Technology and Innovation (MSTI) and two representative variables of institutional performance: i. investments in science, technology and innovation activities (STIA), and ii. investments in research and development (R&D). Using historical information from the independence index as well as investments in STIA and R&D, the results reveal that to improve independence and transparency conditions of the Ministry of Science, Technology and Innovation, it is necessary to generate higher investments in STIA and R&D. This result was obtained through structural vector autoregression (SVAR) and error correction model (SVEC). These models allow an analysis of the average dynamic between a variable set while controlling for other idiosyncratic factors that can generate spurious correlations (Lütkepohl, 2005).

## 2.1 How much does MSTI's independence affect spending on STIA and R&D?

Figure 1 shows the interannual percentage change of the independence index and spending on STIA and R&D, both as a percentage of GDP[4.] Descriptively, a positive correlation of changes in independence and expenditure can be observed in STIA (43%) and R&D (39%). Using the SVAR and SVEC models, these relationships can be established when controlling for other factors that could explain the positive relationship, such as changes in the National Development Plan, effects of macroeconomic destabilization or some international shock.

Time series models require an analysis of the existence of unit roots in the variables involved in the estimates. This allows the identification of the existence of cointegration vectors or long-term equilibria in the variables (see Engle and Granger, 1991). A cointegration vector allows us to analyse how a set of variables tends to stay together over time or how they are expressed differently, as well as whether the

[4]*When spending on ACTI and ID as a percentage of GDP is shown in the graph, the growth rate gap with respect to GDP is presented.*

variables are affected by the same regulatory or market innovations. Therefore, unit root tests were carried out by Dickey and Fuller (1979), Phillips and Perron (1988), and Kwiatkowski, Phillips, Schmidt, and Shin (1992) on spending on STIA and R&D as a percentage of GDP and on the independence and transparency indexes. Their results are presented in Table 1. Thus, the series of STIA, R&D and independence are indicators of the possibility of long-term equilibria, which is explored.

***Figure 1.*** *Historical Evolution of Independence MSTI spending on STIA and R&D*

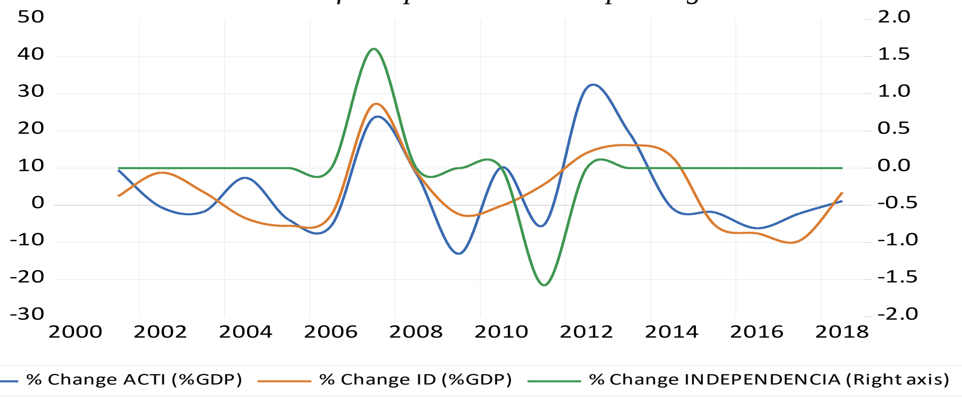



Figure 1. Historical evolution of independence MSTI, spending on STIA and R&D
Source: Author's calculations

***Table 1****. Results of unit root tests*

| | ADF (P-values) | | | PP (P-values) | | | KPSS statistical (1) | |
|---|---|---|---|---|---|---|---|---|
| | Trend | Constant | Nothing | Trend | Constant | Nothing | Trend | Constant |
| STIA | 0.2713 | 0.7433 | 0.9021 | 0.5786 | 0.7264 | 0.9015 | 0.086 | 0.513** |
| $\Delta$STIA | 0.0768 | 0.0183 | 0.0017 | 0.0798 | 0.0189 | 0.0017 | 0.082 | 0.081 |
| R&D | 0.0500 | 0.8580 | 0.9789 | 0.6392 | 0.7387 | 0.9120 | 0.080 | 0.509** |
| $\Delta$R&D | 0.0848 | 0.0210 | 0.0044 | 0.3382 | 0.1268 | 0.0168 | 0.125* | 0.131 |
| Independence | 0.7035 | 0.3910 | 0.6658 | 0.6702 | 0.3528 | 0.6658 | 0.127* | 0.130 |
| $\Delta$Independence | 0.0415 | 0.0103 | 0.0005 | 0.0415 | 0.0103 | 0.0005 | 0.069 | 0.111 |

