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by

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1) Introduction[1]

The goal of this article is to review what is currently done in Argentine institutions at the level of the empirical economywide modeling, particularly in the fields of input-output (IO) and computable general equilibrium (CGE) modeling and to suggest, along the way, some possible lines of further work.

While the empirical economywide modeling of the Argentine economy has been carried out by individual researchers -usually as academic exercises which are not continued after publication- and also by international organizations, the interest here is to focus on domestic, contemporary, team-work institutionally based empirical modeling efforts.[2]

The empirical modeling of developing economies in general, and of the Argentine economy in particular, has been lacking when compared to developed countries. Several restrictions can account for that. First, the lack of enough and reliable data. Second, the high cost of computational capacity. Third, the relative lack of domestic technical capacity. Fourth, the frequent structural change in the economy to be modeled. And fifth, the lack of institutional continuity to sustain the work of modeling teams.

In Argentina, some of these reasons have become less restrictive over the last few years. While still lacking, data collection, quality and availability has improved thanks to lower processing costs and also to the efforts of official agencies.[3] This data limitation

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[1] I thank Edgardo Lifschitz from the National Direction of Regional Economic Programming of Argentina, Omar Chisari, Carlos Romero and Germán Lambardi from the Institute of Economics at UADE, and Jorge Carrera and Martín Cicowiez from the Center of International Economics of the Argentine Ministry of Foreign Affairs for their provision of materials and for the discussions I had with them during the writing of this article.

[2] To my knowledge, there is not work of this kind being carried on in Argentina in the field of macroeconometric modeling beyond the specification of very small time series models (see McCandless et al. (2001)). This is why my focus will be on IO and CGE modeling.
A historical list of IO, CGE and macroeconometric models of the Argentine economy developed since the 1960s can be found at Prof. Horst Uebe web site at:
www.unibw-hamburg.de/WWEB/math/uebe/modelle/titelseite.html

[3] For example, efforts were made at the Ministry of the Economy to re-compute National Accounts from 1993 on, and to compute a new Input-Output matrix for the year 1997. And more information is now available

points toward the convenience of paying particular attention to model robustness analysis through stochastic simulations, something to which we will come back a the end of this article.

The cost of computers has fallen, while processing speed has increased dramatically; the quality and diversity of software for economic modeling also improved significantly[4]; and the domestic technical capacity also improved: more economists are now better trained in quantitative analysis and, to a lesser extent, in computational economics, a relatively new field of economic analysis.[5] This has of course its pros and cons. On the one hand, cheaper computers and better training in modeling techniques may help the development of better models and, hopefully, a better understanding of the Argentine economy. On the other hand, there is a risk of proliferation of computational simulations with weak conceptual and factual basis, or simply replicating the work done in developed countries without proper attention to the specificities of developing economies.[6]

Concerning the frequent structural change in the Argentine economy, this is of course a major obstacle for any modeling effort. In this sense, it may be wise to avoid working with large models, difficult to modify, re-estimate or re-calibrate.

Finally, in connection to the lack of institutional continuity, not much can be said from a modeling perspective. Perhaps a modeling strategy focused on small and medium size models will pay off also here, since they do not require many resources and in that sense they may be easier to sustain.

In what follows, I will review the work on regional Input-Output modeling carried out at the National Direction of Regional Economic Programming of the Ministry of the Economy, the CGE national model developed at the Institute of Economics at UADE

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through the Internet from official sites (see for example the site of and the Secretariat of Economic Policy at www.mecon.gov.ar).

[4] See Amman and Kendrick (1999).

[5] See Amman, Kendrick and Rust (1996).

[6] For an account of these specificities, see for example Agenor and Montiel (1996), Foxley and Vial (1988) and Taylor (1990).

University, and the work on CGE modeling on MERCOSUR developed at the International Economy Center of the Ministry of Foreign Relations. Along the way, I will put forward some suggestions for possible lines of further work.

