Socioeconomic processes as open-ended results. Beyond invariance knowledge for interventionist purposes

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ABSTRACT: In this paper a critique to Cartwright's approaches of capacities and nomological machines is carried out. This approaches share the idea that invariant knowledge is crucial for achieving policy purposes. However, it is shown that socioeconomic processes do not fit to the logic of stable causal factors, but they are more suited to the logic of "open-ended results". On the basis of this ontological variation it is argued that *ex-ante* interventions are not appropriate in the socioeconomic realm. On the contrary, they must be understood in a "dynamic" sense. Finally, derivational robustness analysis is proposed as a useful tool for overcoming the problem of "overconstraint", a typical problem of economic models.

Keywords: invariance, intervention, nomological machines, capacities, derivational robustness analysis.

RESUMEN: En el presente trabajo se hará una crítica a los enfoques de capacidades y máquinas nomológicas propuestos por Cartwright. Estos enfoques comparten la idea de que un conocimiento invariante es crucial para el éxito de una política. No obstante, aquí se mostrará que los procesos socioeconómicos no son compatibles con la lógica de los factores causales estables, sino con la lógica de los "resultados de final abierto". Sobre la base de esta variante ontológica se argumentará que las intervenciones ex-ante no son apropiadas en el reino de lo socioeconómico. Por el contrario, deberían ser entendidas en un sentido "dinámico". Finalmente, se propondrá al análisis de robustez derivacional como una herramienta útil para superar el problema de "sobre-restricción", un problema típico de los modelos económicos.

Palabras clave: invarianza, intervención, máquinas nomológicas, capacidades, análisis de robustez derivacional.

Introduction

According to many approaches in the philosophy of science, adequate interventions must be grounded on prior knowledge of stable or invariant causal factors. This knowledge has been conceptualized in different ways: as regularities that support "active" counterfactuals (Woodward 2003), as "capacities" (Cartwright 1989), as mechanisms (Bunge 1997; 2004; Machamer, Darden and Craver 2000; Glennan 2002; Hedström and Ylikoski 2010), as nomological machines (Cartwright 1997; 1999), etc. Invariance is an important requirement for interventionist purposes, since when an intervention is carried out we are expected to know what the result of manipulating a factor or set of factors will be, and without invariance such predictions seem to be practically impossible.

Using invariant causal factors for interventionist or policy purposes is a very intuitive idea, and it is permanently performed both in the social and the natural sciences. Once we test that there exists an invariant relationship (or at least a stable contribution) between the

use of fexofenadine and lower levels of histamine in the human body, physicians prescribe that drug in case their patients experience allergic reactions. In the Machamer *et al.* terminology we may say that invariant relationships are a consequence of stable *activities*. In the case of the natural sciences, such activities take place because of the specific properties of entities, and these properties hardly change overtime. However, in the case of the social sciences in general and in economics in particular, activities are nothing more than individuals' actions. More precisely, people's decisions depend on a myriad of factors, namely the information they receive from the world, the way in which they interpret such information, their expectations about future, the background conditions such as cultural and institutional factors, etc. This means that people's actions are not stable *per se*. Quite the contrary, socioeconomic phenomena are best suited to the logic of possibility trees or open-ended results: given a certain event (inflation, an increase in government spending, union strikes, etc.), different ways or alternatives are plausible. The resulting event will depend on what signals individuals receive, how they form their expectations, what the institutional framework is, etc.

If this is true, then meeting the requirement of invariant knowledge for policy purposes does not seem feasible in economics. On the one hand, because there are incompatibilities at an ontological level: there are no stable contributions but open-ended results. On the other hand, because even if stable causal factors are "hunted" in the right way, there is no guarantee that such stability will prevail in other scenarios (see Cartwright 2007). Nevertheless, the fact that there is no invariant knowledge in the socioeconomic realm (or that it is more the exception than the rule) does not mean that policies cannot be implemented. Indeed, this is something that is commonly done (and often successfully). In this sense, this paper aims to reflect both about the kind of knowledge used for policy implementation purposes and about the ways in which such interventions are carried out. It will be argued that theoretical knowledge provided by economic models may be comprehended as *blueprints,* where a set of conditions that limit the range of possibilities of a social system in order to achieve the desired result is specified. Following the Bunge's distinction (1997) between "conceptual system" and "concrete system", it will be shown that such knowledge is not about stable causal contributions, but rather about logical relations that *could* turn into causal relations as long as the gap between the conceptual and concrete systems is filled.

To some extent, there is compatibility between the Cartwright's idea of the "dappled world" and the approach defended in the present paper, since both emphasizes the importance of the domain or range of applicability in the understanding of economic models. In this juncture, for every real world scenario there would be a model or blueprint which provides information about the conditions that need to be met for the purpose of achieving a result. However, the use of this kind of theoretical knowledge may involve *external validity* problems: those where the model results can only be exported to circumstances identical to the context in which the result was obtained. This case concerns the social sciences in general and economics in particular. According to Cartwright (2009a), economic models are "over-constrained" by structural assumptions: since the model results are inferred under very specific circumstances, there is no guarantee that they will be obtained in domains different than the model.

Although the approach of the present paper is consistent with the idea of "overconstraint", implications are different from one another. While it is true that all the model assumptions are necessary for making inferences, it will be argued that only some of them are relevant for the construction and implementation of a socioeconomic blueprint. Let's take for instance assumptions like homogeneous goods, continuous and differentiable produc-

tion functions everywhere in the interior of the production set, economies with only two agents, etc. These assumptions play the heuristic role of simplifying the inference results (see Kuorikoski and Lehtinen 2009; Musgrave 1981). If so, then their presence in other scenarios (not only other models, but also the real world) is not important for exporting the model results. In this sense, derivational robustness analysis may be a good method for distinguishing which of the model assumptions are relevant for policy purposes and which just play a tractability role.

