Beyond Cost Benefit Analysis:
A SAM-CGE Model for Project-Program Evaluation

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This paper presents a new methodology of project evaluation based on the use of a social accounting matrix (SAM). The proposed method considers both the project as an autonomous shock and an endogenous activity, thus capturing both the demand and the supply side effects that can be associated with investment. In assessing project impact, these two effects have to be considered complementary, even though they may be combined in different proportions and with different strength in different practical cases. The autonomous dimension is however a distinctive feature of a project as an economic concept. Its consideration has important implications for assessing a project's structural impact as an activity ranging from complete isolation to total embeddedness in the economic system. The paper also shows that both in its construction and operational phases the project displays structural effects on the economic system and that these effects may be sizable and partly offsetting the project's direct impact on demand and supply variables.

Keywords: project, autonomy, embeddedness, structure, social accounting matrix, social rate of return

INTRODUCTION

Investment can be defined as the commitment of resources in the expectation of future returns, but commitment and expectations typically require a "project" to be designed and implemented. The concept of a project is not uncontroversial, and its characteristics range from physical planning (the "analogic" project) to more complex projectization of implementation and governance ("meta-projects"). However, there is a growing consensus that projects may be important vehicles of technological change and institutional innovation and that their impact may extend beyond the benefits and costs envisaged by their stakeholders. Their main advantage in comparison with routine operations of firms and institutions is that they can be isolated from their parent organizations and offered a large degree of autonomy and creative initiative. They can thus be used to launch new ideas and act as catalyzers of technological and institutional change, through new institutional arrangements and innovative and even disruptive technologies. At the same time, their short-term horizon, limited scope and relative institutional insularity allows to carry on experiments of innovation, technology adoption and governance in an environment of limited risks and by maintaining a relative independence from the originating institution. As Vihma and Wolf (2022) point out in a recent EU survey, projects are increasingly developed (Munck Af Rosenschöld and Wolf, 2017;

Sjöblom, Löfgren, and Godenhjelm, 2013; Sjöblom and Godenhjelm, 2009) with the aim to accelerate knowledge creation (innovation surplus) and expand social inclusion (democratic surplus) (Godenhjelm, 2016).

In this study, we examine the economic effects of a project, focusing on aspects often overlooked by traditional cost-benefit and multiplier impact analyses. We explore four key, partly overlapping areas: (1) the crowding in- crowding out effects, induced by the change in the pattern of internal or external resources by the project, which might become scarcer or more abundant for certain sectors; (2) the financing of the project;(3) the influence of the project on technical change and (4) is impact on intermediate and final demand levels. Our study expands the analytical framework established by Scandizzo (2021), by offering a more comprehensive examination of the alterations in the Social Accounting Matrix (SAM) structures resulting from the inclusion of both construction and operational project activities. Along these lines, a step-by-step procedure is developed to incorporate the project into a SAM matrix in a consistent way. Additionally, the study demonstrates the applicability of this analytical framework to Computable General Equilibrium (CGE) models, conceptualizing these models as augmented versions of SAM structures. To illustrate these concepts, a series of numerical experiments are conducted, focusing on the implementation within a major public investment program.

Following Vihma and Wolf (2022), a central tension can be identified between innovative projects and both parent organizations and the economy at large (Godenhjelm and Johanson, 2018; Munck Af Rosenschöld, 2019; Munck Af Rosenschöld and Wolf, 2017; Tukiainen and Granqvist, 2016). Projects can be conceived as operations that need some distance from their institutional stakeholders, in order to deliver their benefits, especially if they experiment innovation and are expected to generate new knowledge. To the extent that they do not reflect average technology and exchange relationships, they are also based on designs of value chains that offer alternatives to the dominant structures prevailing in the economy at any one time. While projects' economy-wide impact may depend also on their size, access and institutional features, their autonomy may create opportunities to spread successful innovations and overcoming barriers to change, due dominant cultures, routines, and oversight (van Buuren and Loorbach, 2009; Kapsali, 2011). As envisaged by many development economists (e.g., Hirschman, 1967; Easterly, 2009), projects may exploit opportunities for changes, but may also be vehicles of rent seeking and power consolidation for the ruling elites. The distinction between marginal and non-marginal projects, or between program and projects, reflects both a certain granularity of the project strategy and a degree of autonomy from its institutional environment. At the same time, projects' autonomy must be considered together with their degree of embeddedness within an economy as a set of existing organizational structures, connections across economic actors and institutions, which represent the extent to which a project is a fruit or a victim of its own past. The first part of the paper analyzes the twofold condition of projects' autonomy and embeddedness by using the network of social accounts represented in a SAM. In the second part, a computable general equilibrium model calibrated on the Italian SAM developed by the same methodology is further applied, applying as a project the Italian Recovery Plan of the Next Generation EU plan to cope with the pandemic situation.

THE PROJECT AS AN ECONOMIC ACTIVITY

According to a widely shared notion, an investment project can be defined as the immediate commitment of resources (the investment) to one endeavor (the project) in the expectation of future benefits (Knudsen and Scandizzo, 2005; Pennisi and Scandizzo, 2006). While this definition appears to be operational and directly concerned with planning and evaluation efforts, it does not circumscribe an unambiguous category. Rather, it subsumes a series of structures and actions that are part of the complexity of capital accumulation. In general, at least three types of projects can be defined, all of them being part of the same investment endeavor. First, the project can be considered as a physical analog of the ultimate investment goal: as such, it can be defined as a design or a reproduction in scale of a physical counterpart resulting from implementing the project. Second, the project can be seen as a set of instructions (a "blueprint") to implement according to an "epigenetic" code similarly to the project contained in living beings through DNA information. Third, the project can be conceived as a programmed shock that impacts its environment according to a plan that is only loosely conceived and discovers its consequences opportunistically and path-dependent. These three concepts are interconnected as they describe different aspects of a project and relate to separable characteristics equally important to accomplish the investment goals. However, they cannot be pursued in a parallel way, since they are linked both by a structured hierarchy of instruments and objectives and by intrinsic dynamic properties that are only imperfectly predictable.

