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# PRODUCTIVITY ANALYSIS FROM A CLASSICAL PERSPECTIVE: THEORY OF MEASUREMENT AND MEASUREMENT OF THEORY

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# Abstract/Summary

This is a study on the notion of productivity, viewed from a Classical perspective. First, the distinction between physical productivity and productiveness (i.e. profitability) is connected to the distinction between the expenditure side and value added side of the economy, seen as a circular flow. Second, a mapping of some theoretical frameworks into empirical structures of the System of National Accounts is advanced. Then, indicators of physical productivity changes with the (growing) subsystem as a unit of analysis are obtained, together with measures reflecting the degree of surplus generating capacity at the level of individual industries. Aggregation rules and reduction procedures are devised and applied to deal with the heterogeneous nature of produced means of production. All throughout the study, empirical applications of the analytical results are provided. For the most part, empirical work is referred to the case of Italy (1999-2007), though some results concern a set of advanced industrial economies (Germany, France, Italy, Japan, UK and the US) during the 1995-2005 decade.

La presente tesi studia la nozione di produttività dal punto di vista Classico. In primo luogo, si connette la distinzione tra produttività (productivity) e profittabilità (productiveness) a quella tra il lato della spesa e quello del valore aggiunto dell'economia, vista come un flusso circolare. In secondo luogo, si collegano vari schemi teorici alle strutture empiriche del sistema di contabilità nazionale. Si calcolano quindi sia degli indicatori dei cambiamenti della produttività fisica, utilizzando come unità dell'analisi i subsistemi in crescita, che delle misure del grado di capacità delle singole industrie di generare sovrappiú. Si ottengono ed utilizzano regole di aggregazione e procedure di riduzione al fine di tenere correttamente conto dell'eterogeneità dei mezzi di produzione prodotti. In tutta la tesi, i risultati analitici ottenuti sono corredati da applicazioni empiriche. In larga misura, tale lavoro empirico concerne l'economia italiana (1999-2007); tuttavia, alcuni risultati riguardano un insieme di paesi industrializzati (Germania, Francia, Italia, Giappone, GB e USA) nel decennio 1995-2005.

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# Chapter 1

# Prologue

> "Productivity has been a major ideology of institutions ever since medieval salvationist ideals ceded to modernist rationality" (Reich 2001, p. 40)

## 1.1 Why Productivity?

Being trapped in history makes our analyses, in appearance, less general, less 'scientific', more speculative, full of counterfactuals, empty of timeless statements. Case-by-case detailed factual description or abstract reconstruction of the most remote past to present day, may appear as the only way out to overcome the cruelty of the historical nature of economic phenomena.

The last couple of hundreds of years had been so little in comparison with thousands of years of man as a producer. Hence, Political Economy could be thought not to be very ambitious. Its object of study has been quite easily circumscribed to the analysis of phenomena of production and distribution in societies *after* the appearance of the capitalist mode of production.[1] Its theories are quite restricted in their time-span, and so its projection onto the future.

By observing regularities we look for principles. The organisation of collective labour is one of these. In this sense, the passage from value to reproduction prices can be analysed as a development in economic history, as a passage from simple to extended reproduction.[2] But in essence, I believe the crucial characterisation is the passage from an 'urban' to a 'capitalist' mode of production.

[1] Though not necessarily being currently *under* the capitalist mode of production.

[2] As stated by Bródy (1970, p. 94): "The different prices systems belonged to different historical layers for Marx".

The 'urban revolution'[3] of the IV century BC and the 'capitalist revolution' of the XVIII century are two of the most important transformations in the mode of production of human history. They both had as a crucial determinant the change in the social organization of collective labour and the specific use of the surplus produced by the community as a whole.[4]

Hence, the human determination to transform the organisation of collective labour is a deep cause in the appearance of the capitalist mode of production. As regards its enforcement, the delicate interplay with primitive accumulation[5] should be acknowledged. However, deep understanding is far from mechanical, as the laws to which the capitalist mode of production obey change continuously in their details, because the changing organisation of human labour in society feedbacks with the root of the mode of production itself.

Wage labour together with individual property of the means of production are probably the two main institutional mechanisms for the enforcement of a particular way of organising collective labour. And this is a general principle. But the details get continuously altered. And one of the details that changes in its long-period trends across time and space is the rhythm of surplus generating capacity of different societies, or what amounts to the same thing, their productivity increases.

But productivity is an elusive concept. There abound meanings and uses (sometimes abuses) that place it as both cause *and* effect of economic growth and compositional changes in economic structure. It is my conviction that conceptual clarification can only come about by looking at the notion of productivity as a piece inside a comprehensive view of the process of production and distribution. As such, productivity analysis cannot be free of value judgement. Not even *physical* productivity, and clearly even less when surplus generating capacity is thought of in terms of profitability.

The task that this dissertation aims to accomplish is to give the notion of productivity a unified treatment, from conceptual discussion to empirical measurement and interpretation of results.

Throughout the dissertation, I adopt a Classical perspective to economic analysis, trying to establish clear differences with traditional views, as regards

[3] Of course the term 'revolution' is clearly a metaphor, its original meaning being "complete overturn of the relative positions of the various elements that constitute a system" (Liverani 1998, p. 3). Processes of social and technological change are slow and gradual.

[4] For a development of the argument, see Gilibert (2010).

[5] In fact, "[t]he necessity of a primitive accumulation of capital, which society could invest in the structural conversion of its mode of production, was not only a Marxist theory. It was a general presupposition at the basis of 'classical' political economy" (Liverani 1998, p. 7).

both theory and measurement. Hence, clarifying the meaning I attach to ‘Classical’ perspective is the place to start.

## 1.2 What do I mean by ‘Classical’ perspective?

The classical standpoint to economic analysis has its roots in the works of the ‘old classical economists’, as intended by Sraffa (1960, Appendix D), with Quesnay’s *Tableau Economique* as its first comprehensive scheme, followed by Marx’s (1885[1978]) schemes of ‘Simple Reproduction’ and ‘Reproduction on an Expanded Scale’, and extending into Leontief’s (1937) Input-Output framework and Sraffa’s (1960) system of production.[6]

The connections and interplay between these works is subject to long-standing debates, which shall not be dealt with. Instead, the aim is only to highlight *some* features of a (modern) classical approach.

First and foremost, the characterising principle is the view of the economy as a circular process based on the notion of physical real costs, i.e. inputs are physically consumed in the process of generating the outputs that reconstitute the capacity to restart the very same process as inputs at the same (or enlarged) scale.

Essentially, “circularity stands here for repetitiveness” (Gilibert 2006, p. 41, n.16). Reproduction begins and returns to the same point, picturing the whole process as an ascending spiral whose diameter expands or contracts. In fact, as Sraffa would phrase it: “in a circular flow scheme ‘The production of a thing has no real definite beginning — the inquiry leads us into infinite time backwards’ (D3/12/7: 27)” (Kurz & Salvadori 2005a, p. 497). Within the language of mathematics, circularity can be represented by eigensystems, which define prices and quantities in terms of themselves.[7]

Second, most of the interest lies in the analysis of those economies whose production exceeds its productive consumption, thus generating a surplus product, a set of commodities that must be allotted to different groups of individuals (classes) in society. Different uses of the surplus by the classes in society generate the income-expenditure loops of a circular process.

When commodities are produced by means of commodities, the notion of ‘cost of production’ as well as that of ‘factor of production’ may not survive close scrutiny, as the circular nature of the process of reproduction implies

[6] In no way this brief comment aims to make an exhaustive enumeration of the works ‘belonging’ to the classical tradition of thought, which extends over centuries to this day.

[7] See Bródy (1970, pp. 84-94) for details.

that produced means of production are both inputs and outputs, whose price or quantity as a 'cost' may not be known in advance to its price or quantity as a 'product'.

In fact, this circularity principle should not be confused with the marginalist view of the flow exchanges between 'product' and 'factor' markets, at the basis of general equilibrium theory. In this stylised view circularity is not straightforward, particularly when considering the notion of a market for 'capital' (or for the 'services of capital'): the 'quantity of capital' is supposed to be a quantitative magnitude "that can be measured independently of, and prior to, the determination of the prices of the products" (Sraffa 1960, p. 9), with the rate of profits (interest) being its price. Hence, notional supply and demand schedules meet to determine the 'equilibrium' price and quantity of this 'factor', thus regulating — according to its 'relative scarcity' — income distribution between labour and capital (wages and profits).

But within the marginalist system, a clearing in the markets for 'factors' is crucial to the markets for 'products' as well, as "a demand schedule can only affect the price of the corresponding product to the extent to which it affects distribution" (Garegnani 1983, p. 310). This is so because the functional relationship between commodity prices and final demand crucially depends on relative factor prices adjusting to the proportion of their employment as inputs when demand for final output changes, i.e. the whole system depends on the mechanism of factor substitution.

It is, however, a well established fact that the factor substitution mechanism cannot be sustained under reasonable assumptions for the representation of economic production.[8]

In contradistinction, when 'capital' is considered as a set of produced means of production — as it is from a classical perspective — it emerges that capital goods become part of the circular process of reproduction, so their view as an aggregate quantity measurable before the determination of prices is clearly untenable.

Furthermore, the rate of profits is *not* the 'price' for the 'quantity of capital'. By following Sraffa's interpretation of Ricardo (1817[1951]):

> A method devised by Ricardo [...] is that of singling out corn as the one product which is required both for its production and for the production of every other commodity. As a result, the rate of profits of the grower of corn is determined independently of value, merely by comparing the physical

[8] The marginalist process of 'input substitution' states that there exists "an inverse monotonic relation between the proportions of any two inputs and their relative prices" (Pasinetti 1977b, p. 390). For an explanation and critique see Pasinetti (1977b), but also see Mas-Colell (1989, p. 505).