2) Input-Output Modeling

Input-Output (IO) modeling, following the pioneering work of Nobel prize winner Leontieff[7], is one of the earliest methods of empirically modeling the structure of economic interdependence within an economic system, be that a regional, national or international system. If we think of an economy as comprised of three main activities (say agriculture, industry and service sector), a formal representation in IO terms would be as follows:

$$x_1 = a_{11}\ x_1 + a_{12}\ x_2 + a_{13}\ x_3 + d_1$$
$$x_2 = a_{21}\ x_1 + a_{22}\ x_2 + a_{23}\ x_3 + d_2$$
$$x_3 = a_{31}\ x_1 + a_{32}\ x_2 + a_{33}\ x_3 + d_3$$

where the *x*´s are each activity production levels, a_{ij} are the input-output coefficients (the intermediate requirements from sector *i* per unit of output of sector *j*), and where the *d*'s are the levels of final demand. In matrix terms, we can write:

$$x = Ax + d$$

where *x* is the vector of levels of production, *d* is the vector of final demands and *A* is the input-output coefficients matrix. Of course, each activity could in time be decomposed into sub-activities, etc. Usually, an IO matrix has hundreds of elements. This indicates that the estimation of an IO matrix is particularly demanding. It is usually done at the Governmental level, and with a low frequency. But once the information becomes available, it provides a useful tool for structural analysis and policymaking.

[7] See Leontieff (1953).

The latest IO matrix for Argentina dates back to 1997 and comprises 124 activities.[8] Not much use of the Argentine IO matrix in itself has been done at institutional levels or in the field of academic research.[9] A typical problem to be answered with this model is that of the determination of the direct and indirect requirements of each sector of production given an autonomous increase in one or more levels of final demand. As is well known, these multipliers are obtained in a straightforward way by performing a matrix inversion, that is:

$$x = \left(I - A\right)^{-1} d$$

where *I* is the identity matrix and where the other elements of the equation were defined above. However, this formulation assumes that all activity levels are free to vary, and this may not be the case when "bottlenecks" are present in the provision of some primary inputs or in some industries. While this problem may be analytically intractable, from a computational point of view it offers no challenge to today's technology, since for example a problem of the form:

$$\max d_1 \text{ subject to:}$$

$$\begin{aligned} x_1 &= a_{11}\ x_1 + a_{12}\ x_2 + a_{13}\ x_3 + d_1 \\ x_2 &= a_{21}\ x_1 + a_{22}\ x_2 + a_{23}\ x_3 + d_2 \\ x_3 &= a_{31}\ x_1 + a_{32}\ x_2 + a_{33}\ x_3 + d_3 \\ x_2 &\le \overline{x}_2,\ \ x \le \overline{x}_3 \end{aligned}$$

can be easily solved on a personal computer with the appropriate optimization software, even if it comprises dozens of equations.

Many more issues and policy problems can be analyzed within an IO framework.[10]

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[8] See INDEC (2001). The first Argentine IO matrix was obtained in 1950 by the Economic Commission for Latin America. Newer matrices were obtained by the Central Bank of Argentina in 1953, 1963 and 1973. The matrices for 1950, 1953 and 1963 comprised 23 activities (see BCRA, 1976). The one for 1973, 56 activities (see BCRA 1989).

[9] Some CGE models to be reviewed below use its information for the modeling of the production sectors.

[10] For examples of the possibilities of work with IO models, see the home page of the International Input-Output Association at www.iioa.org and its journal *Economic Systems Research* at www.tandf.co.uk/journals/routledge/09535314.html.

An interesting work has been made at the DNPER of the Ministry of the Economy to identify sectoral blocks within the Argentine economic structure, and also to approximate the structure of the Argentine provinces with partial IO provincial matrices.

