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Defining efficient policies in a general equilibrium model: a multi-objective approach

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ABSTRACT

Macroeconomic policy makers are typically concerned with several indicators of economic performance. We thus propose to tackle the design of macroeconomic policy using Multicriteria Decision Making (MCDM) techniques. More specifically, we employ Multi-objective Programming (MP) to seek so-called efficient policies. The MP approach is combined with a computable general equilibrium (CGE) model. We chose use of a CGE model since they have the dual advantage of being consistent with standard economic theory while allowing one to measure the effect(s) of a specific policy with real data. Applying the proposed methodology to Spain (via the 1995 Social Accounting Matrix) we first quantified the trade-offs between two specific policy objectives: growth and inflation, when designing fiscal policy. We then constructed a frontier of efficient policies involving real growth and inflation. In doing so, we found that policy in 1995 Spain displayed some degree of inefficiency with respect to these two policy objectives. We then offer two sets of policy recommendations that, ostensibly, could have helped Spain at the time. The first deals with efficiency independent of the importance given to both growth and inflation by policy makers (we label this set: general policy recommendations). A second set depends on which policy objective is seen as more important by policy makers: increasing growth or controlling inflation (we label this one: objective-specific recommendations).

1. Introduction

Macroeconomic policy makers are typically concerned with several indicators such as growth, inflation and unemployment rates, and the level of public deficit. In this sense, policy making can be viewed as a problem with several objectives, some of which may conflict with one another. For example, an active anti-unemployment policy could increase inflation; a greater domestic growth rate could be harmful to the balance of trade, and so on. (See refs. [28,30] and [36] for selected discussions and analyses of the multi-objective nature of policy making.)

The well-known area of Multi-criteria Decision Making (MCDM) offers techniques designed to deal with problems in which there are multiple conflicting goals.[1] It thus appears reasonable to tackle the design of macroeconomic policies using MCDM techniques. More specifically, we explore the use of Multi-objective Programming (MP),[2] which specifically seeks so-called (*Pareto*) *efficient solutions*.

For current purposes, we say that a policy is “efficient” if it is not possible to find an alternative that allows improvement in the value of some objectives without harming the value of others. Importantly, knowledge about

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[1] See ref. [8] for an introduction to MCDM techniques, and their applications to economic problems, and ref. [15] for a state-of-the-art review of the field.

[2] For recent developments and applications of MP, see, for example, [7,11,14,16,17,19,23].

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which policies are efficient or inefficient is of real practical value since, if a given policy is known to be inefficient, guidance can be provided for improvement going forward.

In order to operationalize our MCDM approach, an analytic representation of the economy under study is needed. In the current case, we use a computable general equilibrium (CGE) model. Such structures have been used extensively since the 1980s in the evaluation of public policies and other simulation exercises, both in developed and developing countries. (See refs. [4,18,24,26, 31], and [32] for selected recent applications of CGE models, and [22] for a discussion of the current state-of-the-art.)

CGE modelling is especially attractive for policy makers since, being consistent with standard economic theory, it allows one to measure the effects of a specific change (e.g., a given policy) on the most significant economic variables such as prices, production levels, tax revenues, and income distribution. The principal contribution of the current paper is a methodological proposal for policy making that is both operational/practical and consistent with economic theory. Moreover, it combines two analytical tools that, to the best of our knowledge, have not previously been employed together: CGE modelling and MP. The approach can thus be used to design efficient policies and/or determine if any given (real or potential) policy is efficient or not. A second contribution of the current research is its application to a real economy.

In Section 2, we present an application using the Spanish national Social Accounting Matrix (from 1995) in which growth and inflation are chosen as policy objectives. In Section 3, key results are presented: The trade-off between growth and inflation is assessed, an efficient policy frontier constructed, and the observed policy compared to this frontier. Selected recommendations are offered to improve the observed policy in terms of efficiency. In Section 4, some additional extensions and applications of our methodological proposal are presented. Section 5 concludes the paper, offering some guidelines for future research.