***Note:*** *(1) In the KPSS test, the null hypothesis corresponds to stationarity. (*) Significant at 10%, (**) Significant at 5% and (***) significant at 1%. In the ADF and PP tests, the null hypothesis is a unit root.*

The methodology of Johansen (1992) was used to test and incorporate the cointegration vectors in the model. Table 2 shows the results of the statistics trace and maximum eigenvalue. The methodology of Johansen (1992) assumes multivariate normality; thus, before performing the tests, a VAR (3) was estimated by using the three variables in levels, and the multivariate version of the Jarque and

Bera test (1980) was performed. There is evidence in favour of multivariate normality; the results are shown in Annex 1. There is evidence of cointegration; the information criteria suggest estimating the VEC using an intercept in the cointegration equations and in the VAR. The VEC estimate is presented in Annex 2.

***Table 2.*** *Results of cointegration tests*

Selected (0.05 level*) Number of Cointegrating Relations by Model

| Data Trend: | None | None | Linear | Linear | Quadratic |
|---|---|---|---|---|---|
| Test Type | No Intercept No Trend | Intercept No Trend | Intercept No Trend | Intercept Trend | Intercept Trend |
| Trace | 1 | 2 | 2 | 3 | 3 |
| Max-Eig | 1 | 2 | 2 | 3 | 3 |

*Critical values based on MacKinnon-Haug-Michelis (1999)

***Source:*** *Author's calculations*

Based on the VEC estimates, a structural decomposition of the covariance variance matrix of the error term[5] was performed. The decomposition was carried out in the AB form considering the restrictions imposed by the cointegration vectors. The VAR(p) form of the VEC(p-1) is:

$$Y_t = A_0 + A_1 Y_{t\text{-}1} + \cdots + A_p Y_{t\text{-}p} + e_t \tag{1}$$

And for of VEC(p-1) is:

$$\Delta Y_t = \Gamma_0 + \alpha\beta' Y_{t\text{-}1} + \Gamma_1 \Delta Y_{t\text{-}1} + \cdots + \Gamma_{p\text{-}1} \Delta Y_{t\text{-}p+1} + e_t \tag{2}$$

The structural decomposition is of the form:

$$AY_t(I\text{-}A_1\text{-} \ldots \text{-}A_P) = A_0 + Ae_t = B\varepsilon_t \tag{3}$$

where A and B are three-by-three matrices, Matrix A establishes the contemporary relationships between the variables of the system and matrix B identifies how structural errors influence, $\varepsilon_t$ to the errors of the reduced form $e_t$. In general, we should assume $2m^2\text{-}\frac{m(m+1)}{2}$ restrictions for A and B, where $m$ is the number of variables in the system.

[5] *The variance matrix covariance of the errors is not diagonal. On average, the correlation of errors is 82%.*

There are $\frac{m(m+1)}{2}$ different equations in the term $Ae_t = B\varepsilon_t$ considering that $\Sigma_e^2 = A^{-1}BB'A^{-1\prime}$is symmetric. For the decomposition, the following structure is assumed in matrices $Y_t$, A and B.

$$Y_t = \begin{bmatrix} Independence_t \\ R + D_t \\ STI_t \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & a_{32} & 1 \end{bmatrix} \tag{4}$$

$$B = \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}$$

Table 3 shows the estimation of the SVAR. The estimated coefficients $\widehat{a_{21}} = -0.02$ and $\widehat{a_{31}} = -0.06$ are evidence that with greater independence from the MSTI, there is greater spending on STIA and R&D. Specifically, an increase of one percentage point in independence generates 0.02% more spending on R&D and 0.06% more spending on STIA as percentage of GDP. The estimation of the coefficients is negative because the matrix A is on the left side of the SVAR. Annex 3 shows the model specification tests in its VAR expression; the errors are not autocorrelated, and the estimate is stable.