The concept of investment as “recombinant capital” has recently been revived in the context of a new attention of economics to complexity in human behavior and the autonomous nature of projects as manifestations of entrepreneurship and “animal spirits”. As Harper and Endres (2016) indicate, this development takes as its starting point Schumpeter’s ideas on the combinatorial nature of innovations in terms of construction of new systems combining both old and new technologies, as well as other components that are already available as parts of the existing capital. Rather than to the notion of capital as a stock of productive capacity, therefore, the recombinant-capital approach is more convincingly applicable to investment projects, if these are conceived as autonomous enterprises that emerge from pre-existing structures to create new forms of capital and production processes. In line with E. Phelps’ (2013) analysis, innovators are identified as exuberant and innovative agents of change, transforming discoveries into new forms of capital combinations to pursue profit. This view implies that project design, for example, is not a mere technical exercise aimed to implement production plans through best practice applications. While not all projects can be innovative, they can all be interpreted as enterprises that enjoy, at the same time, given properties of autonomy and belonging, with the implicit mandate to close gaps in the capital structure, use new technologies and find new ways to use existing ones, by reshuffling and recreating production and marketing profiles. Projects’ simultaneous isolation and embeddedness in a pre-existing institutional environment, also offer the opportunity to explore options to achieve given goals, by comparing alternatives and estimating their impact and costs and benefits, without putting at risk parent organizations, efficient and markets. As such, shaping investment through projects empowers economic agents to undertake more daring initiatives, more limited in scale, but not necessarily in scope, with potential larger spill overs on both capital structures and production/consumption outcomes.

Albert O. Hirschman (1967), one of the key supporters of the role of projects in development economics, conceived the investment project as a means to induce change by imparting an asymmetric shock to the economy. This shock would initiate or contribute to transformative development, through the leaps and bounds of unbalanced growth. Hirschman suggested further that this transformative power may be the most important aspect of the investment multiplier. The strength of backward and forward linkages should thus be used as a guiding principle to concentrate investment in industries with the highest potential to generate disruptive growth. While strong linkages imply high multipliers in terms of output and incomes, Hirschman was mainly concerned with the induced effects on private investment, and the importance of public investment to provide overhead capital, which could unleash the dynamic forces of growth of the type considered by Schumpeter and other advocates of “creative destruction”.

Hirschman’s suggestion could be easily overlooked as one more interpretation of Leontief’s input output connections. Its hidden value, however, lies in the attempt to link investment design to the plurality of choices it entails in terms of sectors, activities, institutions, location and design. The modern literature on cognitive architectures emphasizes that these elements are critical for the success of an investment, as a project driven by construction and design. “Knowing how to design something like X is a requirement for understanding how X works. Of course, doing explicit design is consistent with leaving some of the details of the design to be generated by learning or adaptive processes or evolutionary computations, just as evolution in some cases pre-programs almost all the behavioral capabilities (precocial species) and in others leaves significant amounts to be acquired during development (altricial species). In the altricial case, what is needed is higher-order design of bootstrapping mechanisms” (Sloman and Chrisley, 2005, pp. 153-154).”

More generally, the concept of investment project has gradually converged to the concept of an enterprise whose structure has the twofold characteristic of a sustainable architecture and a self-constructing ability that interacts with the market. This is based on observed behaviors and the hypothesis that these behaviors result from the application of human intelligence to economics. In this respect, in a way similar to the debate on artificial intelligence (see, for example, Penrose, 1983), two theories have historically confronted each other: on the one hand the one that sees markets and exchange emerge from the interaction of projects, as complementary or conflicting algorithms of economic agents, and on the other hand an interpretation that instead considers these economic agents the epiphenomena of systemic organizational elements. The more recent literature on the social rate of return or SROI can also be seen as an attempt to pull together these two separate lines of thought, by evoking participating stakeholders and social capital (Lingane and Olsen, 2004).

THE PROJECT AND THE SAM

The Social Accounting Matrix or SAM for short (Stone, 1962, 1981) is a system of national, regional, sub-regional accounts represented in a matrix format. It includes the inter-industry linkages through transactions typically found in the I-O accounts and the transactions and transfers of income between different types of economic agents, such as households, government, firms and external institutional sectors. As a generalization of Leontief input output system, the SAM represents an economy as a network of transactions across production sectors and institutional actors. The SAM depicts the economy as a series of agents interconnected through a double accounting system, with matrix columns representing expenditures as resource outflows and rows representing revenues as matching inflows. Total outflows match total inflows for each agent as accounting identities, but deficits and surpluses are balanced through a capital formation account, which collects savings from agents whose expenditure is lower than revenue (surplus units) and transfers them to agents that spend more than they earn (deficit units). The SAM provides an internally consistent representation of the resource flows across a given disaggregation of the economy and is the basis of the national accounts methodology officially endorsed by the UN and the multilateral organization and used by most countries' national governments.

As shown in Scandizzo (2021), within the SAM framework, an investment project can be analyzed as a vector of expenditure shocks and as a special form of an activity, with its input output parameters that evolve over time. As an activity, the project is characterized by a series of transactions and corresponding cash flows that change over time. Thus, at any point in time it can be represented in a SAM as a column of cash outflows, including all capital and maintenance costs from intermediates and resulting value added, and as a row of cash inflows, including financing from the government and private savings during the construction phase, and revenues from increased production of goods and services during the operational phase. The SAM accounting principles require costs and revenues to balance, so that financing from the capital formation sector, or directly from the government or other project sponsors must be recorded as one or more row entries in the years where cash outflows are larger than cash inflows (typically in the project "construction" phase). Vice versa, once the project is operational and inflows become larger than outflows, returns can be credited to capital (as gross business margins) or institutions (government, enterprises, households). This methodology has also been applied to other published studies (Scandizzo et al., Perali et al., Pecci et al,). Furthermore, it has been applied also as starting methodology to build machine learning models for implementing COVID-19 prediction system (Kavitha, 2022).

The structure of a typical SAM follows a classification scheme that is consistent with international statistical conventions and is based on eight categories of accounts: (i) activities, (ii) commodities, (iii) production factors, (iv) households, (v) enterprises, (vi) government, (vii) capital formation and, (viii) rest of the world. While the SAM provides a system of accounts of the transactions across these different agents for a period of time, it can also be used as a basis for a model, under specific hypotheses of technical and behavioral characteristics of the agents involved. The SAM thus consists of a set of interrelated subsystems that, on the one hand, give an analytical picture of the studied economy in a particular accounting period and, on the other hand, may be used within the framework of general equilibrium models for assessing the effects of changes on the particular resource flows. These may be represented by injections and leakages in the system, which might be the result of policy measures.