2. The proposed methodology and an application to the Spanish economy

2.1. General setting

We assume that a given policy maker has a vector x of policy instruments (which may include, for example, taxes, public expenditures, subsidies, interest rates, etc.). At the same time, s/he also has a vector of policy objectives, say Z. Typically, these objectives include key macroeconomic indicators such as the rate of economic growth, the rate of inflation, the unemployment rate, the level of foreign deficit, and so on. If s/he also has information about how economic agents behave and interact with one another (i.e., an *economic model*), s/he could estimate the equilibrium of the economy. This would allow calculation of relevant macroeconomic indicators as a function of the policy instruments, x. This formulation gives rise to a multicriteria decision problem to be solved by the policy maker.

In this paper, we propose to model this decision problem using MP in seeking efficient policies. A *feasible* policy (i.e., a feasible value of x) is (Pareto) efficient if it provides some values of the objective variables, Z, such that there is no other feasible policy able to achieve the same or better performance for all objectives, while being strictly better for at least one objective. In order to implement this approach, it is first necessary to identify the policy objectives of interest, and their feasible ranges, as well as appropriate policy instruments. Moreover, as suggested above, a model is needed to represent the policy objectives as a function of the chosen instruments. The remainder of the paper offers a proposed approach to this problem as well as a "real-world" application.

2.2. The economic model

As noted above, here we use a CGE model, following the basic principles of Walrasian equilibrium (as in [22]) including the public and foreign sectors. Taxes and public expenditure are taken as exogenous by consumers and firms, but are considered decision variables for the government. An equilibrium of the economy is given by a price vector for all goods and inputs, a vector of activity levels, and a value for public income that satisfies the following conditions:

1. Consumers maximize their utility
2. Firms maximize their profits
3. Public income equals the payments of all economic agents; and, finally
4. Supply equals demand in all markets.

In the interest of brevity, we present only the basic features of the model. For a more detailed description, see ref. [4] or [9].

The proposed model has nine productive sectors. In each sector, there is a single representative firm producing some sort of output. There is also a single representative consumer, one public sector, and one foreign sector. The production technology is described by a nested production function: The domestic output of sector j, measured in euros and denoted by Xd_j, is obtained by combining, through a Leontief technology, outputs from the remaining sectors, and the value added, VA_j. The latter is generated from primary inputs (labour, L, and capital, K), combined by a Cobb–Douglas technology. Overall output of sector j, Q_j, is obtained from a Cobb–Douglas combination of domestic output and imports, $Xrow_j$, according to the Armington hypothesis.[3]

[3] Nested production functions are commonly used in CGE modelling in order to describe the structure of different stages of production (see ref. [27] for a general discussion). Our model uses a Leontief or fixed-coefficient production function to reflect the fact that, in the short term, productive sectors typically use materials and generate value added (VA) in constant proportions. A Cobb–Douglas technology is used for VA to account for substitution between labour and capital. Finally, domestic and foreign outputs are combined through a Cobb–Douglas production function following the Armington hypothesis, according to which domestic and foreign goods are imperfect substitutes (see ref. [6]). For more details about the production structure of the model, see ref. [4] or [9].

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The consumer demands consumption goods and saves the remainder of his disposable income. The government raises taxes to generate public revenue, R, offers transfers to the private sector, TPS, and demands goods and services, GD_j, from each sector $j = 1,\ldots,9$.

PD denotes the final balance (surplus or deficit) of the public budget:

$$PD = R - TPS \times cpi - \sum_{j=1}^{9} GD_j p_j$$

where p_j is a production price index before value added tax (VAT) for the jth good, and cpi is the consumer price index. The cpi is defined in its usual form, as a weighted average of the prices of all goods ($j = 1,\ldots,9$) according to the weight of each good in total consumption (see, e.g., ref. [12], chapter 2).

Consumer disposable income (YD) equals labour and capital income, plus transfers, minus direct taxes:[4]

$$YD = wL + rK + cpi \times TPS + TROW - DT(rK + cpi \times TPS + TROW) - DT(wL - WCwL) - WCwL$$

where w and r denote input prices, L and K input quantities, TROW transfers received by the consumer from the rest of the world, DT the income tax rate (IT), and WC the tax rate corresponding to employees' payment to social security (ESS).