This paper is divided as follows. In the next section two Cartwright's ways of conceptualizing invariant knowledge are examined: capacities and nomological machines. In the third section an ontological alternative to these approaches is offered, and it is asserted that socioeconomic phenomena are better suited to the rationale of possibility trees or open-ended results than to the rationale of stable causal factors. In the fourth section an alternative to the Cartwright's problem of overconstraint is proposed. More precisely, it is argued that, as long as economic models are subjected to a derivational robustness analysis, such models will be able to provide exportable information. In the fifth section a different way of how to conceptualize the notion of intervention is examined: not as an "ex-ante" idea (as proposed by several philosophical approaches), but as a "dynamic" idea, where manipulations are carried out all along the socioeconomic process. The paper culminates mentioning some extensions for further discussions.

Invariance in policy implementation: the Nancy Cartwright's approach

In modern Philosophy of Science there exists a certain consensus on defending the idea that some kind of stable causal knowledge is needed for accomplishing interventionist purposes in general and for policy and planning in particular. Such stability is crucial, since one of the main goals of an intervention is to predict an outcome or control the value of a variable by manipulating certain factors.

Different ways of conceptualizing this knowledge have been offered.[1] One of these is Nancy Cartwright's "capacities" approach. In order to understand scientific practice, Cartwright (1989) argues that the causal claims of science are not about regularities or constant conjunctions of events, but about adscription of capacities that underlie such phenomena. Broadly speaking, capacities are properties of entities or structures that contribute to the production of a result in a stable manner. Nevertheless, such a "contribution" should not be understood in law-like terms. When it is asserted that "aspirin has the capacity to relieve headaches", it is said that there exists an entity (aspirin) that has the property of producing a result (headache relief). This does not mean that aspirin always relieves headaches, or that it relieves headaches most of the time. Rather it is simply asserted that there exists a relatively enduring and stable capacity that an entity carries with itself from case to case (Cartwright 1989).

According to Cartwright (1998) capacities have the following features: (1) potentiality, (2) causation, and (3) stability. Point (1) refers to the very contribution of a causal factor, which may be perturbed due to the operation of other factors. With regard to (2), "ca-

[1] See for instance Woodward (2003), Hedström and Ylikoski (2010), Glennan (2002), etc. Nevertheless, for space reasons these approaches will not be considered in the present paper.

pacity" is an irreducible causal notion, that is to say, it is not expressed in terms of constant conjunction of events (such as the Humean's approach of causation), relations of counterfactual dependence (e.g., Woodward 2003), or the like. Finally in (3), if an entity has indeed the capacity to produce a result, then the relationship must be stable through a certain range of circumstances.

For example, let's suppose that economists have established that the growth of the money supply in an economy has the *capacity* to increase the level of national income. According to Cartwright's approach, we can say that

1. Money supply is not only (positively) correlated with the national income, but also the former actively produces a change in the latter.
2. Although the quantity of money is increasing, it is not possible to predict the behavior of the national income, because there are always other causal factors that may interfere with the causal contribution of the money supply.
3. The capacity of the growth of the quantity of money to increase the national income is *stable* across some range of situations (e.g., geographical regions, economic policies, etc.).

Points 2 and 3 appear to be contradictory, but they are not. "Stability" is not the same as "regularity". Regularity is a pattern of (high) correlation at the level of events. On the contrary, stability is related to the very contribution of a causal factor to the production of a result. In this sense, it is pertinent to note that the notion of capacity rests on a three-fold distinction: the *obtaining* of the capacity, its *exercise* and the *manifest results* (Cartwright 2009a). For example, the fact that money supply has the capacity to bring about changes in the national income is just an "ontological" issue: there exists the chance that no policy maker has ever taken the decision to increase the quantity of money in an economy. The capacity exists (or has been *obtained*, for that matter), but it has not been exercised. Likewise, a positive change in the quantity of money may be carried out. However, this does not guarantee an increase in the national income. In this case the capacity is *exercised*, but the *manifests results* do not take place at the level of events.

Capacities are the *primitive* elements of the world. Regularities are *secondary*. More precisely, Cartwright (1995; 1997; 1999) asserts that there are no laws in the sense of universal regularities or regular associations between properties. The world is "messy" and "dappled", so laws turn out to be observable only in rare circumstances where a particular system of components is properly "shielded" from external influences. Cartwright calls them *nomological machines*, where a nomological machine is "a fixed (enough) arrangement of components, or factors, with stable (enough) capacities that in the right sort of stable (enough) environment will, with repeated operation, give rise to the kind of regular behavior that we represent in our scientific laws" (Cartwright 1999, 50).

Good examples of what a nomological machine is are vending machines. They are machines whose repeated functioning gives rise to a law or a regular association between properties. This process begins after the customer inserts currency or a token into the machine and selects the wanted article. There are a series of mechanical processes inside the machine that end up with the obtaining of the selected product. The "law" emerges from the satisfactory and repeated functioning of the vending machine: *if X* (the coin inserted) *is to occur*, *Y* (the good obtained) *will take place*. However, for this to happen, the machine must be shielded or isolated from anything that might disturb the internal operation. This is

precisely what happens with a vending machine: the mechanism is shielded from several (though not all) types of external influences.

As can be seen, for Cartwright invariant regularities are possible, but conditioned by *ceteris paribus* clauses. The traditional view assumes that situation for the social sciences. Cartwright rejects this position, noting that almost all scientific regularities hold only *ceteris paribus*. Even physics needs machines to generate regularities, machines in the sense of stable configurations of components properly shielded and repeatedly set running (Cartwright 1995).