Indicating with T the SAM as a transaction matrix, the simplest form of SAM derived models is a generalization of the so-called open economy model originally associated with the Leontief input-output structure, and can be simply represented by the equation:

$$(TX_d^{-1})X = QX = 0 \tag{1}$$

where X is an n,1 vector of activity levels for productive sectors, commodities and incomes for factors and institutions and $Q = I - A = (TX_d^{-1})X$ the SAM coefficient matrix.

The SAM definition in (1) offers the opportunity to represent a project as an autonomous activity, emerging from the existing economic context as a separate endeavor, with specific characteristics different from the other activities and, at the same time, endowed with a degree of embeddedness depending on its transactions with the rest of the economy. More precisely, we can think of a project as a two-stage process, first arising as an exogenous shock to the existing equilibrium, and then determining a new equilibrium by modifying the parameters regulating the flows of good and services and thus changing the structure of the economy. In other words, the project can be conceived as a combination of a disruption of an existing equilibrium and then, as an achievement of a new equilibrium that incorporates its structural characteristics in the economy. As shown in Scandizzo (2021), this can be accomplished by considering the investment project as an additional institution engaged in capital formation, in the project's construction period, and as a production activity during the project operational period. This implies augmenting the size of the SAM by adding a column and a row of transactions corresponding, respectively, to the outlays and the receipts of the project cash flow. For the inflows and outflows to balance, this entails the accounting, among the receipts, of any financing flow and, among the expenditures, of any returns distributed to factors of production and other stakeholders.

To represent the impact of the project on the economy, we can write this two-stage process by distinguishing two new equilibrium conditions for the situation" without" and "with the project" SAM as:

$$X_s = A_s X_s \,; X_c = A_c X_c \tag{2}$$

In A_s and A_c are n+1, n+1, SAM matrices augmented of one column and one row to represent, respectively the situation without and with a specific project. The matrix without the project A_s can either contain an additional column and row of zeros, for the case of full project additionality, or the data of the cash flow of an alternative project as a counterfactual.

Subtracting equation (1) from equations (3a) and (3b), we obtain, after some manipulation:

$$X_c - X_s = A_c(X_c - X_s) + (A_c - A_s)X_s \tag{3a}$$

$$X_c - X_s = A_s(X_c - X_s) + (A_c - A_s)X_c \tag{3b}$$

Both the A_s and the A_c matrix are singular, but we can decompose them into a nonsingular square submatrix of coefficients of endogenous variables and three rectangular submatrices of coefficients of both endogenous and exogenous variables:

$$A_i X_i = \begin{bmatrix} A_{ee,i} & A_{ex,i} \\ A_{xe,i} & A_{xx,i} \end{bmatrix} [\begin{matrix} X_{ei} \\ X_{xi} \end{matrix}] \text{for} i = s, c \tag{4}$$

In (4) X_{ei} and X_{xi} are vectors respectively of endogenous and exogenous activity levels and $A_{ee,i}, A_{ex,i,} A_{xe,i,} A_{xx,i}$ corresponding submatrices from partitioning of A_i.Developing the expression, we can re-write (2) and (3) as follows:

$$X_{ei} = A_{ee,i} X_{ei} + A_{ex,i} X_{xi} ; i = s, c \tag{5a}$$

$$X_{xi} = A_{xe,i}X_{ei} + A_{xx,i}X_{xi}\ ;\ i = s, c \tag{5b}$$

By defining the variables X_{xi} as exogenous, we disregard equation (5b), and, as a consequence, we are led to disregardX_{xi}forward linkages, described by their SAM inflows from transactions with all sectors. More generally, exogenous sectors will be able to act as demand shocks on the endogenous sectors, while they will not be able to absorb and recycle induced demand increases, since their forward linkages from equation (5b) are assumed to be severed (i.e., exogeneity amounts to assume that both matrices in (5b) are null). The exogenous sectors thus have a twofold role. On the one hand they amount to exogenous demand shocks, while, on the other hand, as leakages in the circulation of income, since the exogeneity assumption mutes their forward linkages, they put a limit to the demand multipliers generated by external resource injections. More specifically, the size of the demand shock and of the consequent increases of the endogenous variable depend on the level of the exogenous variables, while the sizes of the multipliers are negatively related to the number of exogenous sectors that are excluded from the endogenous circulation of income.

Expression (5a) identifies one part of the system ($A_{ex,i}X_{xi}$) as a vector of exogenous demand levels and one part ($(I - A_{ee,i})X_{ei}$) as a corresponding vector of endogenous supply levels necessary to satisfy the direct and indirect demand generated by the exogenous demand levels.

In the case of full project additionality (no alternative project in the counterfactual), the vectors in (5a) and (5b) have different dimensions, since the vector X_{ec} includes project output, while the vector X_{es} does not. In general, however, we can assume that both $X_{es}$and$X_{ec}$are *n+1, 1* vector. Indicating with x_{pc} the project activity level (e.g., project output), we can write:

$$X_{ec,n+1} - X_{es,n+1} = \begin{pmatrix} X_{ec,n} \\ x_{pc} \end{pmatrix} - \begin{pmatrix} X_{es,n} \\ x_{ps} \end{pmatrix} = \begin{pmatrix} X_{ec,n} - X_{es,n} \\ x_{pc} - x_{ps} \end{pmatrix} \tag{6}$$

where x_{pc} indicates the output of the project under consideration and x_{ps} is the output of a counterfactual project, which is zero in the case of pure project additionality.