> quantity on the side of the means of production to that on the side of the product, both of which consist of the same commodity[.]
>
> (Sraffa 1960, p. 93)

The difficulties of generalising this line of thought are dealt with by Sraffa (1960, pp. 22-23). The (uniform) rate of profits reflects a (possible) rule of distribution for the surplus product of the system. What should be clear is that within the logical structure of classical analysis the distribution of income between wages and profits has a 'degree of freedom', as has been rendered 'transparent' in Sraffa's (1960, Chapter IV) standard system.

Finally, when the demand and supply equilibrium theory of distribution is abandoned, even in presence of variable returns, the determination of outputs entails them to be treated as independent variables *when* determining relative prices, and *vice-versa* (for details, see Garegnani 1987).

Hence, another characterising feature of classical analysis is the separation between prices and quantities, i.e. between the value added and expenditure side of the system. In fact, this aspect extends to empirical structures (input-output schemes, in particular) as well:

> Both the reproduction or *quantity and growth* aspect and the *price and distribution* aspect are dealt with, and it is made clear that input-output analysis is firmly rooted in the 'classical' tradition of economic thought[.]
>
> (Kurz, Dietzenbacher & Lager 1998, p. xiv)

In this sense, from a classical perspective, relative prices "represent the exchange conditions between physical goods that make reproduction within a given technical (methods of production) and social (distribution) framework *possible*" (Schefold 1989, p. 285).[9] Moreover, "with a surplus, prices are influenced by its distribution" (Gilibert 2003, p. 34). Therefore, even an 'objective' theory of relative prices based on the technical conditions ensuing reproduction has a degree of freedom coming from outside the price equations, represented by the given rule of distribution of the surplus.

From the standpoint of classical analysis, it is possible to argue that the determination of relative physical outputs, i.e. the proportions of the system, starts from the consideration of a given (and measurable) set of commodity balances. However, its interpretation in terms of methods of production and activity levels of different processes is not unique.[10] Therefore, from given

[9] Clearly, this conception of relative prices is in striking contrast with that of marginalist theory. Prices are not indices reflecting subjective individual preferences on the desirability of commodities in terms of their relative scarcities.

[10] As argued in Chapter 4, empirical matrices of intermediate consumption and gross fixed capital formation contain implicit expansion and contraction rates, because production requires time. Hence, the separation between activity levels and techniques is not always straightforward.

empirical structures, different mappings to theoretical magnitudes can be attempted.

As to the present dissertation, my argument rests on the conception that observed tabulations of physical outputs in nominal terms contain both a self-replacement and an expansion/contraction component, which need to be separated in *some* cases (though not in others).

What in any case should be clear is the role of the quantity system in the distinction of what re-enters the circular flow (and alters the productive capacity of the system) from what does not (and constitutes a truly final use). In this sense, we endorse the view that produced means of production are induced by the effective demand exerted for final 'consumption' commodities.[11] In other words, we conceive the 'accelerator' relation — the induced character of investment demand — as a mechanism at the basis of output determination. In fact, "[i]t is this *derived demand* aspect of investment goods, due to their being used as means of production, that is new and typical of production systems" (Pasinetti 1981, p. 176).

However, this consideration of investment as induced by the growth trend of final effective demand should *not* be confused with the neoclassical 'inducement to invest'. In this latter case, demand for investment is made equal to the supply of savings through changes in the rate of interest. Under this view current investment is seen as future consumption, so the interest rate is an equilibrating intertemporal price remunerating the consumption forgone today. Hence, the inducement to invest is the remuneration for the 'sacrifice' of waiting. Abstract 'waiting' becomes a 'factor' of production.

This neoclassical view raises three points for discussion. First, whether the interest rate regulates a long-period trade-off between present and future consumption (current investment). Second, whether this long-period trade-off does exist. And third, whether abstract waiting can be considered a 'primary factor' of production on the same ground as labour.

The first point can be quickly addressed by noting that it presupposes the operation of the substitution mechanism (but from the dual quantity side). In fact:

> the standard one capital good case displays a monotonically decreasing relationship between consumption levels and the rate of interest [. . . ]. This

[11] This point is crucial. A capital good is not strictly determined on the basis of which industry is producing it, but also on the use that is made of it, i.e. on whether it re-enters or not the circular flow. Therefore, a machine which is exported is considered a final consumption commodity, while stocks of circulating capital produced in excess of self-replacement requirements that are devoted to expand productive capacity in the following periods are considered *new* investment demand.

> does not generalize and it is now well understood that even with only two capital goods, a non-monotone association [. . . ] is possible[.]
>
> (Mas-Colell 1989, p. 506)

Hence, the interest rate *cannot* be seen as a regulator of intertemporal consumption levels, as it simply does not provide unambiguous 'price' signals.

The second point concerns whether higher investment demand necessarily implies lower consumption *levels*. This can be answered by noting that from a modern classical perspective capacity adjusts to demand, and investment generates the savings required by the system (not necessarily through a change in income distribution between wages and profits), so that an expansion of investment does not imply a necessary *decrease* in the level of consumption (though it will clearly alter its *share* in gross output).

As to the third point, it is particularly interesting that even some approaches that claim to be critical of marginal productivity theory endorse the view of 'waiting' as a primary factor of production:

> Because capital inputs are produced means of production, increases in efficiency due to advances in knowledge or increasing returns to scale will bring about increases in the output, input, and stocks of such capital inputs even when primary input flows remain constant[.] . . . The question that then arises is: What is (are) the primary input(s) that is (are) behind the produced means of production? This is the question at the heart of the Cambridge capital controversy and has nothing to do with the question of the need or the feasibility of consistent aggregation.
>
> (Cas & Rymes 1991, pp. 8-9)

The answer to this question suggested by these authors reads:

> Individuals, supplying labour time, give up the immediate consumption of such time in exchange for the indirect consumption that the selling or nonimmediate consumption of such time avails them. Labour time sold is the measure of the labour input in productivity measures. Individuals, by forgoing present consumption and accumulating capital directly or indirectly through the bond and stock exchanges, are exchanging present for permanent consumption. *The accumulation of capital is the embodiment of the waiting individuals have done.* With technical progress, a given flow of waiting (or the forgoing of a given flow of present consumption) may be embodied in an increasing accumulation of capital that reflects the ever-increasing efficiency of waiting and results in higher levels of permanent consumption.
>
> (Cas & Rymes 1991, p. 11, our italics)

What this answer intends to do is to *exhaust* value added (in this stylised case consisting of profits and wages) into as many 'primary' factors as there components in it, and so justify claims to shares of value added on the basis of the subjective 'sacrifices' of working and waiting.

There is again a precise attempt to establish a 'natural' connection between an institutional phenomenon (the distribution of income) and a physical phenomenon (the accumulation of produced means of production). But even more, this attempt is performed at the *individual* level (it is the single individual who works and waits).

Hence, the inverse monotonic relation between the real wage rate and rate of profits is the trade-off between working (with the ensuing consumption) and waiting (with consequent saving). The social dimension of income distribution has disappeared (profits and wages are equally perceived by single individuals), and interpersonal income distribution comes to the fore, arguing that the distribution between wages and profits is not reflecting the dynamics of social classes but the interior struggle each individual has in deciding whether to work and consume or to wait and save resources.

The notion of *physical real cost* — that emerges from Sraffa's (1960) system of production — aims at establishing a sharp break with any notion of 'cost' conceived as the inducement to overcome the sacrifice of rendering resources available for their productive use. In this sense, the view of 'waiting' as a primary 'factor' serves the same purpose as the view of the endowment of a 'quantity of capital' (it just replaces stocks with flows, 'capital' by the 'use of capital').[12]

From a classical perspective this view is untenable: long-run accumulation is induced precisely by the growth of consumption, and not by the abstinence from consuming, and while it is correct that production takes time, this by no means entails that saving behaviour in the pursuit of interest rewarded as profit has a 'natural' right to become a 'primary' factor.

This theme leads to the role of the quantity of labour as an input in production. On this issue there are disagreements within the classical tradition, so these considerations cannot but be considered as highly personal. I believe one should carefully distinguish between labour inputs in the system of prices (i.e. the value added side) and the role of quantities of labour within the system of physical outputs (i.e. the expenditure side).

In a system of price equations, quantities of labour are explicitly considered as a component of prices through wage payments. In this sense, either by using a uniform wage rate or a vector of industry wage rates, the separation between quantities of labour and their rate of remuneration is an analytical construct.

In this context, as is done by Sraffa (1960, p. 10), wage rate differentials

[12] In fact, in these analyses, the *labour* required for the expansion of productive capacity is considered as 'capital productivity' that accrues to 'waiting' (for example, see Gowdy & Miller 1990, p. 594).

could be applied to quantities of labour employed in every industry in order to render them homogeneous *as regards the process of pricing* (i.e. in order to be able to remunerate each unit of labour with a uniform wage rate $w$). But this should not be interpreted as a process that renders differing 'productivities' of labour homogeneous. Productivity plays absolutely no role in the application of wage rate differentials to quantities of employment.

In contradistinction, as regards physical outputs (i.e. in a set of commodity balances), quantities of labour do not explicitly appear in the system of equations. Their role in the analysis comes in when we acknowledge the necessary link between total employment and gross output (the human labour currently employed in all industries adds up to the total labour required to produce the gross output of the economy).