These variables interact in a dynamic context; thus, an analysis of variance decomposition of structural errors, impulse response and historical decomposition is performed. Table 4 shows the decomposition of variance of the prediction error of the R&D and STIA expenditure. On average, the innovations or changes generated in the independence of the MSTI account for 50% of the variance of the error of expenditure in R&D. For the case of spending on STIA on average innovations in independence explain 60% of the error variance. This result indicates that the independence of the MSTI has a predominant role in establishing the future spending on R&D and STIA.

Similarly, Figure 2 shows the results of an accumulated response impulse exercise is shown. This analysis is done to show how an improvement in the institutionality index affects spending on R&D and STIA as a percentage of GDP. However, a permanent increase of a standard deviation (0.005) in the institutionality index generates and R&D spending increase of 0.1%, 0.2% and 0.4% of GDP 4, 12 and 24 years after the change, respectively. In the case of STIA, the same increase in institutionality means that spending on STIA increases 0.02%, 0.05% and 0.1% of

GDP 4, 12 and 24 years after the change, respectively. The 95% confidence interval indicates that the effect is statistically significant for the first 8 years.

***Table 3.*** *SVAR estimations*

Structural VAR Estimates
Date: 02/16/19 Time: 12:21
Sample (adjusted): 2003 2018
Included observations: 16 after adjustments
Estimation method: Maximum likelihood via Newton-Raphson (analytic derivatives)
Convergence achieved after 13 iterations
Structural VAR is just-identified

Model: Ae = Bu where E[uu']=I

A =

| | | |
|---|---|---|
| 1 | 0 | 0 |
| C(1) | 1 | 0 |
| C(2) | C(3) | 1 |

B =

| | | |
|---|---|---|
| C(4) | 0 | 0 |
| 0 | C(5) | 0 |
| 0 | 0 | C(6) |

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | -0.020539 | 0.004520 | -4.543793 | 0.0000 |
| C(2) | -0.063997 | 0.012777 | -5.008908 | 0.0000 |
| C(3) | -1.038004 | 0.466923 | -2.223072 | 0.0262 |
| C(4) | 0.005364 | 0.000948 | 5.656872 | 0.0000 |
| C(5) | 9.70E-05 | 1.71E-05 | 5.656853 | 0.0000 |
| C(6) | 0.000181 | 3.20E-05 | 5.656853 | 0.0000 |
| Log likelihood | 301.2555 | | | |

Estimated A matrix:

| | | |
|---|---|---|
| 1.000000 | 0.000000 | 0.000000 |
| -0.020539 | 1.000000 | 0.000000 |
| -0.063997 | -1.038004 | 1.000000 |

Estimated B matrix:

| | | |
|---|---|---|
| 0.005364 | 0.000000 | 0.000000 |
| 0.000000 | 9.70E-05 | 0.000000 |
| 0.000000 | 0.000000 | 0.000181 |

***Source:*** *Author's calculations.*

## 3. Conclusions

This study evaluated the effects of new STI institutionality in Colombia using set-identified SVAR and SVEC models. These approaches are useful because they identify STI policy by creating the Ministry of Science, Technology and Innovation and examine its relationship with transparency, independence and investments in STIA and R&D. The results consistently show that strength and increases in the independence and transparency conditions of the Ministry of Science, Technology and Innovation produce higher investments in STIA and R&D over time. The literature suggests that this phenomenon is due to countries with a strong institutionality through MSTI achieving higher investments in R&D, as shown in various OECD countries that achieved development and economic growth through STI.