Whether they be, nomological machines or capacities, they are different ways of conceptualizing a causal knowledge which, since it has the property of being stable or invariant, it may be useful for political purposes. However, the mere discovery of invariant causal factors does not guarantee the success of a policy once these are "used" or implemented. Here there exists a clear problem of external validity which is associated with a lack of a "bridge" that connects the discovery of causal factors with their respective use. Without this bridge, there is no warranty that a causal factor will work in different circumstances or scenarios, regardless of its level of invariance (see Cartwright 2007; Cartwright and Efstathiou 2011).

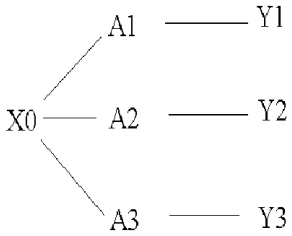
Nevertheless, in Cartwright (2011; 2012), Cartwright, and Hardie (2013) and Rol and Cartwright (2012) it has been suggested that the best way to overcome this problem is to focus on the details of the population in which the intervention is intended to be implemented. Methods for hunting causes only provide information regarding a policy that worked *somewhere*. However, the real interest underlying policy purposes is associated with the causal knowledge that turns out to be relevant for the new policy to be implemented, and not for the others. In this sense, Cartwright and Hardie (2013) and Cartwright (2012) consider that a policymaker should perform two searches prior to implementing a policy: the *horizontal search* and the *vertical search*. In the vertical search, one must find out if the causal principle has been described at the right level of description. Such principle must be general enough to be applicable to both the system under study and the target system. Likewise, in the horizontal search, the policy maker considers whether the support factors obtained in the studied population are obtained in the target population as well. As we can see, the need for a stable causal contribution still remains. The only difference is that now this contribution is complemented with a set of support factors.

Socioeconomic processes as open-ended results

The approaches discussed above share the ontological assumption that there are stable causal factors in the socioeconomic realm. Since one of the main purposes of the present paper is to examine the conditions that contribute to a successful policy implementation, it is important to take into account some ontological aspects of the socioeconomic phenomena. Following the dualistic ontology of mechanisms proposed in Machamer, Darden and Craver (2000) and in Machamer (2004), causal relationships are mediated by *activities*. Activities are the producers of change. They are types of causes. However, Machamer *et al.* follow Anscombe's idea that the word "cause" itself is fairly general and only becomes meaningful when complemented by other, more specific, causal verbs. Thus, activities are not a mere description of the kind of changes that occur, but they are in fact responsible, in a causal sense, of the changes that take place in a mechanism.

In the Machamer *et al.*'s approach activities are usually stable. This stability guarantees the mechanism stable behavior. However, in the social realm the very notion of *activity* is represented by people's actions, which are not necessarily stable or invariant. People's actions depend on a myriad of factors, and changes in any of them may affect decision making and therefore people's activities. On the one hand, individuals' actions depend on signals from the world (e.g., changes in macroeconomic variables, the front page of a newspaper, a financial rumor). These signals are interpreted by people. Once people receive and interpret signals, they form expectations about future states of the world, which will be decisive in their decision making. Likewise, people's actions are influenced by contextual or structural conditions (e.g., institutions, environment, culture, moral principles, etc.). Take for example the case of institutions. Almost without exception, in social systems there exist a great number of norms and institutions which may be understood as a set of rules that coordinate people's activities through restrictions or prohibitions. However, the concept of "institution" is not necessarily associated with a restriction on freedom of action. Rather, some social institutions enable the exercise of certain decisions (such as the stock market: an institution that promotes the exercise of speculative activities).

One of the characteristics of socioeconomic processes is that their basic structure responds to the logic of possibility trees or open-ended results: when a causal factor is activated, there are multiple possible decisions. Depending on which actions people carry out, different results will be achieved. For example, let X be the causal variable, Y the effect, and A the people's activity. Let's suppose that X takes the value X0. Unlike those approaches that assume invariance, here Y can have more than one value (Y1, Y2, ..., Yn). It all depends on people's activities A1, A2, ..., An.



A good example of a socioeconomic process is the so called "Keynes effect". According to this effect, an increase in money supply leads to a decrease in the interest rate, stimulating investment and consequently employment and production. In some interpretations it is assumed that an increase in the quantity of money leads automatically and in a stable way to a decrease in the interest rate. The same applies for the rest of the sequence. However, this is not true. On the contrary, depending on the contextual framework and people's interpretations and expectations, different paths will be plausible in a socioeconomic process. Aware of these limitations, Keynes says:

> For whilst an increase in the quantity of money may be expected, *cet. par.*, to reduce the rate of interest, this will not happen if the liquidity preferences of the public are increasing more than the quantity of money; and whilst a decline in the rate of interest may be expected, *cet. par.*, to increase the volume of investment, this will not happen if the schedule of the marginal efficiency of capital is falling more rapidly than the rate of interest; and whilst an increase in the volume of in-

> vestment may be expected, *cet. par.,* to increase employment, this may not happen if the propensity to consume is falling off. Finally, if employment increases, prices will rise in a degree partly governed by the shapes of the physical supply functions, and partly by the liability of the wage-unit to rise in terms of money. And when output has increased and prices have risen, the effect of this on liquidity-preference will be to increase the quantity of money necessary to maintain a given rate of interest. (Keynes 1936, 155)

In the Keynes effect, economic variables are linked through people's activities. In other words, these actions are responsible for enabling the causal link between economic variables. Nonetheless, socioeconomic activities are not linear, but they may change for lots of reasons. When this happens, a modification in the causal links will be observed. Since these changes are plausible, the feasibility of finding invariant causal factors can be put into question.

