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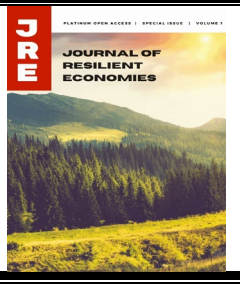

Degrowth and Full Employment—A Modern Monetary Theory Perspective

James Juniper

Email: james.juniper@newcastle.edu.au
University of Newcastle, NSW, Australia

Abstract

This paper advocates for the use of techniques of optimal planning that were developed by Soviet mathematicians. It argues that these techniques, based as they are on the labour theory of value, are compatible with: (a) the efforts of Modern Monetary Theorists to achieve full employment through a return to active fiscal policy (with the GDP gap serving as an estimate of the level of additional aggregate demand required to this end); (b) national income accounting procedures taken up by the United Nations; (c) the work of industrial ecologists who use input-output techniques to support and inform their analysis of waste, pollution, and the unsustainable use of renewable and non-renewable resources. It argues that, with slight modification, the techniques originally developed by Kantorovich and Novozhilov could be applied to the construction of metrics that account for the 'short-changing' of nature. For example, they could incorporate estimates of the labour time required to prevent unsustainable exploitation of renewable resources (including through higher levels of recycling and restocking), the use of non-renewable resources at rates exceeding the time required to produce substitutes, and the time required for adequate remediation and restoration of polluted resources (including investment in new transport and power generation systems).

Keywords: ecology, sustainability, modern monetary theory, linear optimisation

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Introduction

The major aim of this paper is to discuss how Modern Monetary Theory (MMT) advocates could achieve a workable reconciliation between the policy objective of ecological sustainability and that of full employment. From an economic perspective, the policy context for this chosen aim is the fact that many ecological economists and environmental activists, alike: (i) criticise the use of GDP (along with per capita GDP) as a measure of economic performance; while (ii) advancing 'degrowth' strategies designed to achieve a transition towards a steady-state economy (which is one characterised by low levels of resource throughput, waste and pollution, achieved not only through higher levels of recycling but also through more efficient and effective usage of energy, water and other resources necessary for human survival on planet Earth).

In Czech and Mastini's (2020) CASSE paper on "A Steady State Economy", the authors follow Herman Daly in defining the notion of a steady-state economy, which they characterise as one maintaining a *constant* (or *mildly fluctuating*) population and *constant* (or mildly fluctuating) per capita consumption, with energy and material flow *reduced* and kept within ecological limits, where there are more or less *constant stocks* of natural and human-built capital. Daly's conception of a steady-state is one derived from entropic approach. In their paper, the authors observe that Georgescu-Roegen, Herman Daly's PhD supervisor, first turned to thermodynamics, out of necessity, as a means for refuting the neoclassical conception of 'perpetual substitutability'. As Commons and Stagle argue, this neoclassical principle is usually described in terms of "weak substitutability" (i.e. produced capital and natural capital are assumed to be substitutes for one another rather than complements. Complementarity is instead described in terms of "strong substitutability"). Czech and Mastini's efforts at integrating Degrowth and Steady-State culminate in the "Sustainability Slogan", which, in a highly condensed form, advocate for "Degrowth Towards a Steady State Economy". In a 2007 paper, questioning of Herman Daly's thermodynamic approach to sustainability, Schwartmann (2007), has complained that,

> Whatever the change in entropic flux arising from changes in the Earth's surface temperature, the entropic flux in itself will tell us nothing about the actual impacts of global warming, which are both the linear and nonlinear outcomes of fossil fuel consumption and other sources of anthropogenic greenhouse gases. The concrete linkage of cause and effect must be worked out from the application of the relevant sciences.