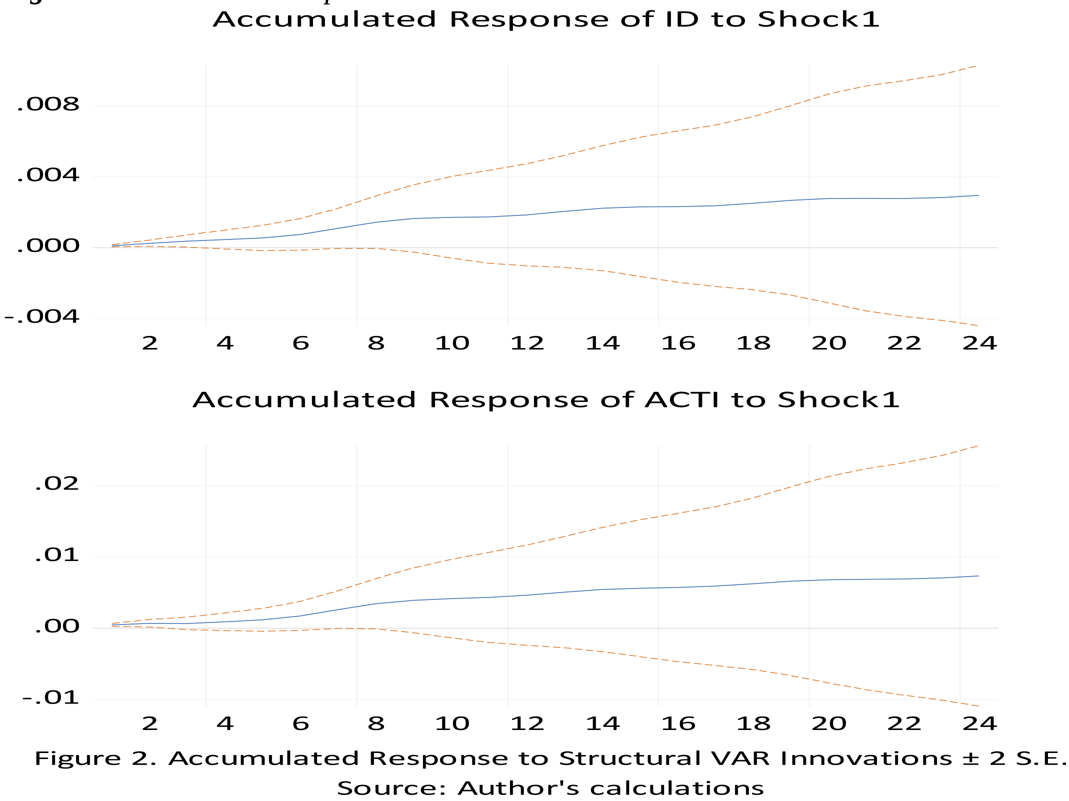
Consequently, policymakers, forecasters and modellers have to consider this issue when considering potential influences in new STI institutionality in Colombia along with investments in STIA and R&D, transparency, independency and policy analysis of other developed and emerging economies that have achieved growth by promoting STI through a Ministry of Science, Technology and Innovation and effective governance.

***Table 4.*** *Decomposition of variance of the prediction error*

| Variance Decomposition of ID: | | | | |
|---|---|---|---|---|
| Period | S.E. | INDEPENDENCIA | ID | ACTI |
| 1 | 0.005364 | 56.33909 | 43.66091 | 0.000000 |
| | | (16.7686) | (16.7686) | (0.00000) |
| 2 | 0.006451 | 55.15347 | 28.55592 | 16.29061 |
| | | (19.0446) | (17.8073) | (12.8548) |
| 3 | 0.007343 | 50.37872 | 19.29265 | 30.32863 |
| | | (20.5900) | (17.8462) | (16.5059) |
| 4 | 0.007537 | 48.25167 | 16.09340 | 35.65493 |
| | | (21.1051) | (16.8952) | (17.5358) |
| 5 | 0.007837 | 51.83587 | 15.18091 | 32.98322 |
| | | (21.3546) | (16.4657) | (16.4434) |
| Variance Decomposition of ACTI: | | | | |
| Period | S.E. | INDEPENDENCIA | ID | ACTI |
| 1 | 0.000147 | 82.98345 | 4.015684 | 13.00086 |
| | | (8.97125) | (5.11306) | (6.52865) |
| 2 | 0.000239 | 66.86538 | 19.51272 | 13.62190 |
| | | (16.2574) | (16.4258) | (10.7994) |
| 3 | 0.000303 | 53.49104 | 16.85309 | 29.65587 |
| | | (17.8134) | (15.1631) | (15.3956) |
| 4 | 0.000332 | 54.28198 | 15.01957 | 30.69845 |
| | | (18.3289) | (15.2740) | (15.2701) |
| 5 | 0.000347 | 58.52134 | 14.12819 | 27.35047 |
| | | (19.1381) | (14.5147) | (14.5028) |
| Standard Errors: Monte Carlo (10000 repetitions) | | | | |

***Source:*** *Author's calculations.*

***Figure 2.*** *Accumulated Responses*

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