But it is possible to gradually modify the disaggregation of total gross output, starting from the sum of gross output by industry, then recognising indirect requirements to self-replace productive capacity (and so defining *net* output as the sum of new investment and final uses), until we account for the indirect requirements to expand productive capacity (and so defining *net* output consisting only in commodities for final uses). In each step labour inputs by industry applied to these *different* direct and indirect commodity requirements redistribute total *co-existing* employment into as many parts as there are products, under each definition of *net* output.

Each of these (logical) parts constitutes a subsystem — in the sense of Sraffa (1960, Appendix A, p. 89) — and is identified by the single component of the net product to which it refers.

In each of these subsystems, the employment of all industries that is used for the production of the identifying *net* output commodity constitutes the labour content of this product. This is the logic we adopt behind the notion of *labour content of commodities*. And under this conception, quantities of labour employed in each industry are all *equally necessary* to satisfy total reproductive requirements. Each industry is equally necessary, directly or indirectly, to produce each single commodity. Then, when applied to each decomposition of gross output, the vector of labour inputs (measured in units of full time employment equivalents or total hours) is homogeneous, *as regards the determination of the labour content of commodities*.

Two points deserve clarification. First, while it is possible to interpret the notion of labour content as embodied labour, this can be done as long as it is clear that we always refer to living, co-existing and concurrent, employment.[13] The subsystem redistributes total direct employment into direct and

[13]This view is clearly not new. In fact, on this specific aspect we follow Hodgskin (1825[1969]). See also Milgate & Stimson (2009, pp. 225-231).

indirect labour requirements to reproduce each different notion of net output, but it is always a logical construct. In no way we consider embodied labour as a locked-in substance travelling through historical time (and methods of production) accumulated in commodities (durable means of production, for example).

The second point is that from the above considerations it emerges that zero profit production prices in terms of labour commanded are *not* necessarily equal to labour content of commodities. While a price system considers wage rate differentials, imported commodities and taxes on products in the definition of a 'zero profit' price, the notion of labour content considers only domestically produced commodities (it is gross *output* and not total *supply* that is redistributed), excludes taxes on products and considers the vector of labour inputs as homogeneous (therefore not allowing for a multiplication by a matrix of wage rate differentials). Hence, in all circumstances concerning *actual* systems (as differently from a theoretical model), these two magnitudes will *not* coincide.

In connection to this point, note that in no place I have referred to the concept of 'labour values'. The considerations just made should make apparent that it would deserve a more careful treatment than is customarily done, though this is not an aim of the present dissertation.

However, one further related aspect should be mentioned, and this is the indispensable character of labour for the production process. In a system that does not admit full automation, i.e. labour is required directly or indirectly to produce at least one basic commodity,[14] labour inputs are indispensable.

It would be quite difficult to find a system where complete automation were possible. In such an hypothetical system, the notion of *labour content* would clearly lose its rationale, as the necessary link between total employment and gross output would be lost. As long as this is not the case, the distribution of total employment into logical parts reveals itself essential to assess the degree of *specialisation* within actual systems.

Given that in purely abstract terms the notion of physical productivity consists in measuring the rhythm of output generation per unit of input, it is possible to attach to each distribution of employment among subsystems a specific pattern of net product per unit of total (direct and indirect) subsystem labour, suggesting a consistent route for productivity analysis from a classical perspective.

However, before further development of these ideas, and in connection to the dual view of prices and quantities at the root of classical analysis, it might prove interesting to clarify the difference between two very similar

[14] In the sense of Sraffa (1960, p. 8).

terms, with quite dissimilar meanings: productiveness and productivity.

## 1.3 Productiveness and Productivity

The idea of productive, as opposed to unproductive, human labour can be traced back to the physiocratic distinction between 'productive' and 'sterile' class in Quesnay's *Tableau Economique*.[15]

In physiocracy, a class was considered 'productive' or 'sterile' according to whether the labour it employed generated a net revenue[16] or not. As rent was the only net income of the system, whose origin was agricultural labour, the only 'productive' class was that of agricultural workers. But this represented a particular social configuration to which the general principle was applied: as a general principle, labour is productive as long as it generates a net revenue.

In fact, when Adam Smith treated the issue, he stated:

> There is one sort of labour *which adds to the value* of the subject upon which it is bestowed: there is another which has no such effect. The former, *as it produces a value*, may be called productive; the latter, unproductive labour.
>
> (Smith 1776[1994], p. 360, our italics)

However, as with his treatment of value, a dual character appears: 'adding to the value' of the product is clearly in line with the physiocratic conception, though 'producing a value' has a further meaning:

> The labour of some of the most respectable orders in the society is, like that of menial servants, unproductive of any value, and *does not fix or realize itself in any permanent subject, or vendible commodity*, which endures after that labour is past[.]
>
> (Smith 1776[1994], p. 361, our italics)

Productive labour, according to Smith, not only must add to the *value* of the product (i.e. workers are productive when the value of their production includes a net income), but it must also generate wealth, it must be materialised in an object. It is clear that both criteria need not always come together. In fact, the first criterion concerns exchange values generating a surplus (and this was the lead taken by, for example, Marx), while the second

[15]See Gilibert (1977, Chapter 4) for a clear exposition and discussion.

[16]Note the interesting meaning of the word *revenue*: "both the concept and the word came from France, where *revenu* is the past participle of *revenir*, to return" (Gilibert 1987c, p. 171). Revenue as the return to the starting point in a circular scheme.

criterion concerns material characteristics of use values (being the lead taken by, for example, Malthus).

But there is an interesting point in Smith's first criterion. As noted by Gilibert (1977, p. 91), it is not the definition of productive labour that has changed with respect to physiocracy, but the social configuration to which the very same definition is applied. With the appearance of the capitalist mode of production, the greater the number of productive labourers generating a net income in the form of profits, the faster the rhythm of capital accumulation can be (as workers do not invest within this scheme). This is clearly reflected in Smith's title for Chapter III, Book II of the Wealth of Nations, from where the above quotations were taken: 'Of the accumulation of capital, or of productive and unproductive labour'.

Smith makes a value judgement as to the importance of the surplus generated by productive labour for the purpose of accumulation. In this he tries to make a connection between net income and its use as new investment, i.e. a connection between the value added (profits) and expenditure (investment) side: the new social organisation of collective labour had to be reflected in a particular use of the surplus by the community.

In dealing with this issue, Marx notes:

> With the progressive accentuation of the co-operative character of the labour process, there necessarily occurs a progressive extension of the concept of productive labour, and of the concept of the bearer of that labour, the productive worker. In order to work productively, it is no longer necessary for the individual himself to put his hand to the object; it is sufficient for him to be an organ of the collective labourer, and to perform any one of its subordinate functions. The *definition of productive labour given above, the original definition*, is derived from the nature of material production itself, and it remains correct for the collective labourer. *But it no longer holds good for each member taken individually.*
>
> (Marx 1867[1976], Chapter 16, pp. 643-644, our italics)

The *original definition*, which concerned the *individual* labour process,[17] stated that labour had been 'objectified' in the product on which man had worked on, creating a *use* value.

But as the labour process becomes progressively co-operative, the productive character of each single worker has to be evaluated in the light of the *final* product which the 'collective labourer' obtains as a result: "[i]t is therefore to the collective labourer that one must refer in considering the labour embodied in a particular commodity" (Lippi 1979, p. 1). And as Marx observes, it is incorrect to apply the original criterion for the evaluation of each

[17] See Marx (1867[1976], Chapter 7, pp. 287).

single worker. This is a particularly acute observation as to whether it is possible to quantify *individual* productivity.

In a circular flow scheme, each worker participates, directly or indirectly, in the production of every final commodity, though produces nothing by himself. Therefore, which would be the numerator of any productivity measure for a single individual? Or better, is it possible to conceive any aggregate productivity measure obtained as the sum of the 'productivities' of individual *microeconomic* agents? I believe the answer is in the negative as long as one retains to be coherent with a classical perspective.

In fact, it must be clear that the distinction between the *macro*-economic and *micro*-economic must not be taken as a distinction between aggregate and disaggregated analysis. Interindustry schemes represent macroeocnomic phenomena, as they deal with the general interdependence of a system, no matter whether its basic unit of analysis consists of the elements of a set of disaggregated industries.

Marx, however, took one further step as to the consideration of the *productiveness* of labour, when he stated that:

> Yet the concept of productive labour also becomes narrower. Capitalist production is not merely the production of commodities, it is, by its very essence, the production of surplus-value. The worker produces not for himself, but for capital. It is no longer sufficient, therefore, for him simply to produce. He must produce surplus-value. *The only worker who is productive is one who produces surplus-value for the capitalist*[.]
>
> (Marx 1867[1976], Chapter 16, p. 644, our italics)

From this definition, Marx's third step[18] implies that the productiveness of labour comes from its social form, i.e. from the definition of what is net income *and* from its rule of distribution among social classes.

In any case, Marx's definition brings to the fore the essential character of productive labour, already present in Quesnay: labour is productive as long as it generates a net income (rent in physiocracy, rent and capitalist profits in Marx). Hence, within the capitalist mode of production, the productiveness of labour is established by the criterion of *profitability*.

However, this opens up a crucial question. How is net income defined? It is possible to argue that neither Leontief (1951) nor Sraffa (1960) gave completely general definitions.[19]

As to Leontief, he clearly recognised an 'arbitrary' nature in the notion of net income, rendered explicit when discussing the aggregation of his system of input-output accounts:

[18] From the individual to the collective, from the collective to the historically determined capitalist labour process.