In the construction phase, the project can be considered an exogenous activity, so we can disregard the last line of equation (6). In the operational period, on the other hand, the project can be subsumed by the augmented n+1 SAM among the endogenous activities. Assuming that m exogenous variables (in addition to the project) can be specified, we obtain, by subtracting the endogenous vector without the project from the one with the project, and using a first difference compact notation:

$$\Delta X_e = A_{ee,i}\Delta X_e + A_{ex,i}\Delta X_x + \Delta A_{ee}X_{es} + \Delta A_{ex}X_{xj} + A_{ep,i}\Delta x_p + \Delta A_{ep}x_p + \Delta A_{ee}\Delta X_e + \Delta A_{ex}\Delta X_x + \Delta A_{ep}\Delta x_p, i, j = c, s \tag{7}$$

Equation (7) suggests a decomposition of the variations of the endogenous variables induced by the project consisting of three separate effects: (1) the variations with the given SAM coefficients (respectively, with and without the project), (2) the variations of these coefficients, and (3) the products of the two sets of variations.

The three coefficient submatrices with the project $A_{ee,c}\ (n, n)$, $A_{ex,c}(n, m) and\ A_{ep,c}\ (n, 1)$ may differ from the corresponding submatrices without the project $A_{ee,s}, A_{ex,s} and\ A_{ep,s}$ from three separate reasons: (i) they may reflect financing from outside sources for the project (e.g., a grant) , (ii) they may reflect a resource shift due to the need to finance the project, (iii) they may reflect productivity changes due to spillovers from project technology, organization or other systemic changes. In order to analyze these possibilities, it is useful to focus on the case in which there is no project in the counterfactual state of the world, i.e., $x_{ps} = 0$.

Assuming full additionality ($A_{ep,s}x_{ps} = 0$), and omitting the n subscript, equations (7) can be solved for the endogenous activities to give the following expression:

$$X_{e,c} - X_{e,s} = \Delta X_e = L_i A_{ep} x_p + L_i[A_{ex,i}\Delta X_x + \Delta A_{ex} X_{xj} + \Delta A_{ex}\Delta X_x] + \Delta L[(A_{exj} X_{xj}) + A_{ex,s}(\Delta X_x) + \Delta A_{ex} X_{xj} + \Delta A_{ex}\Delta X_x], i,j = c,s \qquad (8)$$

where $L_i = (I - A_{ee,i})^{-1}, i = c, s$ and Δ is the difference operator : $\Delta X_x = X_{xc} - X_{xs}$, $\Delta A_{ex} = A_{xc} - X_{xs}$. $\Delta L = L_c - L_s$.

Expressions (7) and (8) yield different results for $i, j = c, s$, because the interaction terms are different. In line with the literature on structural decomposition (e.g., Rose and Casler, 1996, Koppany, 2017), these expressions thus signal an index number problem since project changes can be calculated as differences from the variable levels and the SAM parameter values with the project or without it[1].

Looking at the structure of equation (8), we note that that the first term is the project multiplier as it is usually calculated, with the computation being performed alternatively with the inverse matrix with the project $(i = c)$ or with the matrix without it $i = s$. The term in square brackets measures three different effects: (i) a variation of the exogenous variables in response to the project (for example to finance it), (ii) an effect due to the modification of technical coefficients or institutions' shares due to the project, (iii) the interaction between (i) and (ii). On the other hand, the last term in square brackets, contains a first order effect given by the product of the difference multiplier ΔL by the exogenous variables, and three higher orders differences. In sum, in addition to the indirect effects induced by the project through the traditional multiplier (with and without the project),the inclusion of a project in a market economy may be followed by four different effects to reestablish equilibrium: (i) a variation of the exogenous variables, (ii) resource reallocation /redistribution among the endogenous and the exogenous activities and institutions, (iii) an increase in the interconnectedness of the economy , (iv) a set of interactive changes.

In the operational period, the project becomes an endogenous activity, so that expression (8) is simply modified by dropping the project from the exogenous variables and including it into the endogenous ones. In this case vectors and matrices include the project as an additional endogenous activity, so that the endogenous variables are n+1 in number and the corresponding Leontief inverse and submatrices are: $A_{ee,c}\,(n+1, n+1)$, $L_c(n+1, n+1)$, $A_{ex,c}(n+1, m)$.

This analysis underscores the important difference in the role played by the project respectively during constructions and operations. In the construction period the project can be considered an exogenous shock coming upon an economy in equilibrium, but with underemployed resources. Its impact is thus likely to be dominated by the boost of aggregate demand through the Leontief inverse multiplier. In the operational period, on the other hand, the project becomes an endogenous variable, as one of the ongoing activities of the economy, and its main impact is due to the increase in productive capacity and in increase in the multiplier effect of the exogenous variables. By increasing the interconnectedness of the economy, in other words, and the corresponding level of the Leontief multipliers, the project contributes to boost economic activity in response to any increase in aggregate demand during its operational phase. In this phase the project thus plays a dual role: on the supply side, by opening another line of production that benefits a number of possible stakeholders, and on the demand side, by increasing the circular flow of income throughout the economy. These two outcomes are due not only to the direct effects of the project cash flow, as recognized in traditional cost benefit analysis, but also to its boosting of the multiplier effects in the economy, which is able to take fuller advantage of exogenous demand.

However, integrating the project within the SAM is not a trivial operation. Suppose a new activity is added to a Social Accounting Matrix (SAM). In that case, the resulting Leontief Inverse will reflect the changes in the inter-sectoral linkages and sectoral multipliers that result from the addition of the new activity. To calculate the increase in aggregate demand in response to the output of the new activity, we can use the Leontief Inverse multiplied by the vector of final demand. Specifically, the Leontief Inverse multiplied by the new activity vector would give the output of the new activity sector in response to the given level of final demand.

However, it is important to note that adding a new activity to the SAM will affect the overall balance and consistency of the matrix. Therefore, the new SAM must be re-balanced to ensure that the sum of all incomes equals the sum of all expenditures, and that the total value of production, income, and expenditure in the SAM matches the corresponding values in the national accounts. Once the new SAM is balanced and consistent, it should respect the condition that the Leontief Inverse multiplied by the new activity vector should equal the aggregate demand for the new activity. This relationship reflects the fact that the Leontief Inverse captures the direct and indirect effects of changes in final demand on the output of each endogenous sector of the economy, including the new activity sector that has been added to the SAM.