Let's begin with the case of socioeconomic capacities. When an entity or variable has a capacity, it means that there is a causal factor that, if properly exercised, contributes in a stable way to the production of an effect (we should remember that such an exercise does not guarantee the manifest results of the causal contribution). However, this concept contrasts strongly with the idea that socioeconomic phenomena depend on the interpretations agents make of the signals of the world, the background conditions, etc. Let's take the example of the Keynes effect. If understood as a capacity, we could assert that "money supply have the capacity to increase the national income of a country". But this is not the only possible result: an excess supply of money will not necessarily be associated with an increase in the demand for financial assets. It is plausible that such extra money may be used for increasing the demand of goods and services. In this case, a rise in the general level of prices is likely to occur. Finally, let's assume another scenario where high uncertainty is what prevails. In such a case, the liquidity preferences of the public will increase more than the quantity of money. If so, then no changes in the macroeconomic variables will be observed.

The above example reveals that the rationale of the capacities approach is different from the rationale of socioeconomic processes. When a triggering factor is activated —in this case the money supply—, different causal contributions may be exercised. The assertion that whenever we increase the money supply a causal force that contributes to an increase in the national income will occur is not true, nor is it true that in some cases the expected results may not appear because of the exercise of disturbing factors. Quite the contrary, in each case the exercise of causal factors is different: in one of the cases people increase the demand for goods and services; in another they increase the demand for financial assets; and in the last case people end up hoarding the extra money. There are also problems in obtaining capacities. In Cartwright's approach, capacities can be "hunted" with the method of isolation. Isolation is possible since the contribution of a capacity is *singular* —that is to say, there is only one activity involved—. In the case of socio-economic processes, however, there are no capacities to isolate, since there is no singular contribution between cause and effect, but a set of potential activities involved.

Thus, the ontology of socioeconomic capacities should be replaced for an ontology of *possibility trees* or *open-ended results*. From this new perspective, causal contributions would have no predetermined capacity, but a set of *potential* capacities, which crucially depend on the multiple activities agents are able to perform. The Keynes effect is not a capacity, because in the economic realm there is no singular connection between money supply and the national income. The Keynes effect is just a possible path or scenario among many other scenarios that involve increases in money supply.

In a possible interpretation it could be said that Cartwright would not disagree with the approach of open-ended results. In fact, in Cartwright and Hardie (2013) specifically talks about how the support factors complement the variable policy or causal principle. However, we must remember that the support factors and the causal principle lie in different levels of abstraction. For instance, knowing that nutritional counseling for those who procure the family food and control its distribution in the family improves the child's nutrition does not tell anything about which people must be advised in different cities. This information is provided by the support factors. However, support factors do not play the role of *closing* the possibility trees into a unique result,[2] but of *complementing* the causal principle through concrete specifications. The importance of complementing a causal principle with a set of support factors is recognized, but the need for a stable causal contribution (in this case, the causal principle) still remains.

Neither are socioeconomic processes the product of nomological machines. In building a nomological machine it is necessary that its constituent elements be correctly assembled and protected from any perturbing factors, so that whenever X is to occur, Y will be the obtained result. Let's assume for a moment that it is possible to set up the machine in the economic realm. The problems will arise when such machine is intended to be protected from perturbing factors. In a vending machine the internal mechanism is protected from many external factors. This allows it to exhibit a regular behavior, in the sense that (almost) always that coins are inserted into the slot the selected product is provided by the machine.

However, it is a bit unrealistic to think that nomological machines are plausible in the socioeconomic realm. To begin with, socioeconomic processes are a kind of phenomena that take place in open systems (see Lawson 1997). That means any unexpected exogenous factor can disrupt the functioning of the machine. In such systems prevails uncertainty, so we are not able to know for sure what will happen in the near future. We can predict with some confidence the occurrence of certain events, but they are not guaranteed at all. Even worse, we do not even think about the factual possibility of a myriad of phenomena. If we are not able to know what factors are to occur in future, then it seems inappropriate pretending to *shield* a machine from unknown factors. How we can nullify or counteract the effect of something that we do not know?

Even if we assume the feasibility of shielding a socioeconomic machine, there is the chance that, because of "endogenous" problems, such machine may yield unstable results. For instance, the Keynes effect may be understood as a nomological machine, provided that certain antecedent conditions are fulfilled. Let's suppose that the policy maker has been doing everything he can to make it work in the real world. If so, then a high positive correlation between money supply and national income will be observed. However, let's suppose now that, at some point during the year, a little group of businessmen believes that they could sell much less than expected, and because of this the level of investment decreases. Suppose further that this strategy spreads towards other businessmen. The wider the scope, the greater the negative effect on employment and production. Clearly, such instability is not the result of failures in the shielding or in the assembling of parts. Rather, it has its origin in an "endogenous" problem.

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[2] This point will be examined in the next section.

Models and robustness analysis

In *The Dappled World: A Study of the Boundaries of Science*, Nancy Cartwright (1999) criticizes the positivist approach to science. For her, much of what occurs in the real world occurs by hap, subject to no law at all. Because of this lack of laws the world is both "messy" and "dappled". There is no guarantee that a regularity (if possible) will remain invariant over time.