A sectoral block is defined as a set of IO activities strongly interrelated and relatively autonomous (that is, with a low level of transactions) with respect to the rest of the IO matrix. A systematic procedure (a blocking algorithm) is applied to the national IO matrix to identify sectoral blocks.[11] The application of this procedure allowed the identification of nine sectoral blocks in the Argentine economy: petrochemical, health, wood and paper, agro-industrial, cattle production, chemical, tourism, metal-mechanic and construction, electro-electronics.[12]

Once blocks are identified, an IO matrix is built for each of them. Each matrix comprises all the activities involved within the block plus an extra activity denominated as "rest of the economy" and the corresponding final demand vectors. As IO matrices, they allow the computation of multipliers -in this case, "sectoral block multipliers"- in the same fashion as the national IO matrix. These matrices have the advantage of easy updating when compared against the national matrix. Each matrix border, that is, value added, imports, exports and domestic uses, can be updated with quarterly or annual information from the National Accounts. Relative prices corresponding to the activities within the block can be updated easily. Finally, updating technical coefficients may require the application a partial-survey technique.

Concerning provincial IO analysis, it should be carried out, ideally, with IO matrices estimated at the corresponding provincial level. Since this is costly, the alternative is to derive provincial matrices from the national IO matrix. This is usually done using non-survey or partial-survey techniques to gather the necessary information to compute various

[11] See Hoen (2002). The specific procedure applied by the DNPER is presented in Lifschitz (2000).
[12] The agro-industrial and tourism block where not directly identified with the blocking algorithm, but after performing a provincial level analysis that will be presented below.

quotients or ratios to transform the national matrix into regional ones.[13] In formal terms, the problem is to find the appropriate q_i such that:

$$p_{ij} = a_{ij}\, q_i$$

where p_{ij} and a_{ij} are the provincial and the national technical coefficients respectively.

An easy non-survey way of obtaining q_i is to compute it as a location quotient such as:

$$q_i = \frac{y_i^p}{\sum_i y_i^p} \Bigg/ \frac{y_i^n}{\sum_i y_i^n}$$

where y is usually a variable such as output level or employment, and where the superscripts p and n indicate provincial and national values. This implies that the regional proportionate share of industry i is compared against the national share of that industry. In case that q_i is larger that one, it should be set as equal to one since in that case it is very likely that all local demand will be met by the industry.

As an example of partial-survey techniques we can mention the RAS or Biproportional technique. This technique is used to update IO matrices over short periods of time, and can be applied also to obtain provincial coefficients from national ones. In formal terms:

$$P = rAs$$

where P and A are provincial and national technical coefficients matrices respectively; where r is a diagonal matrix whose elements measure the extent to which each industry i is not able to meet all the input requirements from all other regional industries; and where s is a diagonal matrix whose elements are a measure of the comparison of the use of

[13] See Hewings (1985).

intermediate inputs per unit of gross output between the industry which produces *j* at the provincial level and the same industry at the national level. To obtain the basic information to estimate *r* and *s*, two questions are asked to a sample of firms: what is their volume of sales to other firms within the same province, and what is the volume of purchases to from other firms within the same province.

Given the paucity of the required information at provincial levels in Argentina, and the budgetary restrictions to conduct partial surveys, the DNPER applied a procedure to obtain approximations to the provincial IO matrices which derives from the work they did around the identification of sectoral blocks.[14] This procedure can in a way be linked to the work on identification of regional industrial complexes using IO matrices.[15] It combines the identification of sectoral blocks within the IO national matrix with a partial-survey technique to estimate a "proxy" for each provincial IO matrix.

In a first step, for each province a set of representative activities is chosen. In a second step, the sectoral blocks -previously identified at the national level- to which those activities belong are determined. In a third sep, and back to the provincial level, the activities belonging the the sectoral blocks that were not previously included in the set of representative activities of the province are determined. Finally, an IO matrix is built with all the activities in this way determined. This "provincialized" matrix is the national matrix comprised by input-output relationships between the provincial selected activities -those belonging to sectoral blocks present in the province- plus input-output relationships and final demand relationships with the rest of the national and provincial activities considered in an aggregate way. Notice that this "provincialized" matrix is not properly a provincial matrix, since it only includes activities -and probably not all of them- belonging to some sectoral blocks. As IO matrices, they allow the computation of "provincialized" multipliers.