The above implies that in addition to include one row and one column of transactions to the SAM without the project, it is necessary to rebalance the SAM in such a way that the new totals respect the requirement:

$$X_{ec} = L_c(A_{ex,c}\,X_{x,c} + A_{ep}x_p) \tag{9}$$

where $A_{ep}x_p$ is the project vector and L_c the Leontief inverse with the project. However, the value of the Leontief matrix L_c in turn depends on the new SAM with the project, which can only be calculated if the vector of totals in (9) is estimated. For small projects, the Leontief inverse with the project will be very close to the one without the project. For large projects, however, the following iterative procedure has proved to be effective:

Step 1: Use the Leontief inverse without the project to estimate a set of totals with the project:

$$X_{ec,0} = L_s(A_{ex,s}\,X_{x,s} + X_p) \tag{10a}$$

In (10a), X_p is the vector of project expenditures, which at this stage is still not a proper part of the SAM.

Step 2: Compute a new SAM with the project consistent with the totals in (10a) and compute a new set of totals:

$$X_{ec,1} = L_1(A_{ex,1}\,X_{x,1} + A_{ep,1}x_p) \tag{10b}$$

In (10b) L_1 is the Leontief inverse of the new SAM that incorporates the project as $X_p = A_{ep,1}x_p$, where $A_{ep,1}$ is the project coefficient column vector and x_p total project expenditure. Note that in estimating the new SAM, the matrix of coefficients as well as levels of the exogenous variables may also change.

Step 3: Compute:

$$\Delta X_{e,1} = X_{ec,1} - X_{e,s} = \Delta X_{e,1} = L_1 A_{ep,1}x_p + L_1[A_{ex,1}\Delta X_x + \Delta A_{ex,1}X_{xs} + \Delta A_{ex,1}\Delta X_x] + \\ \Delta L_1[(A_{exs}X_{xs}) + A_{ex,s}(\Delta X_x) + \Delta A_{ex}X_{xs} + \Delta A_{ex}\Delta X_x] \tag{10c}$$

Compute the control as the difference between the totals with the updated matrix and the totals with the original matrix (without the project):

$$\Delta\xi_{e,1} = (A_{ee,1}\,X_{e1} + A_{ex,1}\,X_{x,1} + A_{ep,1}x_p) - (A_{ee,s}\,X_{e,s} + A_{ex,s}\,X_{x,s}) \tag{10d}$$

Step 4: Compute the difference between the new totals and the control: $\Delta X_{e,1} - \Delta\xi_{e,1}$. If this difference is$>$ $|\varepsilon|$ go to step 5

Step 5: Obtain a new set of totals as:

$$X_{ec,2} = L_1(A_{ex,1}\,X_{x,1} + A_{ep,1}x_p) + (\Delta X_{e,1} - \Delta\xi_{e,1}) \tag{10e}$$

Obtain a new matrix consistent with this total and a new inverse L_2.

Step 6: Revise the SAM so that it is consistent with the new totals in (10e) and proceed iteratively until convergence ($\left|\Delta X_{e,i} - \Delta\xi_{e,i}\right| < [\varepsilon]$.

$$X_{ec,i} = L_i\left(A_{ex,i-1}\, X_{x,i-1} + A_{ep,i-1} x_p\right) + \Delta X_{e,i-1} - \Delta\xi_{e,i-1}, i = 1,2 \ldots\ldots n \tag{10f}$$

In (10f) i indicates the ith iteration ($i = 1,2 \ldots$) starting from the values without the project. To sum up, expressions (6)- (8) show that once embedded into the SAM, the project can be considered either an exogenous or an endogenous variable. In the first case, which typically coincides with project implementation (the construction phase), the project can be considered an autonomous initiative, impacting the economy as an exogenous shock and a structural change. In the second case (the operational phase), the project expected cash flow defines a set of coefficients for a new activity producing goods and/or services, whose impact on the economy (including project performance) is determined by the variation of the structural parameters of all other sectors. In this case, project scale and impact are endogenous. However, the project can still be considered autonomous because its expected cash flow reflects a set of parameters from exogenous technologies and expenditure patterns (the project business plan).

Expression (8) also shows that the project's impact can be decomposed into the effects of the variation of the technology and behavioral parameters, evaluated at the average levels of the endogenous and exogenous variables between the situation with and without the project. In the construction period, the impact of a project will depend on its effects, as an exogenous demand shock, on the endogenous variables, as it is generally reported in the literature on the multipliers. However, both in its construction and operational phase, the project may have a significant impact as a supply side shock, that is, by modifying the demand for inputs of both productive sectors and institutions. This second effect will depend on the relative size of the project compared to economy, and will be larger, the larger, for given input change, the values of the exogenous variables. For a given economy, therefore, larger projects that introduce disruptive technologies may display both a broader and a deeper impact, by causing direct, indirect and induced changes in the parameters regulating exchanges for all sectors.

It's important to consider that expression (6) can be viewed as encompassing two conflicting relationships. In this context, if the project operates with complete independence, the second row of the matrix may be disregarded, allowing the first row (aligned with equation (8)) to dominate. Conversely, if the project remains reliant on the broader economic outcomes, it would be integrated into the augmented n+1 Social Accounting Matrix (SAM) as one of the endogenous activities. The difference between these two conditions, and the relative weight of each during project implementation and operations, may indicate the project's limited scope. Even if the projected were granted some autonomy, at the same time it would have to obey the existing parameters of technology and market change. In practice, along the entire project life, there may be a tension between the project's attempt to follow an autonomous course and the tendency of its context to "normalize" it by reconducting its behavior to the basic routines of the parent organization, according to a "short leash-long leash" management dilemma (Wima and Wolf, 2022).

In sum the impact of a project on the economy may be more fully accounted for with the SAM and may depend on whether and to what extent its cash flow involves endogenous or exogenous variables. Since the project requires financing during the construction period, except for cases of earmarked funds, this is obtained by diverting resources from other uses. This impacts the SAM because it affects the allocation of resources within the economy. If the financing is obtained by the capital formation (CF) sector, which is the SAM institutional account acquiring capital goods, the project can be considered a detached part of CF activity in the SAM. This means that the project is an exogenous shock, and at the same time is part of CF, which remains endogenous. The project is thus treated as a separate entity within the model, while CF endogeneity ensures that the equality between investment and savings is maintained.