In this sense, there is some compatibility between the idea of a "dappled world" and the approach defended in the present paper. Firstly, the real world is understood as a system where there are no constant conjunctions of events or regular connections *per se*. If they emerge, it is because there is an ensemble of causal factors that remain invariant at that point of time. In addition, the concept of "dappled world" emphasizes the importance of the domain or range of applicability in the understanding of economic models. More precisely, according to this approach it is possible that several models are "true", provided they belong to different domains. If this is correct, then for every real world scenario there would be a model which provides information about the conditions that need to be met for the purpose of achieving a result. Thus, economic models (at least some types of them) may be understood as blueprints for policy implementation. Such information is important for policy makers, as they would have a theoretical basis for closing the possibility trees of the real world in order to reach the desired goal. Let's see some assumptions of the Keynes effect:

1. There are constant returns to scale so that prices do not rise or fall as output increases.
2. Investment depends on entrepreneurs' expectations and on interest rate.
3. There is a negative causal relationship between interest rate and investment.
4. There are three kinds of liquidity-preference which may be defined as depending on
   (i) the transactions-motive, i.e. the need of cash for the current transaction of personal and business exchanges;
   (ii) the precautionary-motive, i.e. the desire for security as to the future cash equivalent of a certain proportion of total resources; and
   (iii) the speculative-motive, i.e. the object of securing profit from knowing better than the market what the future will bring forth.
5. Money demand depends negatively on the interest rate and positively on the income.
6. Money supply is inelastic with respect to interest rate.
7. Changes in primary employment (in the investment industries) bring about proportionally greater changes in total employment.
8. The marginal propensity to consume remains constant throughout the changes in income.

Taking into account the rationale of socioeconomic processes, the assumptions mentioned above may be understood as a set of conditions that, if successfully accomplished in the real world, then an increase in the quantity of money would contribute to an increase in the national income. It is not asserted that there are *always* constant returns to scale so that prices

do not rise or fall as output increases, but that it is crucial that there are constant returns to scale so that the causal relationship between money supply and income may emerge. Otherwise the socioeconomic process could go on another branch of the possibility tree, making the reached result different than expected.

The approach defended in the present paper is also —though not entirely— compatible with the notion of "overconstraint" (Cartwright 2009a). Specifically, Cartwright (2007; 2009a) asserts that as long as economic models mimic *Galilean experiments*, they will teach us about capacities. However, the author realizes that many of the assumptions of economic models are not *Galilean idealizations*, that is to say, they are not used with the purpose of neutralizing the impact of perturbing factors. According to Cartwright, in sciences like physics there are many principles. This facilitates inferring results using Galilean idealizations. However, this does not seem to be the case for economics. Unlike physics, economics has very few non-controversial principles, which leads to the problem of *overconstraint*: because the number of economic principles is scarce or not enough for inferring results, it is necessary to add structural or *non-Galilean* idealizations to economic models. This makes the results strongly depend on the structure of models. If so, then such models will not be able to teach us about tendencies or capacities. Something similar is defended here: because economics capacities are conceptualized in a potential sense, then the only way to reach inferences in economic models is adding structural assumptions.

From this latter idea Cartwright gets an important implication: if models are over-constrained by structural assumptions, then it will not be possible to extrapolate the inferred results to situations falling outside the range of applicability of the models. As a result, except in the case that *all* the conditions asserted in economic models are accomplished in the real world (even the *ceteris paribus* clauses), extrapolation of results will be meaningless. We face here a typical case of external validity: in order to ensure the inference of the modelling results structural assumptions are needed. This creates increasingly artificial situations, so there is no guarantee that such results are also obtained in circumstances that are beyond the model's domain.

On the contrary, in the present paper it will be argued that, as long as some of the model assumptions are considered as conditions to be met in the real world, models will provide exportable information. Specifically, while all the model assumptions are necessary to infer results, they play different roles, which allow us to clarify the distinction between those assumptions that are relevant for policy implementation and those that are not. The assumptions of homogeneous goods, indifference curves differentiable at every point, economies with only two agents, etc., have the heuristic role of making more tractable the inference of results (see Musgrave 1981; Kuorikoski, Lehtinen and Marchionni 2010). Because this kind of assumptions is incorporated in models only for tractability purposes, their fulfillment in the real world seems to be meaningless.

At this juncture, robustness analysis is a good method for knowing which of the model assumptions must be understood as conditions of a policy blueprint. Broadly speaking, robustness analysis is a mode of analysis that provides epistemic support via triangulation: "a result is more likely to be real or reliable if a number of different and mutually independent routes lead to the same conclusion" (Kuorikoski, Lehtinen and Marchionni 2010, 544). These routes —as any experimental set-up and means of measurement— have their errors and biases. However, "independent ways of determining the same result reduce the probability of error due to mistakes and biases in those different ways of arriving at the result"

(p. 544). This will provide greater confidence that such results do not depend on the auxiliary factors of models, but rather on the substantive hypothesis.

Robustness analysis can be both empirical and theoretical. In the empirical triangulation, experiments are carried out by different techniques, which contribute to reducing the chance of error, biases or mistakes that usually emerge in any experimental situation.[3] However, there are situations in which the chances of carrying out empirical robustness analysis are remote. For this reason, many philosophers both in the social and the natural sciences advocate the use of *theoretical* robustness analysis, or in Woodward's terms (2006), *derivational* robustness analysis. Theoretical triangulation resembles experimental triangulation. In the latter, the reliability of a hypothesis increases to the extent that similar results under changes in the experimental background conditions are obtained. In the case of theoretical triangulation, such reliability increases to the extent that similar results —usually called "robust theorems"— under changes in the model assumptions are obtained. More specifically —and using the terminology of Kuorikoski and Lehtinen (2009)— two kinds of assumptions in a model are distinguished: "substantive" and "auxiliary" assumptions. Substantive assumptions concern aspects of the model's central causal mechanism about which one endeavors to make important assertions. They are assumptions that have some degree of empirical merit, i.e. they are thought to be more or less true of the systems on which it is hoped that the model will shed some light (Kuorikoski and Lehtinen 2009). Auxiliary assumptions, on the other hand, play a heuristic or tractability role. They are required for making feasible the inferences from substantive assumptions to conclusions (Kuorikoski and Lehtinen 2009). Let's take for instance the assumption of indifference curves differentiable at every point. It is used in utility theory for making the inference of results easier or more tractable. However, such assumption is not expected to create significant biases or errors and, what is more, modify the inferred results. This means that, if other (tractability) assumptions were used, the inferred results should not be substantially different than the former case.