It should be noticed that the value of the "provincialized" multipliers may be underestimated, not only because not all the provincial activities are included in the

[14] See Lifschitz (2000).
[15] See for example Norcliffe andKotseff (1980), O' hUallacháin (1984) and Feser et al. (forthcoming).

"provincialized" IO matrix, but also because of the absence of feedback effects. That is, an increase in final demand in a given province may induce an increase in the demand from products from another and this, in time, may imply a "second round" increase in the demand from products from the initial province, etc. Thus, it would be interesting, at least for some obvious cases of high level of provincial interdependence, to move from "provincialized" IO models to inter-provincial or multi-province IO models to better capture feedback effects.[16]

3) CGE Modeling

CGE models try to capture a wide range of economywide interactions between a variety of economic agents and institutions. Given some behavioral assumptions with respect to those agents and institutions and with respect to the functioning of markets, they are used to determine relative prices and quantities produced and consumed, and the distribution of income. They usually provide a highly disaggregated picture of the economy. And they are mostly static and focused on the "real" side, though dynamic and monetary specifications are been increasingly used.[17]

These type of models have already been applied for some time to study developing economies. Some of them are more linked to the Neoclassical tradition, in the sense that they tend to pay particular attention to the specification of demand and supply functions derived from the assumption of utility and profit maximizing consumers and firms respectively; to assume perfect competition; and to impose market clearing.[18] Other models tend to be more grounded on the Structuralist tradition, paying more attention to institutions and political economy, market power and disequilibrium.[19]

From a mathematical point of view, a CGE model is a system of (usually) nonlinear equations. Expressed in formal terms:

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[16] See Hewings (1985).
[17] For a historical and analytical introduction to this topic, see Dixon and Parmenter (1996). For extended textbook presentations, see Dervis et al. (1982) and Dixon et al. (1992).
[18] See for example Shoven and Walley (1992).
[19] See for example Taylor (1990).

$$F(x, z, \mu) = 0$$

where x and z are vectors of endogenous and exogenous variables respectively, and where μ is a vector of parameters.

A CGE usually requires computational techniques to be solved. In general, parameters and base-case variable values are calibrated with information obtained from a Social Accounting Matrix (SAM) which contains information on the flow of goods and payments between institutions in the economy. SAMs, or the information to build them, are usually available from governmental sources.

3.1 National CGE

The Institute of Economics at UADE has developed and maintains a static small open economy CGE model of the Argentine economy.[20] Its basic version comprises 21 sectors of production (10 producing good and 11 producing services), 5 consumers divided by income quintile, a government sector and a foreign sector. There are 3 factors of production: labor, physical capital and financial capital, and 5 main markets: domestic consumption goods, imported goods, investment, labor and bonds.

Each consumer quintile makes consumption, investment, labor supply and financial portfolio decisions maximizing a Cobb-Douglass utility function subject to a budget constraint comprising factor payments, debt payments, financial portfolio returns, profits and government net transfers.

Firms maximize profits subject to Constant Elasticity of Substitution (CES) technologies which combine labor and capital, while they are assumed to use financial capital and intermediate inputs as fixed proportions of their output.

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[20] See Chisari and Romero. (1996).

The Government is assumed to maximize an objective function subject to its budget constraint. This function involves a Leontieff production function of collective goods, that is, public or private goods provided in a collective way, using as inputs consumption and investment goods, and labor. It also includes as arguments bonds, services to retirees and debt payments, and investment as a proxy for future collective goods. The Government budget constraint includes taxes, bonds and the "inflation tax". The last one is modeled as collected on holdings of an asset issued by the Government and demanded by consumers. The "inflation tax" is understood as the price of that asset.

Finally, the foreign sector includes a consumer/investor who buys from Argentina (or sells to) goods and services and bonds. Given the assumption of a small open economy, international prices and the interest rate are given for the Argentine economy.

