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Bioenergy and Employment - A Regional Economic Impact Evaluation

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ABSTRACT

There is a problem in estimating renewable energy's impact on regional economies of developing countries, owing both to the lack of disaggregated data on these renewable energy sources at the subnational level and a method to address its share in the energy matrix (in a context where oil and gas are yet hegemonic). We apply a method to solve both problems and to the case of Santa Fe province, Argentina, an important producer of biofuels (biodiesel from soybean and ethanol from maize). To disaggregate the biofuel sector, we combine aggregated sector information with subsector surveys. Once the share of biofuels is established in the economy and their potential to create jobs, it is possible to generate statistics on the input-output relationships. With the latter, we estimate a hybrid input-output model and calculate the effects of shocks (defined as policies as well as the effect of exogenous elements impacting the performance of the sector) on production and employment stemming from the full utilization of existing idle capacity, as well as from new investments in the sector. The results, allow us to policy evaluations, for instance, the consequences of acceleration of the energy matrix transition to renewables through regulations, to study the effect of changes in relative prices of energy, determine the effect on potential employment creation of subsidies to promote the activity, etc. The sector we analyze empirically had an important idle capacity plus delayed investment projects because of external shocks. In the event of overcoming transient problems to export biofuels (and to attain full capacity utilization of current infrastructure), from expanding supply with new investments, the employment effect is proportionally much larger since transient jobs would be created in the construction phase.

Keywords

Regional Economics;
Bioenergy;
Employment;
Input-Output Analysis.

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1. Introduction

Within a sustainable growth strategy and the 'Agenda 2030' of Sustainable Development Goals of the UN, clean and affordable energy has received considerable attention worldwide. However, it is challenging to estimate its impact on regional economies owing both to the lack of disaggregated data at subnational levels and a methodological approach to address its share in the economy as well as in the energy matrix [1].

In developing countries sometimes official statistics do not have the disaggregation level (both at sectors or regions), the periodical up-to-date (to open classifications for new sectors or activities), or the degree of detail to differentiate into productive structures that can be very different between the national and the subnational levels. The reasons can be diverse: lack of budget, absence of technical capacities to survey the economy outside the capital or important cities, the informality of

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the economy, macroeconomic disturbances, etc. In our case study, the periodic macroeconomic crises, generated budget constraints and difficulties to have complete and modern economic statistics, which in turn impedes detailed analysis of policy interventions besides the macro level. We offer an alternative -technically feasible and affordable- to building an Input-Output Matrix which includes the biofuel sector to analyze its potential for job creation.

We make two contributions. The first contribution is methodological, showing how hybrid methods can reasonably provide information to study an economy where only national (or highly aggregated) social accounting matrices (SAMs) are available. By combining secondary data on biofuels with primary results of specific sectoral surveys, hybrid techniques allow us to estimate the regional input-output tables (IO Tables) and SAMs with the needed degree of detail. The second contribution is empirical: we collect sparse and sometimes incomplete, inconsistent, or outdated information on biofuel production; thus, we process all that information, applying said hybrid methodology to trace increases in biofuel production and investments, output, and employment within the economy.

Input-Output Analysis and Computable General Equilibrium (CGE) models are the most common tools to measure in detail bioenergy expansion impacts. Their use is widespread by governments and international organizations [2, 3, 4, 5, 6, 7, 8], to study their effects on the economy (production), the environment (emissions), and society (employment) [4, 3, 9, 10,11].

We present a hybrid methodology for overcoming the lack of information while maximizing the utility of the existent data. We develop IO Tables and SAMs and thus examine the chain of consequences. Because these instruments are costly, they are often built only at the national level. Regional models face problems with data availability and the disparate structure of the regional economy concerning the national one [12]. We study the Santa Fe Province to quantify the regional impact of an increase in both biofuel production and biofuel plants' investment. With a surface like Greece, populated by 3.5 million inhabitants and generating 7.5% of national GDP in constant 1993 prices, it concentrates 79% of biofuel production in Argentina.

For our empirical objective, we require detailed information on supply and demand in the biofuel sector, input-output relationships in the province, and household employment and expenditure information by activity branch. We make compatible diverse sources of information, often poor, sparse, outdated, collected on a non-regular basis, and sometimes inconsistent.

After this introduction, Section 2 reviews the literature to provide context. Section 3 describes the biofuel sector and green jobs in Santa Fe Province. Section 4 develops the method to estimate a regional IO Table, Section 5 presents the scenarios and simulation outcomes, and Section 6 concludes.