As is common in economic models, the consumer's behaviour is modelled by assuming that s/he aims to maximize welfare,[5] which is derived from consumption goods CD_j ($j = 1,\ldots,9$), and savings SD, according to a Cobb–Douglas utility function, subject to a budget constraint (p_{inv} being an investment price index):

$$\begin{aligned} &\text{maximize} \quad U(CD_1,\ldots,CD_9,SD) = \left(\textstyle\prod_{j=1}^{9} CD_j^{\alpha_j}\right) SD^{\beta} \\ &\text{s.t.} \quad \textstyle\sum_{j=1}^{9} p_j CD_j^{\alpha} + p_{inv} SD = YD \end{aligned}$$

Labour and capital demands are the outcome of profit maximization decisions made by the firms of interest, while capital supply is assumed to be inelastic. For labour supply, we use the following approach showing a feedback between real wage and unemployment rate:[6]

$$\frac{w}{cpi} = \left(\frac{1-u}{1-\bar{u}}\right)^{1/\beta}$$

where u and $\bar{u}$ are the unemployment rates in the simulation and in the benchmark equilibrium, respectively, while w/cpi is the real wage, and β is a flexibility parameter that represents how sensitive real wage is to changes in unemployment. In order to keep our model as close as possible to the real Spanish economy (which is taken for our application), we take from the previous literature a value for this parameter that has been estimated with Spanish data: $\beta = 1.25$ (see [5]).[7]

2.3. Databases and calibration

For current purposes, we used the aggregated 1995 Social Accounting Matrix (SAM) for Spain, which is the most recent version available [10]. It comprises 21 accounts, including nine productive sectors,[8] two inputs (labour and capital), a saving/investment account, a government account, direct (IT and ESS) and indirect taxes (VAT, payroll, output, and tariffs), as well as a foreign sector, and a representative consumer (see [10] for details).

The following model parameters were calibrated: all technical coefficients of the production functions, all tax rates, and the utility function coefficients. The calibration criterion involved reproducing the 1995 SAM as an initial equilibrium for the economy, which was then used as a benchmark for all subsequent simulations. The wage was taken as numeraire ($w = 1$) while all remaining prices were allowed to vary as required in order to meet equilibrium conditions.

2.4. Policy variables, policy objectives, and efficient policies

Here we focus on fiscal policy, with the policy instruments (x) being the public expenditure in each activity sector and the average tax rates applied to every sector, including indirect taxes (social security contributions paid by employers EC_j, tariffs T_j and value added tax VAT_j) as well as direct taxes (social security contributions paid by employees, WC, and income tax, TD).

We impose the following constraints to increase the realism of the exercise: first, all policy instruments are restricted to vary less than 20% with respect to their values under the benchmark situation (denoted as x_0); i.e., $0.8x_0 \le x \le 1.2x_0$. Second, both the overall tax revenue and public expenditure must each be equal to their values under the same benchmark conditions, although the composition across sectors is allowed to vary.

Concerning the policy objectives of interest here, we adopt a simplified bi-criteria setting which assumes that the policy maker focuses on but two macroeconomic indicators. This assumption will allow for results that are clear, easier to interpret, and open to graphical illustration. A larger number of objectives could be considered, but with greater technical complexity and a higher computational cost.

4 See, for example, ref. [12], chapter 2.

5 See, for example, ref. [29].

6 CGE models are built on the assumption that all markets clear in equilibrium. On the other hand, one of the aims of the current analysis is that the model represents reality as closely as possible, which implies the recognition of unemployment. But, such recognition is inconsistent with the equilibrium assumption since unemployment means an excess supply of labour (and, hence, disequilibrium in the labour market). The approach presented here offers an operational way to include the recognition of unemployment in an otherwise equilibrium model. (See ref. [21] for further details of this approach.)

7 As shown in Section 2.3, the rest of the model's parameters are calibrated using the social accounting matrix (SAM) however, this matrix does not contain information needed to calibrate parameter β since the labour market is not a part of national accountability. Therefore, the value of β must be determined from an external estimation.

8 Specifically, the productive sectors are: 1, agriculture, cattle, forestry and fishing; 2, extractives; 3, energy and water; 4, food; 5, chemicals; 6. machinery and transport; 7, manufacturing; 8, construction; and 9, services.

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Table 1
Solution of mono-criteria problems

	Economic growth, γ (%)	Inflation, π (%)
Max γ	**3.62**	6.59
Min π	−9.69	**−6.76**

Bold figures represent the *ideal values* for each objective.