[19] See Gilibert (1987c, p. 172) for details.

> The process of consolidation, i.e., the reduction in the number of independent accounts, may proceed up to the point where the table is reduced to a single box. The *net* content of these completely unified accounts equals zero.
>
> (Leontief 1951, p. 16)

If what constitutes the net income depends on the level of aggregation, the notion itself contains a degree of arbitrariness.

Instead, as to Sraffa, we read:

> The national income of a system *in a self-replacing state* consists of the set of commodities which are left over when from the gross national product we have removed item by item the articles *which go to replace* the means of production used up in all the industries.
>
> (Sraffa 1960, p. 11, our italics)

What happens outside the self-replacing state? There is no explicit answer. Moreover, Sraffa refers to the *value* of the net *product* (i.e. the physical surplus of commodities in excess of productive consumption) to establish a definition of net *income*. But this amounts to looking at net income from the expenditure side, and not explicitly from the value added side. In fact, Sraffa develops the analytical construct of a wage partitioned into a 'productive consumption' component (a physically given wage basket included among the means of production) and a 'surplus' component, which participates in the net revenue of the system. The analytical construct of a partitioned wage could not be part of a purely 'objective' definition of net *income*.

However, the use of the net product in the definition of net income is quite interesting. Sraffa, though, does not develop the implications of alternative uses of this physical surplus, as his "investigation is concerned exclusively with such properties of an economic system as do not depend on changes in the scale of production" (Sraffa 1960, p. iv). On the contrary, the distinction between the different uses of the physical surplus is precisely the starting point of Leontief's original view:

> But now we come up against the customary distinction between net and gross income, 'necessary' maintenance costs and 'free' profit. [...] The sense of surplus theory [...] is best understood if one enquires into the use of this 'free' income. The answer is: it either accumulates or is used up unproductively.
>
> (Leontief 1991[1928], p. 209)

The key point I find behind this statement is that by shifting the focus from net *income* to net *product*, we are actually switching from profitability to productivity, from the value added to the expenditure side of the system.

The productiveness of labour comes from its profitability. Instead, what remains essential for the definition of *physical* productivity is the separation between gross and net *product*, and what distinguishes this separation is *not* the distribution of the physical surplus among classes, but separating what re-enters the circular process and alters the productive capacity of the system (i.e. *gross* investment) from what consists in a final use (consumption and exports).

Hence, instead of a rule of distribution, it becomes necessary to define a rule of accumulation (e.g. the accelerator relationship). And instead of profits as net income, we need to identify consumption commodities as net product. Therefore, while for the analysis of profitability we should look at the system from the value added (relative prices) side, when the interest lies in analysing *physical* productivity, we should look at the economy from the expenditure (or product balances) side.

In fact, if we consider the simplest algebraic representation of the economy, we have that gross output ($X$) can be alternatively seen as:

$$X = U + W + \Pi \qquad \text{(value added side)}$$

$$X = U + C + I \qquad \text{(expenditure side)}$$

with $U$ as means of production that go to replace productive capacity, $W$ as wages, $\Pi$ as profits, $C$ as consumption and $I$ as *new* investment.

Now, to define net income and net product, respectively, we may proceed as follows:

$$\Pi = X - U - W \qquad \text{(net income)}$$

$$C = X - U - I \qquad \text{(net product)}$$

In this way, the labour that participates in the generation of profits ($\Pi$) is seen as *productive* labour, and the labour required to reproduce final consumption commodities ($C$) is a possible measure for the *physical* productivity of the system.[20]

The distinction between productiveness (i.e. profitability) and physical productivity becomes essential for an adequate conceptualisation of the measurement of productivity changes.[21] In many occasions such a distinction has been submerged, resulting in conceptual confusion. Traditional (marginalist)

[20] In this context, it would be provocative to ask: what is the productiveness of labour in an economy without profits? and, at the same time, what is the physical productivity of labour in an economy without consumption? Two certainly interesting questions.

[21] Note how subtle this distinction might sometimes be: Sraffa's (1960) book has a very slim index, giving privilege to truly essential points. We do not find an entry for 'productivity', or an entry for 'profitability', not even one for 'net income', though (with

measurement of productivity changes is clearly no exception to this conceptual blur.

## 1.4 Traditional Measurement of Productivity Changes

While Sraffa defined net income as the *value* of the net product, traditional analysis of technical change — based on marginal productivity theory — proceeded precisely in the opposite way, assigning to each component of net income (i.e. of value added) a *physical* interpretation.

Traditional analysis departs from an accounting identity for value added, disaggregated into as many 'primary factors' as there are components in it. Consider the simplest case in which there are only two such components: profits and wages. Then, using the notation previously introduced, we have:

$$X - U = \Pi + W$$

The first step consists in separating each component into the product of a quantity element by its corresponding rate of remuneration. Consider the simplest case in which there is an homogeneous 'quantity of capital' ($K$) with a rate of remuneration $r$, and an homogeneous quantity of labour ($L$), with a rate of remuneration $w$:

$$X - U = pQ, \quad \Pi + W = rK + wL \quad \text{and therefore:} \quad pQ = rK + wL$$

The second step consists in adopting a standard of value, generally establishing the price of a unit of value added equal to one, then $p = 1$. In this case, the passage of time implies that:

$$\frac{d\ln Q}{dt} = \left(r\frac{K}{Q}\right)\left(\frac{dK}{K}\frac{1}{dt}\right) + \left(w\frac{L}{Q}\right)\left(\frac{dL}{L}\frac{1}{dt}\right) + \left(\frac{dr}{dt}\frac{K}{Q} + \frac{dw}{dt}\frac{L}{Q}\right) \tag{1.1}$$

At the same time, the production process is represented by, for example, $Q = F(K, L, t)$. Then, the passage of time implies that:

$$\frac{d\ln Q}{dt} = \frac{d\ln F(K,L,t)}{dt} = \left(\frac{\partial F}{\partial K}\frac{K}{Q}\right)\left(\frac{dK}{K}\frac{1}{dt}\right) + \left(\frac{\partial F}{\partial L}\frac{L}{Q}\right)\left(\frac{dL}{L}\frac{1}{dt}\right) + \frac{\partial F}{\partial t}\frac{1}{F} \tag{1.2}$$

Now, in order to relate (1.1) with (1.2) it is common practice to assume:[22]

reference to the discussion of negative employment multipliers in the presence of joint products) we find the following entry: 'Negative productivity of labour, not necessarily unprofitable'.

[22] See Rampa (1981b, pp. 109-112) for an exposition with interesting (critical) remarks.

1. The actual economy is immersed in a competitive general equilibrium, in the sense that primary factors are paid their 'marginal products' *for a given* $F(K, L, t)$, i.e. $r = \partial F/\partial K$ and $w = \partial F/\partial L$.

2. The share of each primary factor in value added is constant during the comparison, i.e. $\omega_K(t) = \omega_K = r(K/Q)$ and $\omega_L(t) = \omega_L = w(L/Q)$.

3. The autonomous time trend of value added in constant prices $(\partial F/\partial t)(1/F)$ is independent of $K/L$ (see Solow 1957, p. 313), and is obtained by keeping constant all (primary) inputs.

Then, if we call $\rho_{tfp} = (\partial F/\partial t)(1/F)$ the rate of Total Factor Productivity (TFP, hereinafter) Growth, two empirical strategies emerge from the application of the assumptions above to (1.1)-(1.2):

$$\rho_{tfp} = \frac{d\ln Q}{dt} - \omega_K \frac{d\ln K}{dt} - \omega_L \frac{d\ln L}{dt} \tag{1.3}$$

$$\rho_{tfp} = \omega_K \frac{d\ln r}{dt} + \omega_L \frac{d\ln w}{dt} \tag{1.4}$$

Expressions (1.3) and (1.4) represent the *primal* and *dual* approaches to TFPG measurement, respectively.

The logic behind the primal measure (1.3) runs as follows: under constant returns to scale, assumptions 1. and 2. above identify a production function *invariant* in time, which is applied to *new* inputs. If the 'theoretical' output obtained is different from that effectively measured, $\rho_{tfp} \neq 0$, and this will be interpreted as a *shift* in the production function. On the contrary, if $\rho_{tfp} = 0$, changes in value added in constant prices will be interpreted as resulting from the movement *along* a given (and invariant) production function.

Hence, $\rho_{tfp}$ represents 'technical change' as long as the difference between output and (primary) input growth can be *interpreted* as a shift in the production function, and this is accomplished by *assuming* that 'physical' value added in constant prices is obtained according to $Q = F(K, L, t)$ and the actual economy is in a competitive equilibrium. In fact:

> *If* a production function has constant returns to scale and *if* all marginal rates of substitution are equal to the corresponding price ratios, a change in total factor productivity *may be identified* with a shift in the production function.
>
> (Jorgenson & Griliches 1967, p. 250, our italics)

Complementarily, the logic behind the dual measure (1.4) is based precisely on the equality between factor prices and marginal products, so that

TFPG measures how shifts in the production function accrue to 'capital productivity' (measured by $r$) and 'labour productivity' (measured by $w$).

The dual approach to growth accounting has not been explored as much as the primal one (though it is already explicit in, e.g. Jorgenson & Griliches (1967, p. 252, eq. 4)). Understandably, they should both give *similar* results, if 'factors' are paid their 'marginal products' and aggregation into a 'quantity of capital' poses no serious problems. However, this has not been the case in studies like Hsieh (1999), were significant differences have been found in some estimates. I would find it rather difficult to attribute all the discrepancy to index number problems or measurement errors.