2. Literature Review

2.1 Biofuels

Several thermochemical conversions of biomass into fuels are possible from fermentative and biological processes [13]. The most common first-generation or conventional biofuels are bioethanol and biodiesel, produced through processes of transesterification, distillation, and fermentation. The main feedstock is food crops, starch, and vegetable oil [14, 15]. These biofuels convert biomass through chemical, biochemical, and thermal conversion processes [16]. We do not discuss here the second, third- and fourth generation of biofuels, which are not produced in the area under analysis. The second generation of advanced biofuels uses lignocellulosic feedstocks as the main substrate [17, 13], requiring higher capital expenditures than first-generation biofuels [16, 18, 19]. In the third-generation biofuels, the need for agricultural land is eliminated [13]. Fourth-generation biofuels convert optimized biomass feedstock [17].

Bioethanol (ethylic alcohol) is the most common biofuel, being used in gasoline engines in different blends. It can save net GHG emissions from 87% to 96% concerning regular gasoline. The other most common biofuel is biodiesel, used in regular diesel engines, either pure or blended. Other biofuels include biogas, other bio alcohols, firewood, vegetable oil, bio ethers, dried manure, and agricultural waste [16].

2.2 Importance

The conversion from fossil fuels to biofuels can have several impacts on the economy (income, development, energy security, and trade balance), society (employment, equity, poverty, food security, and access to land), and the environment (on water and arable land availability and quality, erosion, GHG emissions, and biodiversity) [15, 19].

The issue of conversion from fossil fuels to biofuels is of high relevance. [20] find a significant inverse connection between the tech industry, renewable energy consumption, urbanization, and environmental degradation. That indicates ways bioenergy that can help reduce environmental degradation. Organizational, communication and technical factors positively and significantly interact, as [21] states, when analyzing the relationship between critical success factors and the sustainable project success of bioenergy projects in Pakistan. Adding value to agricultural production, increasing the level of female employment, and increasing the share of bioenergy consumption, help reduce carbon dioxide according to [22] a Pakistan study. Increasing education expenditure, the number of female employers, and bioenergy consumption share use will help reduce CO2 emissions, according to an empirical analysis made by [23] with China data. In a study of five countries [24], India, the Philippines, Egypt, Pakistan, and Bangladesh, there is evidence that an increase in received remittances, economic growth, and value-added agriculture help in mitigating carbon emissions. Results for seven South Asian countries reveal the existence of a long-term relationship between energy poverty, employment, education, per capita income, inflation, and economic development [25]. This study suggests that in financing the green and low-carbon economy concept, the economies need to make efforts to use modern, energy-efficient, and green technologies for economic and environmental reasons. Recent research had been focused on different biomass resource utilization, studying cost, GHG emissions, and employment impacts at the regional level [26, 27]. In addition, it is observed research efforts applied to investment in renewable energy sources, as well as energy efficiency in different developing countries, considering social, environmental, technical, and economic criteria [28].

Concerning economic and social impacts, biofuel production competes for natural resources (land or water), with food production. Demand for biofuel cropping may induce food price increases [18, 15]. These price rises have led to discussions about food security, especially in developing countries. Distributional effects would occur within and between countries. Besides, government budgets and trade balances are also affected [19].

2.3 Impact

Because biofuel crops use atmospheric carbon dioxide, biofuels may contribute to mitigating greenhouse gas (GHG) emissions [18]. However, it is not clear whether policies promoting biofuel use result in lower GHG emissions: the net impact depends on how they are generated [19]. For instance, the large use of monoculture for biofuel production increases the use of fertilizers and pesticides [15].

To assess the environmental effects of GHG reductions, one should consider the combined net effects of the energy technology associated with biofuels, carbon emissions, land conversion, and agricultural production [29]. While direct GHG emissions can be computed ex-post using life cycle analysis, indirect GHG emissions need to be computed ex-ante using multimarket or general equilibrium models [18].

2.4 Policies

Promotion policies can be made of incentives to increase productivity in food production. Other measures are investments grants; fuel-excises tax credits for biofuels blenders; the use of tariffs on imported biofuels goods; tax incentives for switching-fuel engine cars; or quality standards on fuels, regulating the blending of ethanol or biodiesel to fossil fuels [29].

2.5 Modeling

There are different ways of modeling biofuels' economic and environmental impacts and assessing the policies' role. [1] provides a survey of the literature, concluding that the typical approach in the partial equilibrium literature is to extend existing models of the agricultural sector, by incorporating the demand for biofuels via an exogenous increase in feedstock demand. Less explored until now, are regional CGE (Computable General Equilibrium) models, which analyze the consequences of regulatory, subsidization, or taxation policies, among others. Several CGE models study biofuels at the national level [15, 30]. Most literature uses input-output modeling to estimate the effects on production, employment, and emissions [31].