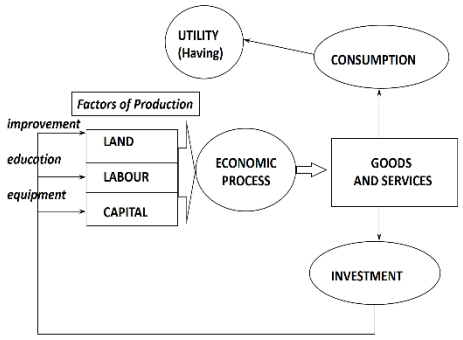
He goes on to insist that the position of those he describes as the anti-growth 'neo-Malthusians' effectively amounts to "an overthrow of Sraffa's arguments for a return to the surplus approach of Classical Political Economy, achieved through replacing the labour theory of value with one predicated on the use of energy or entropy as the supposedly appropriate measure." In deploying this name, Schwartzmann is attempting to distance himself from the pessimistic and conservative views of the Reverend Malthus, for whom the presumed geometric rate of human population growth would continually run up against the natural limits of an arithmetic growth in resources. Moreover, they interpret a problem with a geopolitical solution as one that is biological, which thus has a strictly biological solution (i.e. an asymptotic movement towards complete biomimicry supported by policies to achieve a much smaller global population). Along similar lines, Paul Burkett observes that "Marx criticised Physiocracy's identification of value with nature's material use value" because "It carries with it an unfortunate naturalisation of capitalist forms of valuation (exchange value, money, and profit) and of the class relations that underpin them". The Physiocrats believed that the income flowing to priests, soldiers, and feudal barons had its sole source in the bounty of nature. For Burkett, then, "[w]e are in danger of doing something similar with an energetic approach". Crucially, he insists that we "don't need two pricing systems" (i.e. one energetic and the other labour-theoretic)! But this raises the obvious question of how Classical Political Economy could be taken up and modified so that it could serve as a better guide for policy interventions.

Ultimately, my concern about these conceptions of "Degrowth" has been motivated by recognition of the fact that under Capitalist social relations, the underutilisation of labour is used as a powerful weapon against workers. Marx's analysis of the reserve army of labour mirrors these concerns. In his PhD thesis, Victor Quirk has charted the early history of the British Labour Party, which was established in the midst of political struggles over the "right to work". Workers in Great Britain wanted to have meaningful jobs, rather than be given "sit-down" money. That is the main reason why I insist that Ecological Economists must find better ways to reconcile sustainability with full employment, and this, at a living wage (however these things might be defined). To this end, I want to argue for the development of a range of new metrics based on the allocation of labour time to activities designed to promote sustainability.

Mainstream Approaches in Ecological Economics

One of the influential ways of thinking about sustainability is that developed by Paul Ekins (1992), which is based on the work of Pearce and Turner (1990). Ekins takes the conventional neoclassical model of an inter-dependent, growing economy—as illustrated in Figure 1—and modifies it significantly.

Figure 1- The Neoclassical Model of Economic Growth

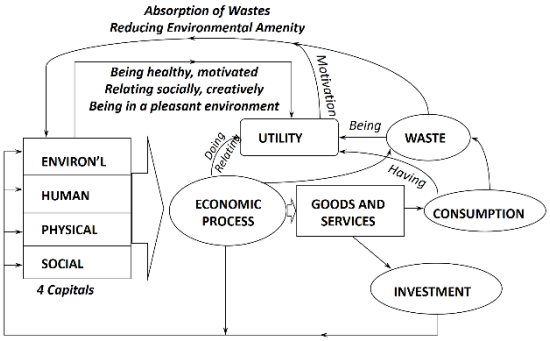


Source: Ekins P. (1992). A four-capital model of wealth creation

First, the three factors of production—land, labour and capital, each of which, by assumption, can be increased or enhanced through certain kinds of investment (improvement of land, education of labour and expansion of capital, respectively) - are replaced by the "*four* capitals", physical human, social or organisational capital, and environmental capital. Each type of capital now contributes to the economic process of providing goods and services.

However, in addition to the production of goods and services for consumption and investment, the economic process also produces waste which can adversely affect other forms of capital, especially environmental capital, and can directly reduce the utility that would otherwise be derived from consumption activity, which also operates as a source of waste. The traditional notion that consumption is a source of utility is decomposed to recognise the utility derived from *having* goods and services, the utility from *doing* creative work, the utility from *being* in a pleasant built or natural environment, and the utility from *relating* to others socially, as illustrated in Figure 2.

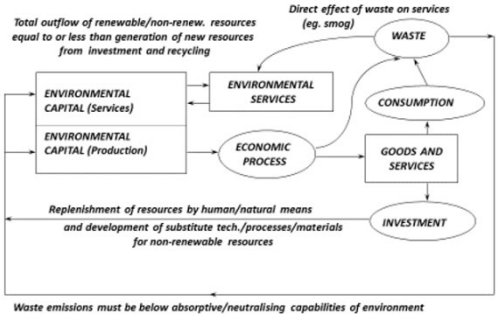
Figure 2- The Four-Capital Model of Economic Growth



Source: Ekins P. (1992). A four-capital model of wealth creation

Finally, economic and environmental interactions are accounted for in the model by introducing a distinction between environmental capital dedicated to production activity within the economic process and environmental capital yielding and being affected by environmental services (as depicted in Figure 3). Now waste can directly affect the level of environmental services and also reduce the efficiency of environmental capital in the economic process. Sustainability is measured in this model by accounting for the balance between outflows of renewable and non-renewable resources relative to the generation or inflow of new resources from recycling and investment (which can augment the replenishment of resources by natural means or discover substitutes for resources that cannot be renewed. For an example of how this model can be translated into an approach to integrated sustainability assessment, see Ekins, Dresner and Dahlström (2008).