In any case, reconsider the whole structure of the approach, beginning from its definition:

> The rate of growth of total factor productivity is *defined* as the difference between the rate of growth of real product and the rate of growth of real factor input. The rates of growth of real product and real factor input are defined, in turn, as weighted averages of the rates of growth of *individual* products and factors.
>
> (Jorgenson & Griliches 1967, p. 250, italics added)

TFP growth is defined as a difference between output and input growth. It is an *effect*, a consequence of two causes (outputs and inputs). How can this be reconciled with TFP *explaining* output growth, as argued by modern growth theory? Only by assuming that the actual system behaves as the total differential of $Q = F(K, L, t)$ in a competitive equilibrium for each period under comparison. So growth theory is taking for granted what it should empirically test, i.e. whether the system does behave competitively, and 'factors' are remunerated accordingly.[23]

As noted in Rampa (1981b, p. 111), a related point concerns the stringent character of assumption 2. above. If in order to identify an invariant production function it is necessary to keep factor shares ($\omega_K$, $\omega_L$) constant, there is an index number problem that gives rise to a relevant degree of arbitrariness. Changing the single (or average) period from where to take factor shares may result in considerably different TFP growth rates.

Note, moreover, that the definition just stated explains how the approach proceeds by aggregating individual products and factors. Disaggregation can go on until the single microeconomic agent is reached, and her/his/*its* productivity will be given by the remuneration she/he/*it* obtains for the services provided. But this can be re-conduced to the discussion about the 'collective labourer' previously introduced. Is it possible to measure physical

[23] In fact, in this context, it should be remembered that "decomposition does not imply anything about causality" (Balk 2010, p. S234).

productivity for a single individual? I believe not. But it is not a problem of insufficient data, it is a matter of principle.

In fact, while it is possible to measure the *productive* character of a single employment unit (it is enough to see whether it contributes to net income, e.g. profits), it is not possible to quantify its physical productivity: in a society with a considerable degree of division of labour a single agent will contribute (directly or indirectly) to the production of all products, though producing nothing completely by itself.

But even granted the logic of the definition, there are still rather important points for discussion.

For example, TFP growth intends to measure *disembodied* technical change, as capital accumulation is separated from the 'speed of technical rationalization'. But if changes in technology also occur in the production of capital goods (for details, see Pasinetti 1959, p. 270), their reproduction implies a different use of resources according to the general state of efficiency (the economy-wide TFP rate). And therefore:

> measured capital deepening is not necessarily an independent contributor to growth, rather it is contingent upon prior shifts in the production function, that is to say the rate of technical progress.
>
> (Metcalfe 2002, p. 4)

Technical change may be *embodied* in new vintages of capital goods, so TFP growth rate, as conventionally measured, is not even reflecting the comprehensive effect of producing commodities with *better* commodities.

This point alerts on the definition of output, input and the representation of the production process in traditional measurement. Note that it is assumed that value added in constant prices is the disaggregated measure of 'physical' output, the 'quantity of capital' is a non-produced primary input, and production is pictured as a "one-way avenue that leads from 'Factors of production' to 'Consumption goods"' (Sraffa 1960, p. 93). These choices have important consequences on the results.

In a multisectoral economy, value added is a residual rather than an independent entity, both according to surplus theory *and* to the System of National Accounts.[24] From the equations above, when means of production for self-replacement are deduced from gross output, an artificial separation between a price and volume component is performed: $X - U = pQ$. If $X$ and $U$ are different composite commodities, then their difference (value added) cannot be an independently measurable composite commodity to which a

[24]See the discussion in Section 3.3 of Chapter 3 for details.

price index is attributed. Value added is the *effect* of two causes ($X$ and $U$), so it is difficult to maintain it has a physical meaning in itself.[25]

Furthermore, taking value added as a disaggregated measure of output does not give a comprehensive picture of the production *process*. Production is circular, and commodities can be given final as well as intermediate uses. For productivity measurement, it is crucial to know the ratio between gross output and final uses, as an economy with a higher ratio would need more gross output to produce the same physical surplus, in the presence of input saving due to technical change. This is not necessarily captured at a disaggregated level by a net income measure such as value added.[26]

Note, then, that value added cannot be a coherent *disaggregated* measure of physical output, and the 'quantity of capital' cannot be a coherent *aggregated* physical measure of inputs. Hence, it is not a matter of aggregation or disaggregation which leads TFP growth to run into troubles.

But even granting a physical interpretation to value added, the common functional forms used for empirical measurement in traditional analysis are not exempt of an essential dimensionality critique, as advanced by Bródy (1970, p. 95-96). Consider a traditional function like: $Q = AK^{\alpha}L^{1-\alpha}$, where $Q$ is measured in flow of money ($M$) per year ($T$), $K$ is measured as a stock of money ($M$), and $L$ is measured in man years ($H \times T$). Then, we have: $M/T = A \times M^{\alpha} \times (H \times T)^{1-\alpha}$.

Now, what is the dimension of $A$ (i.e. the TFP parameter)? If $\alpha = 1$, $M/T = A \times M$, so $A = 1/T$ (the reciprocal of TFP is measured in time units, 'productivity' as *time*). If $\alpha = 0$, then $A = M/(H \times T^2)$, which could be reordered to mean money flow per man year. And what if $0 < \alpha < 1$ (which is the normally assumed case)? TFP parameter $A$ does not have any definite meaning. So what is the *dimension* of TFP? It remains an open question, unless one abandons its purely physical interpretation, based on production functions, and admits that TFP is an accounting 'residual' simply reflecting 'real cost reductions'.[27]

As with the confusion in the distinction between micro/macro and aggregate/disaggregated, it is generally thought that TFP is a complete ('total') measure as against 'partial' measures that consider only, e.g. labour productivity. But it is perfectly possible to derive measures of total labour productivity, as well.[28] The confusion has its origins in the way TFP (or the 'residual') has been conceived:

[25] On this point, see Meade (2010).
[26] See Rampa (1981b, p. 111) on this point.
[27] For example, see Harberger (1998, p. 3).
[28] See Section 2.3.2 of Chapter 2 for a discussion and Chapters 4 and 5 of the dissertation.

> In whichever form, the measured residual typically accounted for an important fraction of the observed output growth, quite often half or more.
>
> This result came as a surprise to the profession, though perhaps less so to those who reached it, or something very like it, *by an alternative route.* They were the people who came at the problem *out of a tradition of measuring labor productivity*, and at some point complemented output per worker with a measure of output per unit of capital, and *finally joined the two* to create a measure of total factor productivity (TFP).
>
> (Harberger 1998, pp. 1-2, italics added)

The 'tradition of measuring labour productivity' (measured as industry *value added* per unit of labour) was conceptually focused on the *productiveness* of labour, not on its physical *productivity.* The 'total' character of TFP comes from the conception of production and distribution according to marginal productivity theory. If capital and labour are the two prominent non-produced primary factors, a measure of *productiveness* has to account for the net income they both generate. But the qualification 'total' is clearly contingent on a *purely theoretical* choice.

What should be clear is that what distinguishes a 'partial' from a 'total' physical *productivity* measure is not the differentiated components in net income, but whether the general interdependence of the system is being taken into account or not. A total measure of labour productivity, i.e. the computation of the labour content of *all* (direct and indirect) commodity requirements to reproduce the net output (possibly expanding productive capacity), considers capital goods as well, accounting for their circulation as inputs and outputs through the 'convoluted' network of Input-Output transactions.

And in this sense, the Input-Output literature on TFP growth measurement is both relevant and insightful.[29] Net income and net product are in most cases clearly differentiated, and the latter is used to derive aggregate measures (for example, see Wolff 1994, p. 81, eq. 3). But while interdependence is accounted for as regards circulating capital inputs, fixed capital is still conceived as a primary factor of production in most cases.[30]

In any case, I think the crux of the matter boils down to the lack of an explicit distinction between physical productivity and productiveness (i.e. profitability). If the derivation of a TFP figure (be that using production functions or by means of Input-Output schemes) departs from a theory of value added, it cannot lead to adequate measurement of disaggregated physical productivity. In fact, even abandoning some stringent assumptions of marginalist production theory, and adopting a sceptical view of the residual simply

[29]See, for example: Wolff (1985), Galatin (1988), Wolff (1994), ten Raa (1994), Casler & Gallatin (1997). Moreover, see Section 3.5 of Chapter 3.

[30]See Peterson (1979, pp. 218-219) and Wolff (1994, pp. 84-86) for some exceptions.

as a reduction in real costs, the confusion about productiveness and productivity remains:

> A simple TFP measure *for firms* with multiple outputs and multiple inputs is to look at the *profitability of a firm*, defined as the revenue of the firm divided by its input cost. [...] [A] strict comparison is difficult since the output and input prices faced by these firms are different. Then only option here is to adjust the value aggregates [...] for differences in price levels.
>
> (Coelli, Prasada Rao, O'Donnell & Battesse 2005, pp. 62-3, italics added)

However, to privilege a physical interpretation of productivity does not mean in the least to deny the importance of profitability changes in the evaluation of the effects of technical change in employment, output proportions and relative prices. What must be clear is the separation in concepts and terminology that is required to distinguish cause from effect. In fact, both the method of subsystems *and* the computation of production prices are used throughout the dissertation to measure and study the effects of physical productivity changes.

## 1.5 Subsystems and Prices of Production

The distinction between physical productivity and profitability is not only established by the alternative reference to the expenditure or value added side of the economy as a starting point, but also to the unit of analysis to which each notion refers.