3. Bioenergy and Green Jobs in Santa Fe Province

Santa Fe Province was responsible for 79% of the national biofuels (generated in 1 bioethanol and 28 biodiesel plants) and 27% of the national biogas production in 2016 (generated in 8 biogas and 3 biomass plants) [32, 33, 34].

Several regulations promote Argentina's bioenergy production: National Law 26,093, enacted in 2006 [61], establishes a system for regulating and promoting the production and sustainable use of biofuels for 15 years. It sets a mandatory floor blending of biofuels with fossil fuels set in 2010 at 5% for biodiesel and bioethanol with diesel and gasoline, respectively, and increased up to 10% for biodiesel and 12% for bioethanol in 2016. Moreover, it grants tax benefits to companies carrying out biofuel production projects.

Additionally, National Law 27,191 [62] enacted in 2016, grants tax benefits for electricity generation from projects embracing renewable sources. In addition to its adherence to national regulations, Santa Fe passed its own Provincial Law 12,692 [63] in 2006, which provides exemptions, breaks, or deferred provincial taxes to non-conventional renewable energy production projects in its territory.

National, provincial, municipal, or private information sources in developing countries in general and in Argentina in particular, generally lack data about relatively small, scattered economic sectors, such as bioenergy production. [32] made a quantitative assessment of the impact on the existing bioenergy sector production and employment (and on new ongoing or planned projects) based on a survey of the sector. We mixed that primary detailed source with aggregated secondary sources. The "FAO survey" [32, 10] identified different processes of bioenergy production with disparate labor requirements both in quantitative and qualitative terms. Once identified, we could draw up a directory of the establishments to project the non-surveyed ones.

Table 1 shows all the surveyed bioenergy activities and their respective production capacity organized by category. The 28 establishments generated 833 jobs of which 88 were female. The biodiesel subsector produced 2,092,488 tons in 2016 and employed 671 workers of which 79 were female. The bioethanol subsector generated 58,000 m3 in the same year and employed 76 persons (7 females). Biogas and biomass electricity generation, complete the information in the Table.

4. Method to estimate the regional IO Tables and Multipliers

To address some problems, a top-down model can solve the attribution of the effects and measure with relative simplicity the direct and indirect consequences arising from exogenous shocks or policies. It can be the case of a standard input-output model at the national level. Nevertheless, difficulties appear when the objective of the analysis is at a regional level (when the economic structure differs from the national one) and/or at specific sectors, which can be important in the region, but very small at the national level, not deserving resources and effort at the national level to go deep in detail. Suppose the context is one of a developed country, and there is interest in studying one region with specific sectors. It is very possible that regional adaptations of the national model do exist, and that opening new sectors is not big deal. The latter happens because resources (institutions, money, and data) are available. Since it can be not the case in developing countries, the shortcut you can use

Table 1: Bioenergy Supply Surveyed in Santa Fe in 2016

Type	Size	# Plants	Capacity (1)	Production (2)	Employment (3)
Biodiesel	Large	8	2,990,000	1,833,303	433 (43)
	Medium	5	160.000	226,032	205 (30)
	Small	3	21,600	33,153	33 (6)
Bioethanol	Large	1	60,000	58,000	76 (7)
Biogas	Large	1	53,000	409	1 (0)
	Medium	4	20,800	3,626	25 (1)
	Small	3	245	13	1 (0)
Biomass Electricity	Medium	1	10.80	5.40	16 (1)
	Small	2	3.00	2.75	43 (0)

(1) In tons of biodiesel, m3 of bioethanol, tons of biomass processed in biogas, MW of electricity generation.
(2) In tons of biodiesel, m3 of bioethanol, thousands m3 of biogas, MWh of electricity.
(3) Full-time equivalent yearly. Female workers between parenthesis,
Source: [32]

consists of complementing the top-down model by adding bottom-up information to the former. The process in the developed country's contexts follows three principal activities: recollection and adequation of the information, calibration of the model and design of scenarios, running of the simulations, and analysis of results. Instead, in developing countries, you cannot assume the first stage is solved, and that is the main contribution of this paper: if you can overcome the information problem, there is no model, no calibration, no scenarios, no simulations, and no results. The bottom-up addition should be technically feasible, and affordable, and make creative use of each piece of available information.

To estimate the size of the biofuel sector and its costs and sales structures, we use information from specific surveys at the firm level, we estimate the IO Table that represents inter-industry relationships in the province based on national information and open the bioenergy sectors according to those surveys using indirect methods [35, 36].

There is no published IO Table for Santa Fe Province. We applied a hybrid method to estimate it: the "FAO survey" was used for bioenergy-related sectors and location quotients (explained below) were applied for the remaining ones. Finally, we apply employment information from the provincial statistics office and estimate the provincial expenditure structure from the national household expenditure survey.