We thus focus here on real economic growth (γ) and inflation (π), since the balance between these variables is an ongoing and substantial challenge in real macroeconomic policy making. Economic growth is calculated as the annual rate of change of real GDP, while inflation is measured as the annual rate of change of the cpi, viz.:

$$\gamma = \frac{GDP_{1995} - GDP_{1994}}{GDP_{1994}} \times 100$$

$$\pi = \frac{cpi_{1995} - cpi_{1994}}{cpi_{1994}} \times 100$$

GDP_{1994} and cpi_{1994} are exogenously available[9] while equilibrium values for 1995 are endogenously determined by the proposed model. Real GDP is calculated as the total value of outputs from all sectors using benchmark rather than current prices. Real growth thus depends only on the evolution of production and not on prices. As noted earlier, a policy x providing (γ,π) is said to be "efficient" if there is no other feasible policy (say, x') providing (γ',π') such that $\gamma' \geq \gamma$ and $\pi' < \pi$, or $\gamma' > \gamma$ and $\pi' \leq \pi$.

The CGE model introduced above gives, as a result, the values of the policy objectives (growth and inflation) as (implicit) functions of the policy instruments (taxes and public expenditure). We assume that the policy maker takes this model as a representation of the economic system and includes all its equations as constraints when designing policies.

3. Results

3.1. Identifying the set of efficient policies

We begin our computations by calculating the highest feasible growth rate, and the lowest feasible inflation rate. These results are displayed in Table 1.

The first row lists the values of growth and inflation obtained when the former is maximized without taking the latter into account, whereas the second row presents the results that follow from the inflation minimizing exercise. If the policy maker was concerned with only growth, s/he could implement an expansive policy resulting in a high growth rate, $\gamma = 3.62\%$ (denoted in bold as the ideal value) compatible with a high inflation rate of $\pi = 6.59\%$. On the other hand, by implementing a deflationary policy, it would be possible to eliminate inflation and actually realize a deflation of 6.76% (denoted in bold as the minimum attainable value for inflation), together with a negative growth rate of $\gamma = -9.69$.

[9] Source: INE (Spanish Statistical Institute) [20].

Table 2
Mono-criteria problems with a lower bound for inflation

	Economic growth, γ (%)	Inflation, π (%)
Max γ	**3.62**	6.59
Min π (bound)	1.57	**0.50**

Bold figures represent the *ideal values* for each objective.

These results have very different economic implications. The first (growth maximizing) solution implies a rather high growth rate, thus representing a desirable policy outcome. Nevertheless, such a solution is probably unacceptable in practice as it would be accompanied by an excessively high inflation rate.

On the other hand, the second (inflation minimizing) solution would likely be seen as entirely undesirable for at least two reasons. First, it implies the existence of a recession in terms of growth. Second, policy makers are typically not interested in deflation, but, rather, in a low inflation rate, e.g., 0.5–1.0%, to ensure stability. In what follows, we will thus take 0.5% as the minimum reasonable inflation rate, with the resulting "acceptable range" being [0.5,6.59].

By maximizing the growth rate subject to $\pi = 0.5$, we determined that the highest compatible growth rate would be $\gamma = 1.57$. Table 2 shows the ideal solutions for both policy objectives when considering our stated lower bound for inflation.

The first row shows the solution for the growth maximizing problem (which entails an excessively high inflation rate), whereas the second row displays the solution when the policy maker is only concerned with maintaining a desirable inflation rate (which entails a lower growth rate). The values along the diagonal (maximum growth rate and desired inflation rate, both denoted in bold) is a non-feasible combination known as the *ideal point*. The vector with the worst element of each row (in this case, the maximum inflation rate and the minimum growth rate within the relevant range) is called the *anti-ideal point*.