In fact, the economic system can be disaggregated in industries, producing a product mix of outputs, but it can also be disaggregated in self-replacing and growing subsystems[31] that produce a single kind of *final* commodity. While profitability measures are computed at the industry level, disaggregated physical productivity measures are conceived with the subsystem in mind.

Computable production prices can be conceived as prices implicit in the (medley of) technique(s) in use in the economic system. They represent exchange ratios satisfying necessary conditions for reproduction under a *given* rule of distribution of the surplus (e.g. a uniform profit factor is computed in proportion to capital advanced).

[31] All throughout the dissertation the terms self-replacing subsystem and vertically integrated sector will be used interchangeably, and the same applies for the terms of growing subsystem and vertically hyper-integrated sector. While the notion of self-replacing subsystem was introduced by Sraffa (1960, Appendix A, p. 89), its compact representation as a vertically integrated sector was introduced by Pasinetti (1973), and its extension to growing subsystems or hyper-integrated sectors was introduced by Pasinetti (1988). See Chapter 4 for a detailed discussion.

The technique in use can be thought to be contained in measurable empirical structures, like Input-Output schemes. And empirical structures reveal changes in techniques when nominal figures can be separated into a volume growth and a price component. In this way, production prices function as aggregators applied to the quantities actually produced to measure changes in inputs and outputs, thus allowing to quantify the changing surplus (in value terms) between revenues and outlays by industry (i.e. changes in profitability due to technical changes for a given distributive configuration).

An important remark on method is in place. Note that by interpreting computable classical production prices as a *possible* set of aggregators,[32] no presumption of descriptive or predictive power is attributed to them. By so doing, the aim is to separate two fields of inquiry.

In this sense, computable prices could be conceived as one answer to the following problem, posed by Sraffa:

> The problem is that of *ascertaining the conditions of equilibrium of a system of prices and the rate of profits, independently of the study of the forces which may bring about such a state of equilibrium.* Since a solution of the second problem carries with it a solution of the first, that is the course usually adopted in modern theory. The first problem however is susceptible of a more general treatment, independent of the particular forces assumed for the second; and in view of the unsatisfactory character of the latter, there is advantage in maintaining its independence. (D3/12/15: 2; emphasis added)
>
> (Kurz & Salvadori 2005b, p. 433)

In fact, among the first computations of prices of production, the works of Hejl, Kyn & Sekerka (1967), Kyn, Sekerka & Hejl (1967) and Sekerka, Kyn & Hejl (1970) — with an origin in the dynamic input-output price model — had the aim of comparing different price *norms* applied to the same technique in use.

Since then, however, computable production prices have been used for multiple purposes. For example, the empirical assessment of capital theory paradoxes, going from Krelle (1977) to Han & Schefold (2006). In connection to this, the degree of (non-) linearity of wage-profit schedules for different standards of value, and the study of the deviation of labour values (empirically defined in a variety of ways), production prices and market prices.[33] A

[32]Computable prices may be considered to be one among the many possible *norms*, in the sense of Pasinetti (1981, p. 127n).

[33]See Marzi (1993) for a review of these lines of inquiry. The crucial points under discussion are: (a) the empirical plausibility of the neoclassical parable of a surrogate production function, (b) the regularity in relative price changes as income distribution is altered, and (c) the empirical plausibility of a pure labour theory of value. Note that all three cases imply a *descriptive/predictive* role for the notion of classical production price.

related use has been to study computable prices under the assumption of heterogeneous rates of profits between industries (though generally maintaining a fixed *relative structure* of profit rate differentials).[34]

For the purpose of this thesis, the interest lies in the use of computable prices to measure the effects of technological progress on the distributive possibilities of the system, i.e. computation of changes in profitability induced by changes in the technique in use, for each given distributive configuration. Among empirical works with this aim, it is possible to mention:

1. the studies of Marzi & Varri (1977) (using only circulating capital) and Marzi (1982) (including also fixed capital) for the Italian economy, assessing the Harrod-neutral character of changes in techniques,

2. the works of Ozol (1984, 1991) for Canada and the US, concluding on the 'cost reducing automation' character of technical change,

3. the study of Leontief (1986) for the US, introducing a linear program to find the most profitable (for a given real wage rate) technique, at each feasible value of the rate of profits,

4. the study by Marzi (1994) for the Italian economy (using only circulating capital), which relates the convexity of the wage-profit schedule (as each *final* commodity alternatively becomes the standard of value) to the capital intensity of the (balanced) growth subsystem associated to each final product,

5. the recent work of Degasperi & Fredholm (2010), proposing the area under alternative wage-profit schedules (for a common *numéraire* commodity) as an indicator of the degree of technical progress across time and space, with an application (using only circulating capital) to selected OECD economies.

All the above-mentioned studies have in common a classical awareness that is applied to input-output data. Some related studies analyse technical change by means of wage-profit curves, which are built only with national accounts data by industy (for example, see Michl 1991, Ferretti 2008).

When Leontief (1951) noticed that by consolidating input-output accounts it was possible to obtain zero *net* income, he connected each income source with a specific use of expenditure. Clearly, the view of an economy with both zero net income *and* zero surplus product corresponds to a closed system, where *all* income-expenditure loops are endogenous.

[34]See Flaschel (2010, Part II, Chapter 8, section 8.5) for details.

In such systems, there is complete duality between prices and quantities, income and expenditure (there are no final uses), and the notions of productivity and profitability acquire a dual character as well. Mathematically, the structure of closed systems is usually formulated as an eigenproblem, where the maximum (in modulus) eigenvalue summarises the system's surplus both in physical and value terms.

Starting from the seminal work of Bródy (1970), different studies have *conceptualised* the measurement of productivity increases as an eigenproblem.[35] Though very appealing from an analytical point of view, its empirical implementation is not straightforward. To adequately separate (statistical) prices from volume growth, it is necessary to neglect the presence of imported commodities (which represent a full matrix as opposed to a single column vector of exports) as well as the presence of taxes on products and production. Moreover, it is necessary to deal with an essential empirical disarray in both wages $\equiv$ consumption and profits $\equiv$ investment theoretical identities.

In any case, the formulation of an eigensystem for the complete 'augmented' matrix and the study of its spectral properties, should not be confused with the computation of the maximum eigenvalue of interindustry flow matrices to assess the intensity of use of intermediate inputs (generally circulating capital).[36] In these cases, the spectral properties serve as a summarising device (with eigenvectors as a particular system of weights for aggregating rows and columns), and not as a comprehensive measure of surplus of self-contained closed systems.

The measurement of disaggregated physical productivity of labour with reference to the subsystem as a unit of analysis has its origin in considering jointly Leontief's (1953) computations of "the roundabout, as compared with the direct, effects which the changes in the input structures of various industries have on the *over-all productivity of labour*" (Leontief 1953, p. 39, italics added), and of Sraffa's (1960, Appendix A, p. 89) constructive algorithm to build the logical device of a subsystem.[37]

[35]For example, Buccellato (1990) has used the left and right eigenvectors associated to the maximum eigenvalue to compute shares in production according to 'standard proportions' or re-value industries according to their associated 'standard prices', in order to detect market over- and under-valuation. In another study, Aulin-Ahmavaara (1999, p. 358) develops (only in theoretical terms) her 'fully effective rate' of productivity change, by assuming that all inputs are (re)produced (including labour).

[36]See, for example, Rampa & Rampa (1982) (including also fixed capital and imported commodities) and Marengo (1992).

[37]A related approach to the measurement of direct and indirect labour requirements, explicitly recognising its meaning as a 'productivity' index, has been advanced by Vincent (1962), who suggested the term "productivité intégrale du travail" (total productivity of labour). See Gossling (1972, pp. 52-54) for a discussion.

Even before the appearance of the subsystem, Pasinetti (1959) (in reply to Solow's (1957) contribution) had already noticed the need to account for the reproducible character of capital goods, measuring them in terms of final commodity-specific units of capacity, in order to derive physical measures of productivity changes.[38] After the subsystem has been devised, Pasinetti (1963, Chapter V) introduced the first algebraic and conceptual relations connecting industries with vertically integrated sectors (i.e. self-replacing subsystems) for the study of technical progress.

Moreover, Gossling & Dovring (1966) presented the first empirical application of productivity measurement adopting the subsystem as a unit of analysis. Gossling (1972) provided a comprehensive empirical study of productivity growth by subsystem, including a comparison with traditional 'partial' and 'total' factor measures.[39]

The crucial idea behind the subsystem is its degree of autonomy. By repartitioning the whole *row* vector of gross outputs and matrix of intermediate uses by industry into as many logical parts as there components in the *column* vector of final uses by commodity, all means of production, labour and outputs are redistributed into each of these parts, according to their contribution as a supporting industry to the activity which produces the final commodity.

The redistribution of commodities in association to others, as an alternative to the aggregation of industries, is thoroughly discussed by Leontief (1967), who noticed that aggregation and reduction were two strategies to deal with too detailed empirical structures:

> Aggregation, i.e. summation of essentially heterogeneous quantities, is one of the two devices that the economist uses to limit the number of variables and functional relationships in terms of which he describes what he observes. The other is reduction, that is, elimination of certain goods and processes.
>
> (Leontief 1967, p. 419)

In a fundamental contribution, Pasinetti (1973) established explicit connections between the subsystem and the logical device of vertical integration, i.e. the reduction of some commodities in terms of others. By introducing a compact algebraic representation of a self-replacing subsystem, as the result of vertically integrating co-existing total employment and capital goods, it became possible to work with alternative representations of the same technique in use, either in direct terms (direct labour and direct productive capacity) or in vertically integrated terms (vertically integrated labour and productive capacity).