Once the IO Table and the bioenergy and employment database have been constructed, we estimate the direct, indirect, and induced effects of increased production and investments in the biofuel provincial sector using open and closed input-output models. We concentrate on the impact of sector changes on output and the labor market (including their multipliers in the value chains).

This section presents a hybrid method to estimate regional IO Tables, explains the Santa Fe province IO Table we develop, and makes considerations on regional I-O models.

4.1 A hybrid method to estimate regional IO Tables

There are three main approaches to regionalizing IO Tables, depending on the statistics used to create them:

1. Direct techniques employing mainly surveys and specific sectoral data, are usually expensive and time-consuming.
2. Indirect or statistical techniques resting mainly on available secondary sources, sometimes inaccurate.
3. A hybrid approach mixing previous methods, useful when the analysis points to a few sectors from which information can be obtained directly.

The availability of an IO Table, in turn, makes it possible to develop SAMs, showing more detail on final consumption and value-added. They are matrices in which rows (incomes) and columns (outflows) represent markets and institutions, and whose elements represent the transactions between government, firms, households, and the rest of the world [37].

The "FAO survey" allows us to improve location quotients (LQ) using RAS or Cross-Entropy techniques [36, 37, 38]. In addition to the national IO Tables, LQs use available statistics on employment or Gross Geographic Product (GGP). Regional and national data should be compatibilized, updated, and aggregated at the same level. There are many applications of such regional indirect methods for Mexico [41], Finland [42, 43], Greece [44], Germany [45], and Argentina [46, 12], among others. [47] presents an extensive survey of location quotient methods.

The LQ method is based on [35] assumption, that intraregional technical coefficients (a_{ij}^{rr}) only differ from national ones ($a_{ij}^{\square}$) by their regional trade participation (lq_{ij}). Thus,

$$a_{ij}^{rr} = lq_{ij}\, a_{ij}^{\square}, \tag{2}$$

where subscripts i and j refer to the seller and buyer sectors, respectively; a_{ij}^{rr} ("regional purchase coefficient") is defined as the necessary quantity of input produced in the region to generate a unit of product .

LQs' techniques assume that regional technologies have the same structure as national ones but admit that interregional coefficients differ from national ones by a shared factor in regional trade, assuming the greater the region, the lower its import propensity. The chosen LQs make it possible to distinguish between regional self-sufficient sectors (with no imports) and net importer sectors from the rest of the country. When the LQ falls below 1, the region is considered a net importer, otherwise, the region is considered self-sufficient.

[34, 46] propose the Flegg Location Quotient (FLQ), which takes the region's size explicitly into account. FLQ postulates an inverse relationship between the region's size and its propensity to import from other regions.

$$FLQ_{ij} = \frac{GGP_{i,r}/GDP_i}{GGP_{j,r}/GDP} \cdot \lambda^* = CILQ_{ij} \cdot \lambda^* \tag{2}$$

$$\lambda^* = \left[\log_2\left(1 + {}^{GGP_r}/_{GDP}\right)\right]^{\delta}, 0 \leq \delta \,°\!\leq 1, \qquad (3)$$

Where λ* weighs the size (importance) of the region in the country. The essence of the base 2 logarithm is that λ* should always fall between 0 and 1. If the region has the same size as the entire country, λ = 1; if it did not exist in the region, λ* = 0. The calculation of λ* adds a new parameter, δ, related to interregional imports. The closer δ is to 1, the greater the interregional imports. If δ = 0, then FLQ = CILQ.

We use FLQ because its theoretical ground is more plausible than other LQ methods [47]. Additionally, [49] evaluation of LQ techniques highlights that FLQ and Augmented FLQ (AFLQ) are preferable quotients, providing satisfactory results even for small regions. In addition, although the AFLQ is theoretically improved compared to the FLQ, they perform similarly [50, 43, 51].

The information from LQ is used jointly with a regional transaction matrix estimated via indirect methods. To ensure consistency between both sets of data, we use matrix balancing methods (RAS and/or cross-entropy) for the final adjustment. RAS or method of bi-proportional adjustment is an iterative process that implies knowing row and column totals to adjust an initial matrix [52]. Cross-entropy method, instead, minimizes a distance measure between an initial matrix and different calculated matrices meeting technological and transactional restrictions [53, 54].

4.2 The IO Table for Santa Fe

We estimated the IO Table and their relevant direct, indirect, and induced coefficient matrices. The eight main sources of information were the 2004 economic census, the 2004 supply and use charts, the GGP (Gross Geographic Product, that is the value added or Gross Production Value minus Inputs Value) disaggregated by sector, employment by sector in the 2010 Santa Fe Census, jobs by sector in the national Annual Survey of Urban Households (EAHU), Argentina's 1997 input-output matrix, crops data per province from the Ministry of Agroindustry, and Argentina's 2015 SAM from the Ministries of Production and Energy.