In order to construct (an approximation of) the efficient set of policies, we use the so-called *constraint method*[10] which involves the following. A grid is constructed for the feasible values of π, viz., [0.5–6.59]. The number of points in the grid depends on how much accuracy is required for the analysis. In our case, 10 values appear to be sufficient to provide a good approximation to the efficient set. Let π_n denote one specific value of π in the grid. For each of these values, we then solve the problem:

$$\begin{array}{ll} \text{maximize} & \gamma \\ \text{s.t.}: \pi \leq \pi_n, & \text{and all the equations of the CGE model} \end{array}$$

By design, each of these optimization problems gives rise to

[10] The constraint method is appropriate here since we seek to construct an *efficient frontier*. This method allows us to fix different target values for one of the variables and, therefore, to determine the graphical distance between the points of the frontier at our convenience. Moreover, it works well from a computational point of view. Some alternative methods that could be brought to bear on the efficient set include the weighting method (which maximizes a weighted sum of the objectives) or the so-called *multicriteria simplex method*, which involves testing all corner points of the feasible region in terms of efficiency). See ref. [25] for a brief introduction to, or ref. [13] for an overview of, these techniques.

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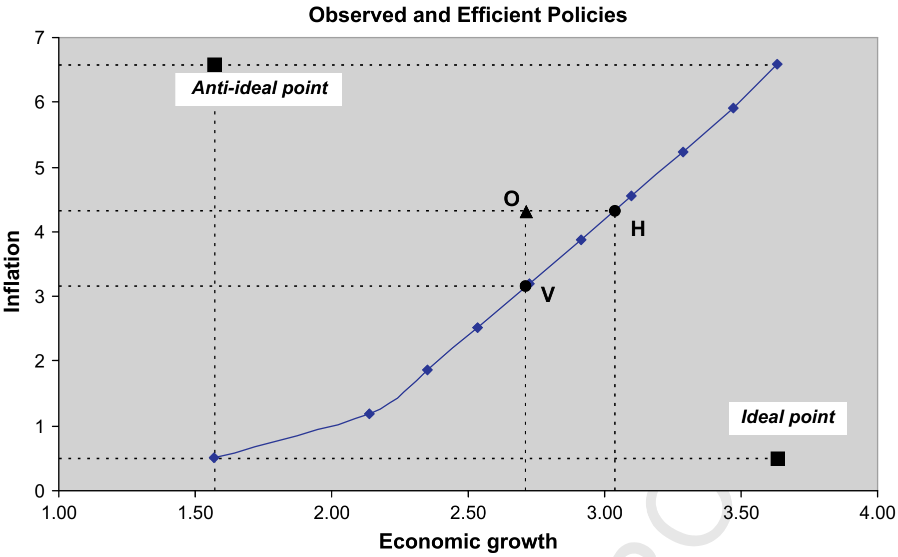

Fig. 1. Projecting the observed policy on the efficient frontier.

an efficient solution. Fig. 1 maps these calculations for the Spanish economy in 1995 with the ideal and anti-ideal solutions displayed. We refer to the line connecting all the efficient solution as the *efficient frontier*. Any combination above this frontier can be considered as inefficient as it entails either a higher inflation rate for the same growth rate (if it is compared with its vertical projection onto the frontier), or a lower growth for the same inflation rate (when compared to the horizontal counterpart in the frontier). On the other hand, all the combinations below the frontier are infeasible.

The slope of the efficient frontier can be understood as the policy *trade-off* between objectives, i.e., the increment in inflation that one must accept in order to increase growth or, alternatively, the reduction in growth that would be implied by a reduction in the inflation rate. It can be seen that, along the efficient frontier, there is a monotonic relationship between growth and inflation in the sense that the slope is always positive.

On the other hand, the frontier can be roughly divided in two parts: the bottom segment (with *low* values of growth and inflation), and the top segment (with *high* values of both variables). Note, moreover, that the slope of the former is smaller than that of the latter. This means that, if the growth rate is high, attaining additional points of economic growth requires larger increments in inflation than if the opposite were true. Alternatively, if the inflation rate is low, reaching additional reductions would be more costly in terms of lost growth than in the opposite case. This seems reasonable from an economic point of view: if the economy is at very good levels on one objective, it would be difficult to realize additional improvements on that same objective.