AN APPLICATION TO THE ITALIAN ECONOMY

To create an interesting case study, we propose analyzing the impact of a large investment program in Italy. Although this exercise should be viewed as an experimental application, utilizing a numerical case study with largely hypothetical inputs, our application is based on a compact and newly estimated Social Accounting Matrix (SAM). This matrix, presented in Table 1 in the appendix, is based on a larger study (Cufari et al., 2022) using data from national statistics and the available literature. These data have been supplemented by nationally representative industrial and household surveys for production disaggregation, employment and Household income and consumption (ISTAT – ASIA; ISTAT - MATIS). The SAM estimated is calibrated with the 2020 national account data. The SAM presented in Table 1 is an aggregate version of a SAM estimated for twenty sectors, one sector for agriculture, eleven sectors for industry, and eight service sectors, including trade, transport services and public administration services.

METHODOLOGY AND RESULTS

Table 2 and Table 3 show the structure of the cash flow of the (financial) costs and benefits hypothesized for the investment program. In the tables, costs and benefits are given as totals (5 years for the construction period) and 25 years for the operational and maintenance (O&M) period, and as present values at a discount rate of 5%.

Project evaluation with the model has been performed using the methodology presented in section 3, combining the SAM with the cash flow components envisaged by project plans to estimate both direct and indirect effects on activities, commodities, and institutions. The numbers in the tables represent estimated costs and benefits, derived from hypothetical scenarios of typical projects. While investment figures are from official documents, the revenue numbers are essentially educated guesses based on typical project outcomes.

TABLE 2
THE PROGRAM TARGET CASH FLOW (DIRECT COSTS IN MILLION €)

	TOTAL (2023-2027)	**Present Value**
INVESTMENT COSTS		
Computers	7,036	6,092
Electric Machineries	7,239	6,268
Machineries	1,609	1,393
Transport Equipment	5,681	4,919
Constructions	68,003	58,884
R&D	7,942	6,877
Labor	3,065	2,654
Indirect Taxes	34,394	29,781
Direct Taxes	11,566	10,015
Agriculture	407	353
Food Industry	407	353
Transport services	3,024	2,618
Other Services	14,611	12,651
Public Administration	12,381	10,721
Education services	12,870	11,144
Health services	1,293	1,120
TOTAL INVESTMENT COSTS	**191,528**	**165,843**
TOTAL O&M COSTS	**43,668**	**12,794**

Source: Authors' hypotheses

TABLE 3
THE PROGRAM REVENUE TARGET CASH FLOW (ANTICIPATED DIRECT REVENUES IN MILLION €)

REVENUES	TOTAL (2027-2050)	PRESENT VALUES
Increasing Production	131,485	73,425
Increasing Value Added	57,511	32,121
Increasing Income	31,765	17,781
Increasing Consumption	40,440	22,597
Increasing Public Expenditure	12,215	6,826
Increasing Exports	17,981	10,039
Increasing Imports	16,227	9,045
Increasing Investments	11,759	6,538
TOTAL BENEFITS	**319,383**	**178,372**

Source: Authors' hypotheses

In practice, we have first disaggregated the investment costs into SAM's activities and then extended the SAM with a further activity containing the project's cash flow.

Table 4-7 show the results of the evaluation using the aggregated SAM (see Table 1in the appendix), incorporating a project cash flow, respectively in the construction period (t=0), and in the operational period (t=1), with the project cash flow being accounted for as an extra activity and/or institution in the matrix. The cash flow data in the construction period include only capital expenditures (capital goods produced by activities) in the account column and financing from Government in the account row. In the operational period, the project account column includes all estimates of project costs (including capital depreciation and operational costs), while the row account contains all estimates of project revenues. As already discussed in Section 3, the cash flow figures for the operational period, are used to estimate correspondent SAM coefficients which determine the project economic profile as a proportion of inputs and outputs.

As Table 4 in the appendix shows, in the construction period, the expenditure for project implementation, detailed in the project column, is financed from Government (in the project row), which in turn is balanced by capital formation and other institutions. Since the project at this stage can be considered an exogenous activity, the row describing its financing can be disregarded, while the column can be considered an exogenous shock, which generates, to the extent that its expenditures mobilize unemployed resources, increases in revenues, consumption, trade and value added through indirect effects. In other words, the project operates as a demand stimulus in the construction period and produces spillover effects. Because its introduction in the SAM changes also the SAM parameters, the project has also some structural effects, with a prevailing role of its expenditure pattern. In its operational phase, on the other hand, the project becomes an activity endowed with the productive capacity created in the construction phase. To be sustainable, it has to collect revenues equal or exceeding the capital costs undergone in the construction phase plus the operating costs of the operational phase, including any financing. Project revenues are listed in the project row in Table 5. They are collected from various stakeholders who purchase the goods or services provided by the project, including households and government. With no indirect effects, project net (financial) benefits would thus simply be the portion of value added credited to capital, net of any charges due to user costs for maintenance.

The value-added account in the operation phase is the sum of the project direct payments to production factors and indirect taxes to meet operational costs and of the returns to capital obtained from project revenues after paying for intermediate goods and capital formation. The capital formation expenditures include loan repayments, interests, capital depreciation (assumed to be 5% per year) and any expenditure for replacement of capital goods.

As an endogenous activity, the project cash flow in the operation period is consistent with the revenues and the expenditures of the other accounts in the SAM and is determined by the value of the exogenous variables.

The two transaction matrices in Table 4 and Table 5 in the appendix correspond to two coefficient matrices (CFM). Impact estimates for the construction phase are reported in Table 6. The structural impact of the project through the coefficients of the endogenous variables is mainly negative for all sectors except for the project, their negativity being attributable to a crowding out effect, since the project acts as a substitute of existing activities and thus absorbs resources that the other sectors would otherwise use. In the case considered, the project draws additional resources only from the capital formation account, but this withdrawal has a negative impact not only on the coefficients of this account, but also, due to the interdependencies in the SAM, on the coefficients of resource requirements of all other accounts, except for the government whose savings are used to finance the project withdrawal from capital formation and Rest of the World. The structural impact of the project on value-added is also negative for the endogenous variables, with significant negative effects for households' incomes, while it is modestly positive for value added of the exogenous variables. The impact of the demand shock is instead always positive and dominates the negative impact of the structural changes with a value-added overall project multiplier of 1.95. The net effect of the two changes is thus positive. Still, the negative structural effects signal possible diseconomies due to the displacement of existing activities, except for project strategic sectors such as R&D and construction, and for the Government.