According to Weisberg (2006; 2012), (derivational) robustness analysis begins by examining a group of similar, but distinct models for a robust result or behavior *R*. The next step involves finding the common structure *C* which gives rise to the robust property. Given the distinction between auxiliary and substantive assumptions, we say that *C* is comprised of a set of substantive assumptions. Once these conditions are met, the theorist can formulate the robust theorem, which has the following form (see Weisberg 2006):

> *Ceteris paribus*, *if* a common causal structure ***C*** obtains, *then* robust property ***R*** will obtain.

Let's now suppose three models M1, M2 y M3, such that

$$\begin{array}{l} \text{M1: C \& S1} \rightarrow \text{R} \\ \text{M2: C \& S2} \rightarrow \text{R} \\ \text{M3: C \& S3} \rightarrow \text{R} \\ \hline \text{Ergo, C} \rightarrow \text{R} \end{array}$$

[3] Perhaps the best example of empirical robustness analysis is Avogadro's constant (see Hacking 1983, 54-5; Salmon 1984, 214-20).

where C represents the set of substantive assumptions (or core mechanism), and where the S_i represents the set of auxiliary assumptions (tractability assumptions, Galilean idealizations, etc.). It is assumed that S1 ≠ S2 ≠ S3. However, the three models share a common result R. In this context, the purpose of using derivational robustness analysis lies in (inductively) inferring a robust theorem, where such theorem asserts that R does not depend on the auxiliary assumptions, but on the substantive assumptions (that is, C).

Cartwright (2009a) claims that economic models are over-constrained by structural or extra-Galilean assumptions. In the terminology used above, this is similar to saying that the model results depend on *all* the model assumptions (both substantive and auxiliary assumptions). This may be true when we are making inferences and drawing results, and researchers who advocate the use of derivational robustness analysis are aware of this. If one could infer R without using any auxiliary assumptions, derivational robustness analysis would be meaningless. Derivational robustness analysis arises precisely because the inference of the model results intrinsically depends on this kind of assumptions. However, with derivational robustness analysis it is expected to argue that there is a property R which actually depends on a set of substantive assumptions.

To illustrate this situation let's take three liberal models of international trade. A first model —the "Ricardian" model of comparative advantage— assumes one factor of production (labor), perfect competition, no transportation costs, constant opportunity costs, etc. Based on these (and other) assumptions it can be asserted that if (1) the relative prices of goods between countries in autarky are different, (2) the equilibrium relative price lies between the relative prices in autarky of both countries, and (3) each country specializes in the production of the commodity with comparative advantage, then countries opened to the international trade will obtain more benefits than in autarky.

Let's now suppose a second model —the neoclassical model of international trade— which, unlike the previous one, introduces concave utility functions throughout its domain, increasing opportunity costs, two factors of production (capital and labor), etc. Some inferences will be different. For example, in the Ricardian model opportunity costs are constant, and as a consequence specialization of commodities is total. Instead, in the neo-classical model opportunity costs rise with increasing output, so specialization of commodities is partial. However, they share a common result: the benefits of opening up to international trade, as long as (1) the relative prices of goods between countries in autarky are different, (2) the equilibrium relative price lies between the relative prices in autarky of both countries, and (3) each country specializes in the production of the commodity with comparative advantage.

A third model (the Hescher-Holin model of international trade) introduces new concepts. Firstly, countries have different relative endowments of the factors of production (land, labor, and capital).In addition to this, those goods that require inputs that are locally abundant will be cheaper to produce than those goods that require inputs that are locally scarce. From these and other assumptions it is inferred that each country specializes in the production of the good that intensively uses the factor it is relatively richer in (Hecksher-Ohlin Theorem). However, this model shares a common result: if (1) the relative prices of the goods between countries in autarky are different, (2) the equilibrium relative price lies between the relative prices in autarky of both countries, and (3) each country specializes in the production of the commodity with comparative advantage, then countries opened to the international trade will obtain more benefits than in autarky. Thus, the robust theorem may be expressed in the following way:

Ceteris paribus, if

— the relative prices of goods between countries in autarky are different,
— the equilibrium relative price lies between the relative prices in autarky of both countries, and
— each country specializes in the production of the commodity with comparative advantage,

then countries opened to the international trade will obtain more benefits than in autarky.

However, the analysis does not end there. The robust theorem is a conditional statement that says: "if a set of substantive assumptions *C* obtains, then robust property *R* will obtain". In other words, the relationship between *C* and *R* is not causal, but logical or conceptual. In this context, Bunge (1997) distinguishes between two kinds of systems: concrete and conceptual. A concrete system is "a bundle of real things held together by some bonds or forces, behaving as a unit in some respects and (except for the universe as a whole) embedded in some environment" (Bunge 1997, 415). Natural, social and technical systems are concrete. In contrast, models, theories, classifications and codes are "conceptual systems", and their bonds are not material or causal but logical.

Hence, the knowledge of robust theorems is about something that takes place in the conceptual system, and even something that *could* take place in the real world. That is the reason why robust theorems are considered "blueprints" for policy implementation. Nevertheless, to make such kind of statements it is necessary to take a leap from conceptual system to concrete system. More precisely, when the leap toward concrete system is made, the robust theorem must be understood in a feasibility sense, i.e.,

If causal structure *C* is obtained in the real world, *then* R is *likely* to be obtained.