3.2. Testing the efficiency of observed policies

We can now evaluate the efficiency of any policy – real or potential. As suggested earlier, we focus here on the real/actual policy applied in Spain in 1995. As a result of this policy, the observed growth and inflation rates were $\gamma = 2.71\%$, $\pi = 4.3\%$,[11] respectively. These values are represented by point O in Fig. 1. Since this point lies strictly above the frontier, the policy displays some degree of inefficiency with respect to the selected objectives. Note that point H ("horizontal projection") provides the same inflation rate with a strictly higher growth rate (specifically, $\gamma_H = 3.02$, $\pi_H = 4.3$), while point V ("vertical projection") provides the same growth rate with a strictly lower inflation rate ($\gamma_V = 2.71$, $\pi_V = 3.15$). A rational policy maker interested in increasing growth and/or decreasing inflation should thus reformulate policy by moving it towards the efficient frontier, i.e., towards point H, or point V, or, in fact, towards any point intermediate between the two.

In order to determine in which direction(s) the (fiscal) policy should be reformulated, we solve two optimization problems. The first maximizes γ subject to $\pi \leq 4.3$ (observed inflation). The second minimizes π subject to $\gamma \geq 2.71$ (observed growth). Solving these formulations is equivalent to projecting point O onto H and V, respectively. The values of the (fiscal) policy instruments that solve the problems represent the policies that should be implemented in order to drive the economy to each of the two efficient points.

The results of these exercises are shown in Table 3. The column headed *Observed* displays the values of the policy instruments (public expenditure[12] and taxes, by sector) under observed conditions (resulting from calibration). The columns headed *Point H* and *Point V* present the changes that should be applied in order to move from the observed situation (O) to H and V, respectively. In each case, the

[11] Source: INE (Spanish Statistical Institute) [20].

[12] Note that the public expenditure in 1995 Spain only appeared to be positive in Sectors 5, 6 and 9, and zero in the rest. Since we imposed the constraint that all policy instruments vary less than 20% with respect to the observed value, the public expenditures in all sectors except 5, 6 and 9 were constrained to zero.

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Table 3
Values of policy instruments (observed and projected)

	Sector	Observed[a]	Point H		Point V	
			Value[a]	Change rate[b]	Value[a]	Change rate[b]
Public expenditure	5	3295	3954	20.00	3954	20.00
	6	119	143	20.00	143	20.00
	9	80362	79679	−0.85	79679	−0.85
VAT	1	0.65	0.52	−20.0	0.52	−20.0
	2	1.30	1.04	−20.0	1.04	−20.0
	3	3.29	2.63	−20.0	2.63	−20.0
	4	2.28	1.82	−20.0	1.82	−20.0
	5	1.02	1.22	20.0	1.22	20.0
	6	1.42	1.71	20.0	1.71	20.0
	7	1.89	2.26	19.5	1.86	−1.7
	8	1.70	2.04	20.0	2.04	20.0
	9	3.61	2.89	−20.0	2.89	−20.0
Social security employers	1	11.17	8.94	−20.0	8.94	−20.0
	2	39.64	31.72	−20.0	31.72	−20.0
	3	36.22	28.98	−20.0	28.98	−20.0
	4	27.28	21.83	−20.0	21.83	−20.0
	5	32.33	32.73	1.2	29.57	−8.5
	6	28.52	34.23	20.0	34.23	20.0
	7	25.58	28.05	9.6	26.70	4.4
	8	23.28	27.94	20.0	27.94	20.0
	9	26.60	27.44	3.2	24.84	−6.6
Tariffs	1	0.15	0.15	0.0	0.15	0.0
	2	0.11	0.11	0.0	0.11	0.0
	4	0.57	0.56	−1.75	0.57	0.0
	5	0.56	0.66	17.85	0.56	0.0
	6	1.62	1.62	0.0	1.59	−2.2
	7	0.89	0.89	0.0	0.89	0.0
Income tax		10.29	10.75	4.5	11.47	11.5
Social security employees		6.50	5.17	−20.0	5.17	−20.5

In the columns "Point H" and "Point V", shaded cells represent objective-specific policy recommendations, while the white cells represent general efficiency recommendations.
[a] Million euros for public expenditure and percent average rate for taxes.
[b] Percent rate of change with respect to the observed value.

column labelled *Value* displays the value of each instrument while *Change* displays the rate of change with respect to the observed situation (which is constrained to fall between −20% and +20%. See Section 2.4).