Table 7 reports the results for the operational period. The structural changes caused by the project also lead to negative effects for all sectors, due to their contraction to make space for the project. However, these effects are more than compensated by the expansion of project transactions and its higher value-added shares. In terms of value-added, project performance adds about a net amount of 19 billion Euros per year to the economy, roughly equivalent to a PV (at 5% discount) of more than 211 billion Euros. Compared to PV project costs of about 157 billion Euros, this indicates that a positive NPV would be achieved by project's operations even without considering the benefits from the construction phase.

TABLE 6
CONSTRUCTION PHASE IMPACT (MILLION EUROS)

	DAX Endogenous	DAX Exogenous	DAX Total	DX (Demand Shock)	Total Impact	Project Multipliers
Agriculture	-119.69	-23.48	-143.17	2760.51	2617.34	0.07
Industry	-2728.44	-8989.50	-11717.95	54910.74	43192.79	1.14
Construction	11985.51	7300.14	19285.65	19101.32	38386.97	1.02
Research and Development	1542.91	1093.49	2636.40	1736.65	4373.05	0.12
Services	-2416.45	1915.73	-500.71	94743.53	94242.81	2.50
Public Admin	-3290.75	5136.42	1845.67	27326.90	29172.57	0.77
Value Added	**-12388.35**	**605.63**	**-11782.72**	**85419.66**	**73636.94**	**1.95**
Low Income Households	-2070.45	-42.68	-2113.12	12253.95	10140.82	0.27
Middle Income Households	-2573.09	-48.47	-2621.56	21221.09	18599.53	0.49
High Income Households	-4036.91	-129.22	-4166.13	56411.28	52245.14	1.38
Government	-8790.05	32942.22	24152.17	88575.14	112727.31	2.99
Enterprises	-767.67	0.00	-767.67	34376.79	33609.12	0.89
Project	37746.08	0.00	37746.08	-	37746.08	1.00

Source: Model Simulations

TABLE 7
OPERATIONAL PHASE IMPACT (MILLION EUROS)

	DAX Project	DAX Endogenous	DAX Exogenous	Total Impact per year	Total Present Values (30 years of operations)
Agriculture	1,748.29	-758.46	-940.56	49.27	533
Industry	30,563.74	-21,962.97	-26,413.85	-17,813.08	-192,559
Construction	2,029.70	-2,978.67	-9,288.38	-10,237.36	-110,666
Research and Development	107.34	-125.47	-838.62	-856.75	-9,261
Services	59,422.46	-17,571.14	-29,085.31	12,766.02	138,001
Public Admin	21,328.26	1,782.46	-4,325.17	18,785.54	203,072
Value Added	**55,018.61**	**-9,201.23**	**-26,262.43**	**19,554.96**	**211,389**
Low Income Households	9,697.83	-409.35	-2,998.52	6,289.97	67,995
Middle Income Households	15,867.85	-1,468.48	-5,590.91	8,808.46	95,219
High Income Households	39,828.93	-5,938.06	-15,703.05	18,187.83	196,610
Government	89,052.47	45,269.53	-15,787.03	118,534.97	1,281,363
Enterprises	22,489.29	-5,808.42	-10,376.91	6,303.96	68,146
Project	1,501.45	40,716.26	3,514.52	45,732.24	494,365

Source. Model Simulations

CONCLUSIONS

This paper has presented a new technique of economic analysis for investment projects, based on a social accounting matrix (SAM), that can be applied to different modelling frames using the SAM, including Computable General Equilibrium Models. The technique expounds the approach developed in Scandizzo (2021), to consider the twofold case in which the project is considered an exogenous, autonomous endeavor, or is embedded in the economic system which ultimately determines its performance as an endogenous economic activity. These two polar cases are identified, respectively, with the project's construction and operational phase of the project, but in practice can be combined to fit the structural and management characteristics of the projects examined. The use of the SAM allows distinguishing among project phases, the evolution of project over time and the impact on technology, demand structure and social variables. It thus extends the project evaluation to the assessment of its impact on different institutions and social groups, participating and absentee stakeholders, and allows to analyze the different components of the social return to investment. In general, both the theory developed, and the numerical examples show that a successful project tends to be disruptive of the previous social order and that its success depends on striking the right balance between positive shifts in demand and supply on one hand, and reduction of pre-existing incomes and rents on the other hand. Even in the case of seemingly neutral projects, with apparently inoffensive spending profiles, their mere introduction in the economic system tends to reduce some of the gains of the ongoing transactions, giving rise to major shifts of benefits and costs. Net project impact, therefore, even when it is highly positive, as in the numerical examples developed, appears to be characterized by structural changes that may reduce direct project gains by shifting resources across stakeholders. Depending on the project scale and structural features, these resource shifts may be significant and create diverse and possibly diverging patterns of benefits and costs across project stakeholders.

As a numerical illustration, the above framework was applied to evaluate the PNRR impact on the Italian economy using a compact SAM estimated with the latest data available. The simulations indicated that sizable sector diseconomies should be expected from crowding out effects due to structural changes, but that these would be overcompensated by both demand and productivity effects from project increased resources and by its positive allocation impact. Overall, the SAM experiments indicate that the PNRR's effects on GDP could be approximately 73 billion Euros per year during the construction phase, compared to the business-as-usual scenario, and around 20 billion Euros per year during the operational phase. It is important to interpret these results as illustrative of the reported methodology rather than a reliable evaluation of the investment program examined, which would require more accurate project-level data.

ENDNOTE

[1] Taking into account that we can define $X_c = X_s + \Delta X_c$ and$A_c = A_s + \Delta A_c X_s = X_c + \Delta X_s$, $A_s = A_c + \Delta A_s$ we can write equations (3a) and (3b) as follows:
$X_c - X_s = \Delta X = A_c \Delta X + (\Delta A) X_s + \Delta A_c \Delta X_c; X_c - X_s = \Delta X = A_s \Delta X + (\Delta A) X_c - \Delta A_s \Delta X_s$.
The index number problem arises from the need to approximate the two interaction terms $\Delta A_c \Delta X_c$ and$-\Delta A_s \Delta X_s$ (Rose and Cassler, 1996, p.48).