[38] See Chapter 4 for an exposition of the debate between Solow and Pasinetti.

[39] In a related article, Gossling (1974b) complemented his study considering the open economy, i.e. direct and indirect requirements of imported commodities.

But even though it dealt with the case of balanced growth, Pasinetti (1973) remained an essentially static construct, in the sense of representing only self-replacing subsystems. New investments were still included in the net output, so part of the physical surplus of industries producing capital goods still needed to be exchanged between (or redistributed among) these self-replacing sectors, in order for each of them to expand their *commodity-specific* productive capacity. This clearly posed difficulties to the degree of autonomy of the self-replacing subsystem.[40]

Thus, in the context of a dynamic economy, Pasinetti (1988) introduced the logical device of vertical hyper-integration in explicit association to the notion of a *growing* subsystem. The key difference is that *gross* investment to self-replace and expand commodity-specific productive capacities is redistributed among industries according to their reproduction requirements (which now includes expansion/contraction), when the reduction process is performed. Therefore, investment becomes fully induced by the growth of effective demand for final uses.[41]

Among the different works either applying the concept of total labour requirements or explicitly adopting a self-replacing subsystem perspective, it is possible to mention:

1. the study by Gupta & Steedman (1971) for the UK, in which direct and total labour requirements are computed, leading the authors to conclude that "total (or system) labour use falls but less rapidly than direct labour use" (Gupta & Steedman 1971, p. 32),

2. the empirical studies by Rampa (1981a) and Rampa & Rampa (1982), the theoretical considerations of Siniscalco (1982), and the recent work by Fredholm & Zambelli (2009), which explicitly adopt Gossling's (1972) operator to map between industries and self-replacing subsystems,

3. the studies by Ochoa (1986), De Juan & Febrero (2000) and Flaschel (2010, Part I, Chapter 3, pp. 63-68), connecting total labour productivity to labour content of commodities *through* labour values,

4. the theoretical considerations by Seyfried (1988), who explicitly separates vertically integrated labour productivity from vertically integrated labour *rentability*, this latter concept measuring "how much

[40]The idea on this subtle but essential point is due to Garbellini (2010, pp. 48-51). The reader is referred to this source for a clear exposition and discussion.

[41]See Section 2.4.2 of Chapter 2 for some further comments, as well as Chapter 4 for a detailed exposition.

labour must be disposed to produce one unit of output [...] if beside the reproduction of capital the capital owners can claim part of the product as profit" (Seyfried 1988, p. 172),

5. the studies by Milberg & Elmslie (1992), Elmslie & Milberg (1996) and Dietzenbacher, Hoen & Los (2000), which adopt an Input-Output approach to study cross-country convergence of labour productivity at the vertically integrated level.

It should be noticed that none of the above-mentioned studies explicitly considers the *growing* subsystem as a unit of analysis. To devise, discuss and empirically implement disaggregated (and aggregate) productivity measures in terms of growing subsystems is one of the main tasks of the present dissertation.[42]

The idea of using the subsystem (or vertically integrated sector) as a unit of analysis for the study of technical change has often been criticised (see e.g. Schefold (1982, p. 549) and Hagemann (1987, p. 346)). I believe this is mainly due to two misunderstandings.

First, vertical integration is sometimes considered as going backwards in time, in a sort of 'neo-austrian' perspective. I think the origin of this confusion comes from placing the *general* analytical device of vertical integration in the context of a *specific* joint production model (the 'pure fixed-capital system'), in which machines of different years are consolidated — through a discounting procedure applied to the price equations — in order to obtain a single-product system:

> We may call this operation 'vertical integration in a temporal sense' of the activities employing the machine in its various years of age; it allows us to formally eliminate the joint-production component and bring the analysis back to the forms of single production with only circulating capital.
>
> (Baldone 1980, p. 96)

Second, it is sometimes maintained that rates of productivity growth at the vertically integrated level are exogenous data of the analysis:

> The industry-specific nature of technical change also implies that, contrary to Pasinetti's assumption, rates of productivity growth in the different vertically integrated sectors cannot be thought of as being independent of each other.
>
> (Hagemann 1987, p. 346)

In this case, I think the origin of the confusion comes from taking a *specific* description of the technique in use present in Pasinetti's (1981) model — in

[42] See Chapters 4 and 5 for details.

which capital goods are produced by labour alone — and assigning to it a *general* interpretation of vertically integrated magnitudes.[43]

Pasinetti's (1981) 'intermediate case' (i.e. a description of technology without basic commodities) was thought of as a purely expository theoretical device. *In this particular case*, the rates of growth of direct labour coefficients coincide with those of vertically (hyper-) integrated labour coefficients. But this is clearly far from being a general principle.

In fact, it is apparent that vertically (hyper-) integrated magnitudes are *derived* from industry level ones, claiming no logical primacy or independence.[44] In any general empirical application, vertical integration is a device applied to existing direct (industry) magnitudes to obtain derived (vertically integrated) productivity growth rates.

This second source of misunderstanding alerts, however, on the importance of making a clear statement as regards the aims and purposes of productivity analysis from the perspective of subsystems. As stated by Pasinetti himself:

> the analytical device of vertical integration *is not meant* to catch the detailed and localized sources of technical change; on the contrary, it is meant to synthesize the overall *effect* of technical change (whatever its sources, or nature, or remote localization in the economic system) on the final stage of production, of prices and of employment.
>
> (Pasinetti 1990, p. 258, italics in the original)

Thus, the focus is on measuring the *effects* of technical change on proportions, prices and employment, and not to study the *causes* behind changing productivities. The whole dissertation builds upon this principle, so it would be useful to clarify the interplay between theory and measurement assumed throughout the thesis.

## 1.6 Theory and Measurement

It is of course true that "to measure is not to understand" (Salter 1966, p. 1), and this is particularly so as regards productivity analysis:

> One of the reasons why interpretative analysis of productivity has been slow to develop has been the interminable controversy over what is productivity and what do we really wish to measure. The word now carries a multitude of meanings; to some it measures the personal efficiency of labour;

[43] See Garbellini (2010, pp. 152-155) for a development of the argument, and Garbellini (2010, pp. 138-164) for a reply to other criticisms to the vertically (hyper-) integrated approach.

[44] See the early comments by Pasinetti (1963, Chapter V).

> to others, it is the output derived from a composite bundle of resources; to the more philosophic, it is almost synonymous with welfare; and in one extreme case it has been identified with time. I personally believe that much of this discussion has proved fruitless and *only served to confuse the issues of measurement with the issues of interpretation.* Unless there is a revolution in statistical techniques and information, *only one type of productivity concept is measurable.* This is the concept of output per unit of input.
>
> (Salter 1966, p. 2, italics added)

Far from being a trivial statement, the position taken by Salter (1966) was not the usual one at the time of writing (and clearly even less nowadays). But I believe it serves to clarify the task at hand. This dissertation intends to carry out productivity analysis by measuring changes in physical input use per unit of output produced (as seen from the expenditure side), as well as to study the effects that changes in physical productivity have on the (price) surplus of the system (as seen from the value added side).

With this aim in mind, a new terminology is introduced to refer precisely to the surplus generating capacity of every industry in the economy, conditional upon each distributive configuration: the notion of $r$-Productivity (where $r$ stands for the uniform rate of profits, assumed as given). But in no place this measure carries a *physical* interpretation, as I think that the technological (output) and economic (price) discourses are rich enough by themselves as to need any further mixing up. Of course, this does not deny the presence of connections between them. These are, however, not fully explored in the thesis.

In a multisectoral economy, a scalar or subsystem measure of physical input per unit of output is not straightforward to obtain, given the multitude of output-input productivity ratios present in the economy. It is necessary to solve the aggregation of commodities, *or* the reduction of some of them in terms of others.

This is particularly difficult for capital goods, which by being reproducible, are themselves subject to productivity improvements. In fact, in the summary record of the debate at the 1958 Conference on the Theory of Capital, Kaldor noticed two radically different positions on this issue:

> *One extreme case* was to assume that there was no technical progress in the production of capital goods but that these always required the same amount of real resources. This was obviously quite unrealistic. *At the other extreme*, one could say that a unit of capital was whatever unit was capable of producing a given output in a given year — ignoring both longer and shorter output streams. Here any distinction between the quantity of capital and its productivity was washed away by the definition itself. Any idea that

> capital might have varying productivities was lost; its output was always constant. (Hague 1961, p. 304, italics added)

The first 'extreme case' corresponds to the traditional TFP treatment of the 'quantity of capital', in which a TFP growth measure is assumed to capture disembodied efficiency changes, independently from capital deepening, which is assumed to require the same amount of *real* resources (e.g. 'waiting') per unit of saving.

The second 'extreme case' consists in measuring capital goods in 'units of capacity', i.e. as a set of composite commodities of heterogeneous physical content, specific for each final product of the economy. But then, if capacity is defined in terms of the final output *actually* produced, at every moment the number of units of commodity-specific capacity would coincide with the number of units of each final product (from here Kaldor's idea of a 'constant output coming from capital').

However, by adopting such measuring rod, the 'quantity of capital' in real terms would not be needed anymore and, at the same time, each of these composite commodities would change their physical composition from one period to the next, though retaining their function as commodity-specific 'productive capacities'. This route was precisely the one taken by Pasinetti (1959), all throughout his approach to structural economic dynamics.[45] What Kaldor observes is true, 'the difference between the quantity of capital and its productivity' is dispensed with. But this is not a problem when productivity measurement is *not* conceived from the value added side, as there is no net income to distribute among 'factors'. In fact, the procedure of using a *reduction* (through vertical integration) rather than an *aggregation* of capital goods is perfectly in line with adopting a subsystem perspective.