The GGP information is very aggregated. We disaggregate by using national intra-chapter weights according to national SAMs, corresponding to bioenergy output branches: Biodiesel, Bioethanol, and Biogas, from surveys of provincial productive companies. To capture the main inputs in the biofuels value chain, we could identify the primary production activities related to Corn, Soybean, Vegetable Oils, and Oil Refineries using the Grain Exchange price information, provincial production data, and the 2008 agricultural input-output matrix [55].

Since the Gross Production Value (GPV) of the agricultural sector is presented as aggregated data in the national accounts and bearing in mind the importance of the provincial soybean and corn crops for biofuel production, we estimated the GPV of these crops based on the structure of costs and sales from the supply and use tables and the input-output matrix designed by the Ministry of Agroindustry for 2008. We use the total soybean and corn tons produced in 2015, and the mean prices of the Rosario Grain Exchange for the GPV estimation.

We estimated the transaction matrix following the FLQ method for all sectors except bioenergy ones, using the optimal parameters for Argentina from [46] For the latter, cost structures were derived directly from the surveys [32]. Regarding employment, the job allocation by sector comes from EAHU, resulting from the ongoing "Permanent Household Survey – 31 Urban Conglomerates" [56].

The household consumption vector was estimated from large expenditure items data in the ENGHO (National Household Expenditures Survey) and Santa Fe's consumer price index weights. We applied the FLQ coefficient to determine which part of consumption is attributed to provincial production. As a consistency criterion, exports of provincial origin were used, and consumption was adjusted to match intra-sectoral supply and demand with the usual IO Tables balancing techniques.

We estimated technologies for the biodiesel and bioethanol sectors in terms of technical coefficients, following the input-cost structures and factors [32]. The aggregation was made by activity. The technical coefficients of the biofuel sectors were escalated to 2015 production. To estimate sales by destination, we extracted internal sales for gasoline blending from the data provided by the provincial Ministry of Energy and Mining and allocated the rest to power generation and exports using national IO Tables. Sales from the biomass sector were allotted to each sector (when self-consumption was declared), and the rest was allocated to the market according to the declared use of energy, mostly electric power.

Table 2 shows Santa Fe's production structure opened into 28 productive sectors [57].

Table 2: Shares of local and imported inputs, value-added structure, and employment by sector

Description	Intermediate Inputs from Santa Fe	Gross Value Added (%)	Jobs (%)
Agriculture, forestry, and fishing	24%	55%	2.45%
Corn	22%	55%	0.11%
Soybeans	20%	55%	0.49%
Mining, and non-metallic minerals	73%	24%	0.16%
Food, beverages, and tobacco	58%	34%	3.15%
Vegetable oil	62%	34%	0.51%
Textiles and leather	44%	45%	1.28%
Paper, wood, and editions	38%	45%	1.90%
Biodiesel	64%	28%	0.06%
Bioethanol	44%	44%	0.01%
Biogas	11%	87%	0.01%
Oil Refineries	2%	55%	0.05%
Rubber, chemicals, and petrochemicals	83%	12%	1.76%
Basic metals and metallic products	28%	40%	3.89%
Machinery & equipment	25%	41%	0.88%
Automobiles and transportation equipment.	41%	30%	0.71%
Other manufactures	2%	97%	1.17%
Maintenance of machinery & equipment	20%	60%	0.50%
Electricity generation and distribution	12%	23%	0.68%
Gas distribution	13%	-34%	0.06%
Water distribution	25%	56%	0.06%
Construction	22%	48%	10.56%
Commerce, restaurants, and hotels	40%	55%	26.38%
Transportation	35%	45%	5.96%
Communications	38%	49%	1.19%
Financial and business activities	22%	72%	10.28%
Public administration and education	16%	76%	15.57%
Health and social services	29%	63%	10.22%
TOTAL	35%	50%	100.00%

Source: Own compilation.

4.3 Regional Input-Output Models

To carry out the impact study, we used an input-output model based on regional coefficients. In this way, we could achieve a more comprehensive and detailed analysis of the effects of a given policy directly on a sector, as well as on other sectors, which might indirectly benefit or be harmed by it.