The basic model was calibrated for 1993, using a SAM built on the 1984 Argentine IO matrix and complementary government statistics for 1993, and represented and solved in GAMS-MPSGE. A newer version uses an updated SAM, built on the 1997 IO matrix and recent complementary information. Also, this newer version has more production sectors, divides consumers by income deciles, and gives a slightly different treatment to the government sector. The model has been used over the years to study the relationship between macroeconomic shocks and income distribution (Chisari and Romero., 1996), the macroeconomic and distributional effects of the privatization and regulation of utilities in Argentina (Chisari et al., 1999), and in other specific applications.

3.2 MERCOSUR CGE

The Center for International Economics of the Argentina Ministry of Foreign Affairs has developed a static multicountry model to study the macroeconomic interdependence of Argentina, Brazil and Uruguay, the three main economies within the South American Common Market (MERCOSUR).[21] The model treats those three

[21] See Lacunza et al. (2002). This Center also has a CGE model of the Argentine economy (see CEI (2002)). However, this last one is built on the standard model, software and data base provided by the Global Trade

economies as small open economies, trading among themselves and with the rest of the world. Each country is modeled in the same fashion, with 34 endogenous variables and 16 exogenous. There is one sector of production, one consumer, a government sector, a foreign sector and a monetary sector. The factors of production are labor and capital.

For each country, in the production sector a representative firm maximizes profits subject to a Cobb-Douglass technology, employing labor and capital. A representative consumer minimizes her total expenditure, generating the corresponding demands for the domestic good, imports from the other two trading partners and imports from the rest of the world. The Government collects taxes from labor and capital, from consumption, and from tariffs on exports and imports, while Government expenditure is determined exogenously. Concerning the foreign sector, while the demand for imports is generated, as was said above, by the representative consumer, exports are a function of the real exchange rate with the rest of the world and with each of the trading partners. Finally, the monetary sector is modeled with a money supply and a moneyl demand equation, this one as a positive function of the production level and as a negative function of the interest rate.

The model was calibrated for the year 1997 using a database built by the Center of International Economics with data from the IMF, the World Bank and government agencies from Argentina, Brazil and Uruguay. It is represented and simulated in GAMS. So far it has been used to study the responses of the economies of those three countries to different macroeconomic shocks (i.e. an increase in the international interest rate, a drop in capital flows to MERCOSUR, changes in Government spending or in the money supply in one of the three countries, etc.) under five alternative exchange rate systems: fixed exchange rates; flexible exchange rates; Argentina with a fixed exchange rate w.r.t the rest of the world (row) and Brazil and Uruguay with flexible regimes w.r.t. the row; Brazil with a fixed exchange rate w.r.t the row and Argentina and Uruguay with flexible exchange rate w.r.t. the row; and the three countries with a fixed regime among themselves but flexible w.r.t. the row.

Analysis Project (GTAP) housed at Purdue University. Given the focus of this article, we will review the multicountry model only.

3.3 Parameter Uncertainty and Policy Analysis

Ideally, the parameters of CGE models should be jointly and econometrically estimated, using system of equations methods such as three-stages least squares or full information maximum likelihood, or at least equation-by-equation methods such as two-stages least squares or limited information maximum likelihood. However, the paucity of available data, particularly in the case of developing countries, usually does not allow the application of those methods.

As an alternative, parameter values are sometimes taken from specific studies, be those from the country being modeled or from other countries with similar economic structures. As another popular option, those parameters are calibrated. In the case of static models, this is usually done for a base-case year. Parameter values are adjusted by the modeler -each one within a plausible range- until the model endogenous variable values reproduce those corresponding to the base case. Finally, it is not unusual to find models in which some parameter values are taken from econometric studies and others are chosen by "educated guesses" while the remaining ones are calibrated, as it is the case of the two CGE Argentine models mentioned above.