Values in the H and V columns can be seen as policy recommendations for those interested in designing efficient strategies in terms of our dual objectives of growth and inflation. More specifically, the H-values can be seen as recommendations for increasing growth (while keeping inflation unchanged), while the V-values are directed at reducing inflation (while keeping growth as observed). The following subsection presents a classification of the policy recommendations.

3.3. *Policy recommendations*

Since point H results from maximizing γ (while restricting π), and V from minimizing π (while restricting γ), *a priori*, one could expect dramatically different policy recommendations in each case. Nevertheless, our analyses found that, although some policy instruments may assume varying values under conditions depicted by H and V, others can obtain virtually the same results in both scenarios. The implication is that we can split the set of policy recommendations into two groups.

The first would include those recommendations that appear efficiency-enhancing regardless of policy priority (growth or inflation). We label these as *general efficiency recommendations* (unshaded/white cells in Table 3). In this category, the model recommends an increase of 20% in public sector expenditures for Sectors 5 (Chemicals) and 6 (Machinery and Transport), and a slight reduction (−0.85%) for Sector 9 (Services). One could conclude, therefore, that if the Spanish government wanted to increase the efficiency of its fiscal policy, it should expend more in Chemicals and Machinery and Transport. Notably, these recommendations hold independently of what is the main focus of the policy: Growth or inflation control.

In terms of VAT, the tax rates should decrease as much as possible within the feasible range for Sectors 1–4 and 9, and increase as much as possible for Sectors 5, 6 and 8. Further, the social security contributions paid by employees, and those paid by employers in Sectors 1–4 should decrease by 20%, whereas those paid by employers should increase in Sectors 6, 8 and, to a lesser extent, in Sector 7. As a general comment, the model seems to suggest that taxation should be reduced in less productive sectors (Agriculture, Extractives, Energy or Food) or those generating a lower valued added (Services), and increased in dynamic sectors such as Machinery and transport, or Construction.

A second set of policy recommendations *depends* on policy priority: maximizing growth (H) or minimizing inflation (V). We label these as *objective-specific recommendations* (shaded cells in Table 3). In general, the differences between the two policy strategies (H and V) appear to be rather small compared to their common features. First, note that there are policy-specific recommendations regarding taxes, but not public expenditure. The most notable differences arise in the social security contributions paid by employers in Sectors 5 and 9, which should be higher in order to increase growth, and lower to reduce inflation. Something similar happens with the indirect tax on consumption (VAT) in Sector 7, and tariffs in Sectors 4, 5 and 6. Our analysis thus suggests that, by following each group of recommendations, the government could increase efficiency while "fine-tuning" its policy in the desired direction (either growth or inflation control).

4. Extensions

Beyond the current application, one of the main purposes of this work was to introduce a methodological approach to designing public policies with multiple criteria, using MCDM. The proposed methodology may be further developed and applied to a variety of policy scenarios. Indeed, this paper is part of a larger research project involving the design of macroeconomic policies with multiple criteria. Here, we offer a sample of extensions of the current analysis which have already been developed.

As a first topic to be addressed, note that, depending on the underlying structure of the policy making problem, the set of efficient policies is capable of being very large, or even infinite. If that is the case, having knowledge of the entire efficient set might not be very useful, or even operational (because of excess information). It might therefore

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be appropriate to apply some additional criteria (apart from efficiency) to reduce the number of eligible policies that should be presented as recommendations to policy makers. In the first companion paper by the authors, André et al. [2] proposes to use Compromise Programming (CP) in order to identify a smaller set of rational/feasible macroeconomic policies. This well-known technique, which was pioneered in refs. [33–35], identifies the so-called *compromise set*, which is a subset of the efficient set that includes those solutions that are "as close as possible" to the ideal point.

It is also important to note that the *definition* of an efficient policy is a function of the objectives of interest. Thus, a policy that appears inefficient with respect to a given set of objectives could surely be efficient if evaluated under different criteria. Although our application focuses on growth and inflation, plausible applications could easily be made to other policy scenarios, such as improving the incomes of two sectors, two socio-economic groups, etc. Moreover, there is no need to limit the analysis to problems with just two objectives. An immediate extension of this work would be to increase the number of policy objectives beyond two. Other companion papers, André and Cardenete [1] and André et al. [3], explore these lines of extensions (i.e., modifying and enlarging the set of policy objectives). Specifically, André and Cardenete [1] uses Multi-objective Programming to find efficient subsidy policies in a regional economy considering as objectives the profit of selected sectors, and the overall growth of the economy, while André et al. [3] presents an approach to design public policies considering both macroeconomic and environmental objectives.