The resolution is identical in both the regional and the national models [37]. According to the "open model", all final demand is exogenous: private consumption, public expenditure, investment, and exports. It means that the increase in household income because of greater output does not cause additional ("induced") demand due to greater consumption. The regional "open model" is as follows:

$$x^r = (I - A^{rr})^{-1} f^r = L^{rr} f^r, \tag{4}$$

Where x^r is the production vector of the region, I is the identity matrix, A^{rr} is the matrix of the region's technical coefficients, f^r is the region's final demand vector, including purchases from other regions, r is the number of sectors, and L^{rr} is the requirement coefficients' Leontief matrix, both direct (initial) and indirect (secondary).

To find a solution, we "close" the model by making household income and spending endogenous, i.e., including households as just another sector of the model. The "closed model" thus changes to:

$$\overline{x}^r = (I - \overline{A}^{rr})^{-1}\overline{f}^r = \overline{L}^{rr}\overline{f}^r \quad (5)$$

Where $\overline{x}^r$ is the region's production vector including household income in the last row, I is the identity matrix, $\overline{A}^{rr}$ is the technical coefficient matrix showing household income in the last row, and household expenditure in the column on the right, $\overline{f}^r$ is the vector for the remaining final demand (without household consumption in the region), r is the number of sectors, and $\overline{L}^{rr}$ is Leontief matrix for direct, indirect and induced (tertiary) requirement coefficients.

In addition to the simple product multipliers resulting from the "open model" (type 1 multipliers) and total product multipliers resulting from the "closed model" (type 2 multipliers), we also estimated job multipliers. Job multipliers are obtained by changing the measurement unit of the coefficients in matrixes L^{rr} and $\overline{L}^{rr}$, using, for instance, the number of persons employed per product unit [37]. They allow us to approach the problem from a different angle: instead of concentrating on the monetary values of production increase, these employment multipliers compute the number of jobs that the production increase generates.

5. Scenarios and Simulation Results

Simulation scenarios are described as follows:

1. *PROD Scenario*: It simulates the increase in bioenergy production led by a demand increase which needs to be fulfilled through the full utilization of idle capacity plus ongoing investments, both measured at the survey date. The initial idle capacity was different for disparate reasons in each sub-sector: biodiesel, the biggest, sells its products locally and abroad and was suffering from transient restrictions to accessing markets of developed countries; bioethanol was a small sector; and biogas depended heavily on self-consumption, experiencing the same problems their sectors had. The demand push in the PROD scenario which would lead to full capacity utilization can be understood as a remotion of external access to markets.
2. *INVE Scenario*: It simulates demand increases motivating the expansion of production capacity due to a set of new investment projects (under a business-as-usual situation, that is without the impediments to access export markets which guarantee that current capacity is fully utilized) identified by FAO in consultation with social actors in the province, also encompassing the transient effects of the construction stage (plus the fact that the machinery is produced outside the province). We considered three types of plants: 1) cogeneration, 2) biodigesters, and 3) biofuels. For each plant type, we use the expenditure information as a percentage of GPV presented in [58, 59, 60], respectively.

Given the reduced size of the shocks to the province economy, we should not expect any migration of households from other provinces attracted by the growth in bioenergy sectors. Therefore, the induced effect stems from the average household expenditure within the province.

5.1 Production Increase Scenario (PROD)

We applied an increase in production equal to the new capacity minus the existing capacity ratio (idle/total) for each bioenergy category, plus the impact on the production of ongoing investment projects of new capacity, assuming their full utilization, both at the "FAO survey" date.

The biodiesel sector is much larger than the bioethanol and biogas sectors. Initially, they produce, taken together, ARS 6.774 billion (or 744.4 million dollars in 2015; ARS 9.10 = USD 1), and their initial effect registers ARS 7.084 billion production increase (778.46 million dollars of 2015; 105% increase). Table 3 shows how the results are built.

The GPV expansion, in turn, creates 1,186 direct jobs, 3,191 direct plus indirect jobs, and 1,716 induced jobs, resulting in an overall employment effect of 6,093 new jobs. The biodiesel sector has the largest total employment multiplier: an impressive 8.58 if induced employment is computed. This can be explained by the high labor productivity (units produced per worker) in the biodiesel sector, compared to the bioethanol and biogas sectors. The direct employment coefficient of biodiesel is relatively low; hence, its job multiplier is high. The weighted average employment multiplier for the three subsectors is 5.14 (adding the induced effects). All the information on GPV increase, output multipliers,

Table 3: PROD scenario

Energy type	Potential GPV (full capacity) in 2015 billion ARS (Qf)	Current GPV in billion 2015 ARS (Q)	Idle Capacity GPV in 2015 billion ARS (Qf-Q)	Percentage of Idle capacity (Qf-Q)/Qf	GPV Surveyed Projects Adding New Capacity in 2015 ARS (ΔK)	Percentage of GPV increase in Planned New Capacity (ΔQ)	Total GPV increase (ΔQ + ΔK) or Direct Effect in 2015 billion ARS	GPV increase in percentage [(ΔQ + ΔK) / Q]
	A	B	C = A-B	D = C/A	E	F = E/A	G = C + E	H = G/B
Biodiesel	10.360	6.216	4.144	40%	1.241	12%	5.385	87%
Bioethanol	0.373	0.336	0.037	10%	0.127	34%	0.165	49%
Biogas	0.443	0.222	0.222	50%	1.312	296%	1.534	692%
Total	11.177	6.774	4.403	61%	2.681	24%	7.084	105%

Source: Own compilation (based on FAO Survey).