The causal relationship between *C* and *R* is not guaranteed. To be causal, *C* has to *produce R*. However, there are many reasons why, although *C* is obtained, *R* may not emerge in the real world. In the Keynes effect, even if the necessary measures are carried out in the real world, *R* might not emerge. Such emergence depends on a myriad of reasons. Some of these reasons may be associated with the countering of the causal contribution (e.g., the capacity is exercised, but the manifest results are not obtained). It also may be related with the deviation of the socioeconomic process towards other nodes of the possibility tree. If the interest rate is very low and people believe that it may rise in the near future, then even if an increase in money supply occurs, people will not buy financial assets. If entrepreneurs do not have good expectations of future sales, then even if the interest rate is falling the level of investment will not rise. The core structure *C* mentioned in the present paper is not a nomological machine that works in isolation or shielded from external influences. Instead, it operates in open systems. While it is expected that once *C* is obtained *R* will occur in the real world, we must be aware that this may not be the case.

The difference between the idea of overconstraint and the approach defended here is straightforward. For Cartwright, the models that allow exporting information about capacities are those which mimic Galilean experiments. This turns out to be problematic in economics because of the scarcity of economic principles. For the case of policy implementation, this is like saying that such extrapolated knowledge would only be meaningful if *all* the model assumptions (including the tractability assumptions) were met. Instead, while it

is true that the policy maker must necessarily make use of structural assumptions for closing the several courses of action of a possibility tree in economic models, we must recognize, however, that not all the model assumptions play the same role. That is why the use of derivational robustness analysis has been proposed: to find those conditions which, in the real world, are expected to play a substantial role in the production of *R*. The robust theorem serves as theoretical basis for policy implementation, which consists of fulfilling the set of conditions specified in the theorem. Once the policy is implemented, the desired result is likely to be obtained in the real world.

Permanent/dynamic interventions

So far certain problems concerning the need for an invariant knowledge for accomplishing interventionist purposes have been exposed. To begin with, there exists an ontological problem: there are no capacities or nomological machines, but possibility trees or open-ended results. There also exists a problem with its use: the discovery of invariant factors (if possible) in one scenario does not guarantee its use in other different scenarios (the problem of "external validity") nor in a scenario where the structure that supports it has changed (the problem of "unstable enablers").

In this section a new issue will be considered: the idea of "intervention". Since many philosophical approaches assume the feasibility of both acquiring and using invariant causal factors, the idea of intervention turns out to be an *ex-ante* concept: once the mechanism, capacity, or nomological machine has been found (or constructed), the intervention consists of activating the triggering factor. After this a sequence that leads automatically to an expected result will begin.

Nevertheless, as far as socioeconomic policy implementation is concerned, the *ex-ante* notion of intervention is misleading, or at least incomplete. Interventions will be important not only in the start-conditions of socioeconomic processes, but also in the intermediate stages of such processes. Let's take once again the Keynes effect. It is a socioeconomic process that takes place to the extent that certain conditions are met. Regarding its functioning, it is clear that in order to increase the national income, more than one intervention (not only ex-ante interventions) should be carried out. One of the multiple interventions is to increase the money supply (the triggering factor is activated). However we have seen above that such an intervention may not be enough. It will also be necessary for people to increase their demand of financial assets, that employers have good expectations of future sales, etc.

Let's suppose that the Keynes effect takes place in the real world by means of a policy implemented at a specific point in time. In such a policy not only the set of conditions have been met, but also the triggering factor (increase in money supply) has been properly activated. We have here an *ex-ante* intervention, precisely the kind of manipulations advocated by many interventionist approaches. However, the system where the Keynes effect takes place is open (see Lawson 1997; 2003), so it is not "shielded" from external perturbing factors. This means that any factor is likely to bring about distortions, which could result in a deviation of the socioeconomic process from the expected path. Continuing the example of the Keynes effect, it is possible that the marginal efficiency of capital decreases because some signals from the market bring about negative expectations of future sales. This obstacle may not have been foreseen (and indeed, most of the time is often so) by the policy

makers. Therefore, the *ex-ante* idea of intervention is inadequate for understanding the rationale of policy implementation in socioeconomic processes. In order to reach the desired results permanent interventions must be taken into account.[4]

The break with the interventionist approaches examined in this paper is evident. Because such approaches assume the feasibility of using stable causal factors, they —implicitly— assume an *ex-ante* notion of intervention. They do not criticize the idea of *permanent interventions*, because they do not even take it into account. In assuming the feasibility of stable regularities these approaches end up drawing analogies of interventions with vending machines. But if socioeconomic processes are not the consequence of stable causal factors, then analogies should not be associated with vending machines, but with cases that involve permanent interventions, such as driving a car or managing a football match. When driving a car we must intervene at every moment. Even if we got a GPS, if we are familiarized with the foot pedals, if we know how to use the shift lever, we have already checked the air pressure in tires, etc., we must constantly intervene. This is because drivers face a world that to some extent is unknown: we do not know if a street is closed, if there are bumps in the road, sometimes we may get lost, etc. Similarly, a football team manager may design a strategy based on information both from his team and from the rival team (players available for the next match, the rival's possible tactics, etc.). However, once the game has kicked off things may not result as expected. Due to these unexpected circumstances, managers usually end up modifying their initial strategy.

In the above examples interventions are not only *ex-ante*, but also *during* the course of the process. And the fact that policy makers must intervene permanently or *during* the course of a socioeconomic process does not depend on their inability to make good blueprints, but on their facing an open and uncertain scenario. Policy makers may develop a blueprint that is expected to be useful for reaching a result. However, because they intervene on open systems there exists the possibility that contingencies will appear, and sometimes such contingencies may involve altogether changing the initial plan.