In the next section, we suggest further extensions which remain to be developed, and thus offer promising lines of future research.

5. Concluding remarks and further research

In this article, we have presented a methodological approach for the design of public policies accounting for the fact that policy makers are usually concerned with a variety of conflicting criteria. We thus address two types of readers: first, researchers interested in economics in general, and designing macroeconomic policies in particular; and, second, policy makers interested in an operational tool for the design of rational and practical macroeconomic policies.

We thus offered general guidelines to model policy with several criteria (i.e., policy objectives) and provided a definition of an efficient policy. We then presented an application to illustrate the potential usefulness of our approach. A CGE model calibrated for the (1995) Spanish economy allowed us to quantify the trade-offs between real growth and inflation when designing fiscal policy, and to construct a frontier of efficient policies in terms of these two factors. The observed policy was tested in terms of efficiency with results showing that the combination of growth and inflation was strictly above the efficient frontier. We were thus able to conclude that the existing policy displayed some degree of inefficiency with respect to the two economic objectives.

A key contribution of this paper is the application of the Paretian concept of efficiency to the field of policy design. Efficiency is, to be sure, a desirable property of macroeconomic policies, since any inefficient policy could be unambiguously improved in terms of a given set of objectives. This is a relevant issue in practice since, if the applied policy is, in fact, inefficient, we can argue that it should be re-oriented to ensure that resources are managed in a (more) rational way. As we have shown, multi-objective programming, employed in conjunction with a CGE model, appears to be a useful approach to identifying efficient policies in practice, and to assessing the efficiency of a given (real or hypothetical) policy.

Based on our analyses, a key conclusion/recommendation is methodological in nature, and not particularly surprising: once policy objectives have been stated and understood, decision makers should implement an appropriate procedure to ensure that relevant instruments are used in an efficient manner. Our results illustrate how not doing so may lead to inefficient (and, hence, unsatisfactory) economic results.

At the same time, the proposed model provides selected and specific recommendations for the case under study. These can be grouped in two categories: the first includes so-called general efficiency recommendations. These include changes to be made in fiscal policy for the sake of efficiency (in order to drive the economy to the efficient frontier) independent of any focus of policy makers, i.e., either increasing growth or reducing inflation.

In our case, these recommendations include, first, increasing public expenditures in Sectors 5 (Chemicals) and 6 (Machinery and Transport) while reducing them in Sector 9 (Services). It is also recommended that taxation be tempered in traditional sectors such as agriculture, extractives, energy and food, but increased in more dynamic sectors such as machinery and transport, and construction.

The second group of specific policy recommendations (objective-specific recommendations) depends on where the policy focuses, i.e., on increasing growth, or on controlling inflation. It is interesting to note that, for each of the analyzed policy-making problems (H and V), the first group includes 21 policy recommendations while the latter includes just eight. Conventional economic wisdom suggests that fostering growth and controlling inflation are two very different objectives and thus require different, even conflicting, policy measures. Nevertheless, our results suggest that there is significant overlap between fiscal policies needed to pursue both objectives in a general efficiency-seeking framework.

The current article is the first in a line of research aimed at designing public policies with multiple criteria. In this regard, we have introduced selected extensions and applications of our approach, such as a procedure to reduce the set of eligible policies and alternative sets of policy objectives. Nevertheless, there remain additional extensions that could be addressed in future research.

One possibility is the use of alternative multi-criteria methods. Although we used multi-objective programming (for reasons explained earlier), other MCDM techniques could be used, and done so within different problem context(s). For example, in applications with a large number of objectives, where it is not realistic to seek a global

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optimum, but, rather, to satisfy "reasonable" aspiration levels, goal programming might be a more suitable tool.

As another possibility, interactive MCDM methods provide a way to "fine-tune" policies by incorporating the preferences of the policy makers once initial policy suggestions have been offered.

At the same time, there are some meaningful ways to improve and enlarge the CGE model itself. A natural extension would be to address the dynamic aspects of the economy.

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