Table 4: GPV Increase in 2015 billion ARS and Employment increase in # persons (PROD scenario)

	Initial	Direct + indirect	Induced	Total	Total multiplier
Biodiesel	5.385	6.427	1.933	13.745	2.55
Bioethanol	0.165	0.100	0.061	0.326	1.98
Biogas	1.534	0.234	0.398	2.166	1.41
TOTAL GPV	7.084	6.761	2.392	16.237	2.29
Biodiesel	581	3,018	1,387	4,986	8.58
Bioethanol	37	57	44	138	3.71
Biogas	567	116	286	969	1.71
TOTAL Jobs	1,186	3,191	1,716	6,093	5.14

Source: Own compilation.

job creation, and employment multipliers is presented in Table 4.

5.2 Investment Increase Scenario (INVE)

In this scenario, we considered a 50% increase over the existing capacity of 75 MW for cogeneration and 81 thousand m3 capacity for biodigesters, which we then multiplied by a USD 5000 cost per MW and a USD 2000 cost per m3. For biofuel plants we consider costs estimated at 2015 ARS for the construction of a 50 thousand tons/year plant, re-escalated at the expected capacity. We assumed all expenditure on machinery and equipment was imported from outside the region, based on survey responses.

Table 5 shows simulation results for the INVE scenario, reflecting a direct increase in GPV of ARS 1.697 billion, and a total effect of ARS 3.832 billion. Direct employment, in turn, climbs to 3,618 new jobs, mainly employed in the cogeneration plant construction, and 5,684 once all effects are computed. Indeed, note that employment timing differs from the PROD scenario. In the INVE case, most of the employment ends once the works have been completed, whereupon the PROD multiplier effect will last during a certain period depending, all other things being equal, on the service life of such plants.

Direct and indirect job creation is greater in the case of INVE than in the PROD scenario (with the caveat of the persistent character of the latter concerning the transient nature of the former). Total job creation is 5,684 in the INVE scenario compared to 6,093 in the PROD scenario. Again, the biofuel industry has the largest multipliers, as in the PROD scenario.

5.3 Gender and Age Group Impacts on Employment

In this subsection, we analyze the impact of the “open model” and “closed model” on employment in the PROD scenario. The results in Table 6 present job creation and job multipliers by gender and age group.

In the open model, consolidating direct and indirect effects, even when jobs created are overwhelmingly for males (3,560 of 4,377 or 81.33%), note the significant impact on female job creation in biodiesel, both in

Table 5: GPV Increase in 2015 billion ARS and Employment increase in # persons (INVE scenario)

	Initial	Direct + indirect	Induced	Total	Total multiplier
Power Plants	1.355	0.448	1.223	3.026	2.23
Biogas Plants	0.035	0.013	0.032	0.080	2.28
Biofuel Plants	0.306	0.098	0.321	0.725	2.37
TOTAL GPV	1.697	0.559	1.576	3.832	2.26
Power Plants	2,821	753	877	4,452	1.58
Biogas Plants	91	22	23	135	1.49
Biofuel Plants	706	161	231	1,097	1.55
TOTAL JOBS	3,618	936	1,131	5,684	1.57

Source: Own compilation.

Table 6: Effects of increases in production on employment (PROD scenario), open and closed models

Open Model	Jobs #					Multipliers				
Category	Gender: Female	Gender: Male	Age < 25	Age > 25	Total	Gender: Female	Gender: Male	Age < 25	Age > 25	Total
Biodiesel	775	2,825	363	3,237	3,600	11.33	5.51	5.26	6.32	6.19
Bioethanol	13	82	9	86	95	3.81	2.41	1.96	2.61	2.54
Biogas	29	654	76	607	683	2.09	1.18	1.13	1.21	1.2
Total	817	3,560	448	3,930	4,377	9.53	3.24	3.18	3.76	3.69
Closed Model	Jobs #					Multipliers				
Category	Gender: Female	Gender: Fale	Age < 25	Age > 25	Total	Gender: female	Gender: Male	Age < 25	Age > 25	Total
Biodiesel	1,244	3,742	518	4,468	4,986	18.18	7.3	7.51	8.72	8.58
Bioethanol	28	110	14	125	138	8.12	3.26	3.06	3.8	3.71
Biogas	126	843	108	861	969	9.07	1.52	1.6	1.72	1.71
Total	1,398	4,696	640	5,454	6,093	16.31	4.27	4.54	5.22	5.14

Source: Own compilation.

absolute and in relative terms (775 on 3,600 or 21.52%). The female job creation multiplier is far greater in both biodiesel and total (in the latter, influenced by the weight of the biodiesel sector on the total).