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APPENDIX

TABLE 1
SOCIAL ACCOUNTING MATRIX FOR ITALY, 2021, BILLION EUROS

	Agric.	Industry	Construc.	R&D	Serv.	Public Adm.	Value Added	Low Inc. HH	Middle Inc. HH	High Inc. HH	Govern.	Enterpr.	Invest.	RoW	**Total**
Agriculture	4	26	0	0	6	0	0	4	5	9	1	0	0	5	**62**
Industry	10	547	36	1	141	21	0	53	78	135	6	0	89	377	**1494**
Construction	0	8	36	0	12	4	0	2	3	5	1	0	105	1	**179**
Research and Development	0	2	0	0	1	0	0	0	0	0	0	0	10	2	**15**
Services	4	229	36	3	461	44	0	135	209	376	40	0	70	80	**1685**
Public Admin	0	3	0	0	6	13	0	6	11	22	271	0	1	1	**334**
Value Added	31	285	62	9	844	228	0	0	0	0	0	0	0	0	**1460**
Low Inc. HH	0	0	0	0	0	0	94	0	0	0	74	31	0	-4	**194**
Middle Inc. HH	0	0	0	0	0	0	195	0	0	0	89	64	0	-4	**344**
High Inc. HH	0	0	0	0	0	0	604	0	0	0	141	196	0	-10	**931**
Government	0	46	8	1	142	23	0	21	45	172	634	176	0	4	**1273**
Enterprises	0	0	0	0	0	0	567	0	0	0	18	0	0	0	**585**
Investments	0	0	0	0	0	0	0	-27	-7	213	-2	118	0	-20	**275**
Rest of the World	12	347	1	1	71	1	0	0	0	0	0	0	0	0	**432**
Total	**62**	**1494**	**179**	**15**	**1685**	**334**	**1460**	**194**	**344**	**931**	**1273**	**585**	**275**	**432**	

Source: Authors' estimation

TABLE 4
SAM WITH PROJECT IN THE CONSTRUCTION PHASE (T=0) (BLN €)

	Agric.	Industry	Construc.	R&D	Serv.	Public Adm.	Value Added	Low Inc. HH	Middle Inc. HH	High Inc. HH	Govern.	Enterpr.	Project	Invest.	RoW	**Total**
Agriculture	4	26	0	0	6	0	0	4	5	8	1	0	0	0	5	**62**
Industry	10	539	48	2	144	22	0	56	78	122	6	0	19	88	381	**1513**
Construction	0	8	46	0	12	4	0	2	3	4	1	0	56	100	1	**238**
Research and Development	0	2	0	0	1	0	0	0	0	0	0	0	7	10	2	**22**
Services	4	227	49	4	473	48	0	143	208	340	37	0	26	70	82	**1711**
Public Admin	0	3	0	0	7	14	0	7	12	21	266	0	23	2	1	**356**
Value Added	30	270	81	12	828	239	0	0	0	0	0	0	3	0	0	**1462**
Low Inc. HH	0	0	0	0	0	0	93	0	0	0	76	29	0	0	-4	**194**
Middle Inc. HH	0	0	0	0	0	0	196	0	0	0	93	61	0	0	-5	**344**
High Inc. HH	0	0	0	0	0	0	607	0	0	0	147	189	0	0	-12	**931**
Government	0	50	13	2	159	27	0	24	49	166	631	161	32	60	66	**1439**
Enterprises	0	0	0	0	0	0	566	0	0	0	18	0	0	0	0	**585**
Project	0	0	0	0	0	0	0	0	0	0	166	0	0	0	0	**166**
Investments	0	0	0	0	0	0	0	-42	-11	270	-3	145	0	0	-30	**330**
Rest of the World	14	388	1	1	82	1	0	0	0	0	0	0	0	0	0	**488**
Total	**62**	**1513**	**238**	**22**	**1711**	**356**	**1462**	**194**	**344**	**931**	**1439**	**585**	**166**	**330**	**488**	

Source: Authors' estimation

TABLE 5
SAM WITH PROJECT IN THE OPERATIONAL PHASE (T=1) (BLN €)

	Agric.	Industry	Construc.	R&D	Serv.	Public Adm.	Value Added	Low Inc. HH	Middle Inc. HH	High Inc. HH	Govern.	Enterpr.	Project	Invest.	RoW	Total
Agriculture	5	27	0	0	6	0	0	4	5	9	1	0	0	1	6	**64**
Industry	10	543	35	1	139	20	0	52	77	131	6	0	1	102	415	**1533**
Construction	0	8	33	0	11	4	0	2	3	5	1	0	4	113	1	**185**
Research and Development	0	2	0	0	1	0	0	0	0	0	0	0	0	10	2	**15**
Services	4	235	37	3	471	45	0	136	211	378	41	0	1	85	93	**1741**
Public Admin	0	3	0	0	6	13	0	6	11	23	279	0	2	2	2	**346**
Value Added	31	288	64	9	841	228	0	0	0	0	0	0	4	0	0	**1464**
Low Inc. HH	0	0	0	0	0	0	94	0	0	0	81	32	0	0	-5	**202**
Middle Inc. HH	0	0	0	0	0	0	196	0	0	0	98	66	0	0	-5	**356**
High Inc. HH	0	0	0	0	0	0	608	0	0	0	156	204	0	0	-13	**955**
Government	0	47	9	1	143	23	0	21	45	170	640	167	169	0	5	**1441**
Enterprises	0	0	0	0	0	0	566	0	0	0	19	0	0	0	0	**585**
Project	2	39	6	1	55	12	0	7	11	23	7	0	0	8	11	**182**
Investments	0	0	0	0	0	0	0	-27	-8	216	112	115	0	0	-24	**385**
Rest of the World	12	341	1	1	68	1	0	0	0	0	0	0	0	64	0	**488**
Total	**64**	**1533**	**185**	**15**	**1741**	**346**	**1464**	**202**	**356**	**955**	**1441**	**585**	**182**	**385**	**488**	

Source: Authors’ estimation