A further point that deserves a brief discussion is the distinction between measurement in theory and measurement in practice. In the summary record of the debate at the same Conference mentioned above, Sraffa made a truly interesting statement:

> [O]ne should emphasize the distinction between two types of measurement. First, there was the one in which the statisticians were mainly interested. Second there was measurement in theory. The statisticians' measures were only approximate and provided a suitable field for work in solving index number problems. The theoretical measures required absolute precision. Any imperfections in these theoretical measures were not merely upsetting, but knocked down the whole theoretical basis.
>
> (Hague 1961, p. 305)

[45] See Pasinetti (1963, 1973, 1981, 1986, 1988). See also Chapter 4.

It is clear that the mapping from empirically given structures to theoretical models cannot be complete or perfectly faithful. There are always some compromises. One of the aims of this thesis is to render explicit the necessary compromises to go, with the mediation of a data model, *from* the empirical structure *to* the theoretical framework.

For *data model* I mean a quantitative accounting scheme that describes the mutual consistency relations between *measurable* magnitudes, as they would ideally be available to carry out empirical computations — for example, the set of Supply-Use Tables of the System of National Accounts is the data model employed in this work. As such, a data model is built on a series of assumptions, e.g. a uniform basic price for each commodity.[46] The key point is to recognise that when one faces actual empirical data at current and past-year-prices, and discovers that price changes between columns of the *same* commodity row differ, this is due to the unavoidable aggregation of table compilation procedures, and *not* to an invalid assumption of the data model.

The notion of a data model is essential in this dissertation. *All* the productivity measures that are empirically implemented are devised with the data model in mind, rather than at the theoretical level. Working with a data model is crucial to understand the dependence of *computable* productivity measures on relative prices.[47]

In fact, the importance of focusing on the interplay between a data model and a theoretical scheme is one of the most important points I would like to convey in this dissertation. The data model is precisely the interface between a theory of measurement and the measurement of theory.

## 1.7 Structure of the Thesis

The dissertation is organised as follows.

Chapter 2 discusses the concept of productivity from the perspective of the production and consumption process seen as a circular flow. Deeply rooted in this perspective, Leontief's (1937) early formulation of the *theory* of an Input-Output system, included the specific notion of 'productivity coefficients'. A reappraisal of his original scheme in terms of eigensystems is performed, identifying the explicit role of productivity levels in ensuring the reproduction conditions of the economy. All throughout the chapter produc-

[46]Basic price in the sense of national accounts, i.e. a statistical price net of taxes on products, trade and transport margins. See section 3.4 of Chapter 3 for details.

[47]Given that the aim is to compute physical productivity changes, a correct separation between price and volume growth is essential.

tivity is seen as a primitive *datum*, whose effects in physical outputs and prices are captured by means of different computable measures. However, given the simplified framework adopted, the analysis is always kept at the level of theory.

In contradistinction, Chapter 3 starts with a discussion on the relationship between basic categories of economic analysis and their implementation in the System of National Accounts. The chapter proceeds by introducing the accounting framework of Supply-Use Tables as a data model, characterising it by means of a set of assumptions, leading to the formulation of two systems: the expenditure system (based on a set of commodity balances) and the system of revenue-outlay relations (as seen from the value added side). This data model will be used for the rest of the dissertation.

Throughout Chapter 3, the value added side will be privileged[48]. In this sense, computable measures of Total Factor Productivity (TFP) growth by industry are derived, discussing the implications of assuming the 'quantity of capital' as a non-produced primary factor with the rate of profits as its price.

Instead, foundational analyses of technical progress from the view of a classical system of production prices consist either in (a) establishing stylised forms of progress according to the shape of wage-profit schedules[49], or (b) obtaining aggregation rules for industry 'process improvement' rates in a joint production model[50]. Both approaches are taken up in Chapter 3 to devise and implement computable measures of $r$-Productivity changes, reflecting the surplus conditions of the economy in a (pure) joint products framework with fixed capital.

All the measures derived are then applied to study the case of Italy for the period 1999-2007, discussing the results obtained.

Chapter 4 (co-authored with Nadia Garbellini) switches the perspective to the expenditure side of the economy, in order to measure changes in physical productivity by adopting the (growing) subsystem as the unit of analysis.

The chapter begins with a fresh look at the discussion between Solow (1957) and Pasinetti (1959) on the 'concepts and measures of changes in productivity', in the light of the contributions that followed in the course of more than 40 years.

A reformulation of Pasinetti's (1959) early attempt to devise an index of the direction of technical change based on physical magnitudes is advanced, accounting for pure joint production and the reproduction of fixed

[48] With the exception of the computation of commodity surplus rates by product.

[49] See Schefold (1976, 1979).

[50] See Steedman (1983, 1985b).

capital. This treatment highlights the crucial, theoretical *as well as* empirical, differences between self-replacing and growing subsystems, particularly as regards the delicate issue of depreciation, retirements and replacements of fixed capital inputs. Computable measures of physical productivity changes and indexes of capital intensity are then derived, both at the aggregate and disaggregated level.

The chapter includes an empirical application to the Italian economy for the period 1999-2007, with a discussion of results. Finally, a comparison between TFP growth rates by industry and hyper-integrated labour productivity changes by growing subsystem is carried out by means of a graphical device (a Harberger (1998) diagram) that renders transparent the sectoral distribution of the growth pattern under each method.

The last chapter of the dissertation, Chapter 5, may be read as a 'variation on a theme' of Chapter 4. Here again, the concept of growing subsystem is used to approximate the patterns of productivity growth of a set of selected OECD economies (Germany, France, Italy, Japan, UK and the US) during the 1995-2005 decade.

Three points of this chapter may be highlighted. First, the derivation of the precise dependence of computable productivity measures on relative prices when — because of data availability — there is no other choice than to adopt an Input-Output technology assumption, switching from a commodity $\times$ industry data model to an industry $\times$ industry one. Second, the chapter approaches the convergence of productivity debate from the perspective of growing subsystems. Finally, the graphical strategy of Harberger (1998) diagrams is adapted to the concept of hyper-integrated labour productivity to depict the pattern of labour saving trends among industrialised economies.

## 1.8 Some general remarks on notation

Besides verbal discourse, the main language of the dissertation is that of matrix algebra. Therefore, I believe the most straightforward thing to do is to specify from the beginning the use of notation.

Matrices and vectors are represented by boldface upper-case (e.g. $\mathbf{X}$) and lower-case (e.g. $\mathbf{x}$) letters, respectively. All vectors are column vectors, and their transposition is explicitly indicated (e.g. $\mathbf{p}^T$). A vector with a hat (e.g. $\widehat{\mathbf{x}}$) indicates a diagonal matrix with each element of the vector on the main diagonal.

Generally, the total number of commodities or industries (given that only square systems are considered) is given by $n$. Index $i$ will preferably be used when referring to a commodity, and index $j$ when referring to an industry.

Unless otherwise specified, the terms commodity and product will be used interchangeably, and the same applies for the terms industry, activity and process.

All vectors are of dimension $n \times 1$, and all matrices are of dimension $n \times n$. All magnitudes belong to the real field ($\Re$). Unless otherwise specified, all square ($n \times n$) commodity $\times$ activity matrices are read from the standpoint of commodities by rows and from the perspective of industries by columns, i.e. $x_{ij}$ refers to the value of $x$ at the intersection between commodity $i$ and industry $j$.

As to aggregation and selection of components, vector $\mathbf{e} = [1, \ldots, 1]^T$ is an $n \times 1$ column vector that sums across columns (i.e. sums all columns in each row), while $\mathbf{e}_i = [0, \ldots 0, 1, 0 \ldots, 0]^T$ is an $n \times 1$ column vector that selects the *i-th*. column. The same applies for vectors $\mathbf{e}^T$ and $\mathbf{e}_i^T$ with respect to rows.

As specifically regards Chapters 3 and 4, to distinguish domestically produced from imported commodities, as well as from their sum, I proceed as follows: superscript $^*$ indicates total (domestically produced plus imported), superscript $^m$ indicates imported, while the absence of a superscript indicates a domestically produced magnitude. Moreover, unless otherwise specified, the subscript $_q$ applied to *matrices* indicates a matrix in volume terms.

As to empirical results, units of measurement are indicated in parenthesis at the end of the title of each Table. Note that '(p.p.)' stands for 'percentage points' and '(%)' generally indicates a 'percentage distribution', while '$\Delta\%x$' indicates the percentage rate of change of variable $x$.

**Note:** The notation of Chapter 2 is different in some respects from the one adopted throughout Chapters 3, 4 and 5. For this reason, two different Glossary of Symbols have been prepared. Appendix H presents the main symbols for Chapter 2, while Appendix I contains a list of symbols for the other three chapters.

As regards operators, in Chapter 2, the total differential operator will be indicated by $d(.)$, generally including parenthesis even in the presence of one single argument.

Instead, throughout Chapters 3, 4, and 5, the total differential operator will be indicated by the symbol $\mathrm{d}(.)$ and parenthesis are included only when it is strictly necessary, i.e. $\mathrm{d}xy$ refers to the total differential of variable $x$, then multiplied by variable $y$, while $\mathrm{d}(xy)$ refers to the total differential of the product between $x$ and $y$. The same criterion applies to the discrete difference operator: $\Delta$.