Youth employment (15–25 years of age) represents slightly more than 10% of total job creation (448 out of 4,377), and this proportion is almost the same in the three subsectors. Multipliers for job creation for older workers are slightly higher than those for younger ones.

In the closed model, computing additionally induced effects, total job creation amounts to 6,093 jobs, of which 1,398 are for female workers (or 23%). Jobs for young workers are about 10%.

6. Conclusions

The transition of an energy matrix based on fossil fuels to one based on renewables implies both changes in the productive structure as well as in the number and type of jobs each form of energy production generates. For instance, industries such as oil and gas are capital-intensive, in the sense the direct employment they generate needs a certain investment per job unit, while other forms of energy generation require fewer dollars per job created. However, direct jobs are only part of the story since each activity has indirect and induced effects both on production and employment. Thus, the introduction of a renewable energy sector in an economy will create direct and indirect employment and will destroy direct and indirect employment in the sector its products replace. In the same vein, qualitative aspects of the jobs would be different: both sectors (the growing and the replaced) can employ people of different ages, genres, or qualifications, or the jobs can be in different places in a country. All those issues can and should be measured to analyze the impact of spontaneous and policy-induced changes in economic sectors. An input-output matrix traces the direct and indirect nexuses allowing the attribution of each effect. Sometimes, as in the case of several developing countries, the information is not available, not published, or does not have the needed degree of detail or modernity as is needed to simulate and evaluate policies.

Our first objective is methodological, showing how hybrid methods can reasonably provide information to study any developing economy where only highly aggregated social accounting matrices are available, lacking data about relatively small, scattered economic sectors. The hybrid method, mixing sectoral (and affordable) surveys with more aggregated information based on location quotients (a non-survey method), yields reasonable substitutes for otherwise nonexistent regional IO Tables and SAMs. The second objective is empirical: we collect sparse and sometimes incomplete, inconsistent, or outdated information on biofuel production; thus, we process all that information, applying said hybrid methodology to trace the effect of policies.

We apply it to increases in biofuel production and investments, explaining changes in output and employment within the economy. However, our method is intended to perform different simulations of policies and other exogenous shocks and can determine economic (production), social (employment), and environmental (emissions) consequences of a variety of measures (regulations, subsidies, taxes, etc.).

Sometimes, policies are advocated with partial equilibrium arguments, pointing to job creation, output expansion, or emissions saved. However, those methods are insufficient since every policy could impose costs or benefits in another part of the economy linked to the sector under analysis. The method we apply tries to address net effects on the whole economy, tracing unintended or not-so-visible influences in other sectors.

We apply our hybrid methodology to a rich soybean and maize producer, which concentrates four-fifths of Argentina's biofuel production. In addition, we also evaluate job creation potential, disaggregating its effect by gender and age. This kind of model allows us to address "qualitative" (referred to attributes of the jobs, such as age, gender, skills, etc.) as well as "quantitative" changes in net jobs, giving policymakers tools for planning if the objective is to promote certain employment. Two scenarios consider an increase in bioenergy production (using existent idle capacity plus ongoing investments at the survey date), and in bioenergy investments (based on expenditure needed to install new plants.). The sector has an initial value added of 745 million dollars and employs near to 1200 persons, and an important idle capacity plus delayed projects because of external shocks. Under full capacity utilization plus ongoing investments, production more than doubled, and employment grow 414%. On the other hand, a 50% additional increase in new capacity implies a total value-added increase of 421 million dollars (56% increase) and a 378% increase in jobs. The second scenario accounts for the employment effect of temporary investments until the construction stage is over, while the job effect of production increases tends to last until the end-of-life of the plant.

Two policy implications derive from the analysis: first, the relevance of measuring exhaustively the effects of renewable energy in the economy, environment, and society; second, the distinction between transient and more permanent effects of alternative policies. Also, we highlight the importance of the instrument we employed to objectively compare the effects of different policies and shocks, and the need of being aware that conventional statistics (especially in developing countries) do not have the degree of detail needed for this kind of analysis.

These types of studies have logical limitations: even when informational problems would be solved, the model requires re-calibrations if structural conditions change.

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