Extensions

Although for reasons of space some issues have not been discussed in the present paper, it is important to note that they require further discussion. The first issue concerns the use of derivational robustness analysis. Earlier on it has been argued that the discovery of robust theorems allows us to export results to different backgrounds. However, derivational robustness analysis involves making inductive inference, so that its use may originate some drawbacks. To begin with, there are *external validity* problems related to the differences between the context of discovery and the context of application of causal factors (Cartwright 2007; Jiménez Buedo and Miller 2010). Likewise, there exists the chance that the inferred

[4] However, we must recognize that these interventions are not necessarily based on an invariant knowledge. For instance, policy makers may try to increase the marginal efficiency of capital through a number of signals that have positive repercussions on entrepreneurs. Let's suppose that such policy consists of providing incentives for production, or making agreements between workers and entrepreneurs or the like. If these arrangements are mainly grounded on the socio-cultural context of that time, it is clear that policy makers will not be making use of invariant knowledge.

robust theorem may be false. In this latter case, in order to achieve greater reliability such analysis should be complemented, for instance, with a research that involves finding models which share the common structure *C* but with inferred results other than *R*. The models of international trade developed by Emmanuel (1972) on the one hand and Prebisch (1950; 1959) on the other hand may exemplify this situation. Prebisch's model shares the three conditions specified in the robust theorem: (1) the relative prices of the goods between countries in autarky are different, (2) the equilibrium relative price lies between the relative prices in autarky of both countries, and (3) each country specializes in the production of the commodity with comparative advantage. Nevertheless, this model introduces a new assumption: the systematic deterioration of the terms of trade. In a static model —or one period model— international prices do not fluctuate. However, it may occur in a dynamic —or more than one period— model. Therefore, an additional condition (4) should be added to the robust theorem: that no significant changes in the terms of trade are observed intertemporally. Something similar happens in Emmanuel's theory of unequal exchange. Unlike the "liberal" models examined in the robustness analysis, Emmanuel's model assumes capital mobility between countries. If this is to occur, then a process of foreign direct investment will start, which will end up generating benefits to one country albeit to the detriment of the other. Therefore, another condition (5) should be taken into account: no capital mobility among countries.

It is also important that the common structure *C* refers to a set of conditions that are achievable in the real world. This may reopen once again the issue about the realism of assumptions in economics. While it is true that Friedman (1953) has posed the infeasibility of testing the assumptions independently of the model implications, it is also true that the use of realistic assumptions can be a good basis for thinking which blueprints are more or less plausible for a successful policy. More precisely, Friedman argues that it is not adequate to ask about the realism of assumptions, because they never are. What is important is that assumptions are *good approximations* to reality, and the only way to know it is by examining the implications of the models. However, assessing the performance of models or blueprints according to their predictive accuracy leads to external validity problems. Just as Cartwright (2012) criticized the evidence-based policy approach for assuming that a policy that worked somewhere will also work "here and now", the idea of using accurate predictive models may be put into question in the same way: there is no guarantee that models that worked in the past will provide accurate predictions in the target system. In addition to this, Musgrave (1981) criticizes Friedman's approach for not being able to distinguish between three different types of assumptions: neglibility assumptions, domain assumptions and heuristic assumptions. Musgrave recognizes that both neglibility and heuristic assumptions may be unrealistic. However, domain assumptions have to be realistic, as they specify the scope, domain or range of applicability of models. Therefore, if domain assumptions are always false, then the theory containing it can be applied to no actual situation. Unlike the two other cases, Musgrave pretends more realism to this class: "the more unrealistic domain assumptions are, the less testable and hence less significant is the theory. Contrariwise, the more significant the theory, the more widely applicable it will be" (Musgrave 1981, 382).

Finally, even if causal principles are used in conjunction with a set of helping factors, or if robust theorems are inferred with great confidence, or if any other kind of theoretical knowledge is used for policy purposes, such knowledge may not be enough for controlling

the behavior of socioeconomic variables. It is also necessary to understand *how* to influence people's minds and decisions. For example, it has been shown in the Keynes effect that, in order to increase the level of investment, a lower interest rate may not be enough: it also depends on the entrepreneurs' future sales expectations. Reducing the interest rate is a step that can be implemented in a rather direct way. However, dissipating the entrepreneurs' uncertainty is somehow more difficult to achieve because it depends on a complex set of factors. In particular, it presupposes a kind of knowledge that, properly speaking, is not scientific knowledge. Theoretical knowledge instructs about "what" (i.e., what expectations would be suitable for reaching the goals), but not about "how" (how to obtain them). It is known that good future sales expectations must be achieved, but the theory does not say anything about *how* to generate them.

Therefore, policy makers face two types of problems. One is purely theoretical and concerns how to reach a result *R*, such as stop childhood malnutrition, improve academic quality or increase the level of employment. However, there are other problems for which theoretical knowledge is unproductive. These problems are not exclusively economic problems (e.g. how to lower inflation, improve national income, etc.). On the contrary, they are associated with people's decisions and actions, such as how to improve entrepreneurs' expectations, how to negotiate with the IMF or how to solve conflicts with a trade union. Another kind of knowledge is needed: a practical knowledge or "know-how" (Ivarola, Marqués and Weisman 2013).

Clearly, the solution to these problems requires a knowledge that, for obvious reasons, economic theory does not provide. The rationale of socioeconomic processes involves not only economic problems, but also social problems. Thus, the solution of how to achieve a socioeconomic result requires both theoretical and extra-theoretical knowledge. The idea that a successful intervention depends on using theoretical knowledge is not denied. Rather, it is stressed that, even in possession of such knowledge, it only informs us about the *possibility* of modifying a factor Y by changing another factor X (and the Keynes effect tells us about the *possibility* of increasing the level of employment and national income as long as positive changes in money supply are carried out). Although theoretical knowledge is not problematic from an epistemic point of view, we must recognize that, for interventionist purposes, it is not enough. On the contrary, and in order to increase the chances of success in policy implementation, such knowledge must be complemented with extra-theoretical or "know-how" knowledge.

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