The lack of enough and reliable data to apply econometric methods, and the use of the alternative methods just mentioned, raise the question of the robustness of the results obtained when simulating CGE models. Usually, some partial sensitivity analysis is undertaken by the modelers, changing the values of one, or some, selected parameters and checking the robustness of the solutions obtained. However, the substantial increase in computer power and specialized software availability it make possible today to carry on more systematic analyses. That is, to take seriously into account the issue of parameter uncertainty, a relatively recent trend in the field of CGE modeling.[22]

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[22] Abler et al. (1999) provide a compact presentation of the most used methods to deal with parameter uncertainty in CGE modeling. See also Harrison and Vinod (1992), Harrison et al. (1993) and Arndt (1996).

A systematic way of checking the robustness of a model to parameter uncertainty is with Monte Carlo simulations. Given or specifying a priori distributions for the model parameters, sets of parameter values are randomly drawn from those distributions. The model is solved for each drawing, and the expected values for the endogenous variables are computed as the average of all the simulation results, while standard deviations (std) are computed in the usual way once the expected values are obtained. In general, to obtain reasonable approximations with this procedure a very large number of simulations is required, something that may be problematic if the model to be solved is relatively large.[23]

An alternative procedure which may substantially reduce the number of simulations is to approach the simulation of a model as a problem of numerical integration. In formal terms, the problem is:

$$E\{x\} = \int_{\Omega} x \; g(\mu) \; d\mu$$

where *E* is the expected value operator, x is the vector of solution values for the model endogenous variables, *g* is the multivariate density function of μ -the model parameters vector-, and Ω is the domain of integration. Numerical approximations to the formula shown above are in general of the form:

$$\sum_{i=1}^{n} w_i x_i$$

where n is the number of solutions of the model, w_i is the weight corresponding to each solution, and x_i is the vector of model solution values for each solution.[24] Some particular numerical procedures, such as Gaussian quadratures, provide methods to obtain good approximations with a small *n*, by way of a smart choice of weights and points -in our case, parameter values- to proceed with each model solution. This is the case for example of the

[23] For some examples, see Arndt (1996).
[24] See Judd (1999), chapter 7.

Equally Weighted Symmetric Order Three Gaussian Quadratures method which allows for a systematic sensitivity analysis of *n* parameters requiring 2*n* simulations only. [25]

Finally, a few words concerning policy analysis and uncertainty within the field of CGE. With CGE models, policy analysis is mostly carried on as “shock analysis”. That is, changing the values of selected policy variables and computing the corresponding model results. However, today’s computer and software developments allow us to perform optimal policy exercises, even for relatively large models. That is, for the specification of an objective function and the computation of the corresponding optimal values for selected policy variables, and where the CGE model operates a the constraint of the optimization exercise.[26] In formal terms, the problem can be stated as:

$$\max_{u} J = g\left(x^{*}\right)$$

$$\text{s.t. } F\left(x,u,z,\mu\right) = 0$$

where x^{*} is a vector of target variables (a subset of the vector of endogenous variables *x*), z is a vector of exogenous variables, μ is a vector of parameters and *u* is a vector of policy variables whose values are endogenously determined as a result of the optimization problem. This structure can be generalized to dynamic problems with a intertemporal objective function and a dynamic model -with standard or forward-looking variables- as the dynamic constraint.

Moreover, parameter uncertainty may also be taken into account in a sophisticated way when performing optimal policy exercises, something with a long tradition in the

[25] An introduction to this method is provided by Arndt (1996).
[26] For example, when the model is represented in GAMS, the implementation of this kind of exercises is not very difficult. See Mercado et al. (1998).

realm of empirical macroeconomics[27], and to which CGE modeling may perhaps begin to converge.[28]

[27] The seminal work in that tradition is Brainard (1967). For some examples of recent contributions at the empirical, experimental and theoretical levels, see Sack (2000), Amman and Kendrick (1999) and Mercado and Kendrick (2000) respectively.
[28] See for example Kim (2002), who takes a first step in that direction.

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