Figure 3- Environment – Economy Interaction



Source: Ekins P. (1992). A four-capital model of wealth creation

Social Ecological Economic and Eco-Socialist Critiques of the Mainstream

In his 2011 critique of mainstream environmental economics Clive Spash, a prominent Social-Ecological Economist (SEE), complains about the general assumption that "asocial,

> ahistorical individuals choose among scarce resources to meet competing ends given unlimited wants" while theoretical explanation uses "fictitious concepts and a deductivist, closed-system methodology". Accordingly, Spash advocates the deployment of key biological constructs such as "complexity, levels of abstraction, appropriate units of analysis, irreversibility, nonmarginal and qualitative change, and non-optimising behaviour" where the emphasis is placed on "the limits to material and energy throughput" (i.e. Degrowth!). However, he really doesn't go on to explain how this could be done!

Douai (2009) acknowledges the contribution that SEE has made to our understanding of how we can move towards ecological sustainability. For him, the institutional approach of SEE is invaluable in (i) highlighting the importance of property rights and the state; as well as, (ii) the way institutions regulate conflict; especially by, (iii) recognising some interests while ignoring others; while (iv) acknowledging the socio-historical and contingent nature of institutions; along with, (v) the endogenous nature of conceptions of efficiency; as well as, (vi) the role of ideas as ideological supports for certain institutional structures. Nevertheless, in his view, SEE needs to apply a more holistic approach focusing on the transformation of social relationships with nature and the objective social conditions that are, themselves, responsible for the formation of values and ideologies. In this light, he argues for a return to the distinction that both David Ricardo and Karl Marx made between use-value and exchange-value. From both Spash's and Douai's perspective, the construction of shadow prices (e.g. through the application of techniques of Cost-Benefit Analysis that have been advocated by mainstream economists and by Ekins) implies that, in effect, we are looking at environmental problems through the "lens of capital"!

Two quotes from Marx (1990, Chpt. 29), illustrate the danger of viewing both labour and financial sources of income from the perspective of capital. In the first quote, Marx raises concerns about the concepts of human capital, which is based on the capitalisation of labour services using a discount rate that is, itself, an expression of the rate of exploitation of labour!

> We shall now consider labour-power in contrast to the capital of the national debt, where a negative quantity appears as capital—just as interest-bearing capital, in general, is the fountain-head of all manner of insane forms, so that debts, for instance, can appear to the banker as commodities. Wages are conceived here as interest, and therefore labour-power as the capital yielding this interest. For example, if the wage for one year amounts to 50 and the interest rate is 5%, the annual labour-power is equal to the capital of 1,000. The insanity of the capitalist mode of conception reaches its climax here, for instead of explaining the expansion of capital on the basis of the exploitation of labour-power, the matter is reversed, and the productivity of labour-power is explained by attributing this mystical quality of interest-bearing capital to labour-power itself.

The second quote is concerned with "fictitious capital", i.e. financial assets conceived as a source of period income or return.

> The formation of fictitious capital is called capitalisation. Every periodic income is capitalised by calculating it on the basis of the average rate of interest, as an income which would be realised by a capital loaned at this rate of interest. For example, if the annual income is £100 and the rate of interest 5%, then the £100 would represent the annual interest on £2,000, and the £2,000 is regarded as the capital value of the legal title of ownership on the £100 annually. For the person who buys this title of ownership, the annual income of £100 represents indeed the interest on his capital invested at 5%. All connection with the actual expansion process of capital is thus completely lost, and the conception of capital as something with automatic self-expansion properties is thereby strengthened.

It is obvious that similar criticism could be directed at Ekins when he capitalises on environmental services!

To counter this, Eco-Socialists such as Paul Burkett and John Bellamy-Foster, have discussed at considerable length Marx's ideas about how productive activity should be conceived in energetic terms as a metabolic relationship between human labour and nature, which can gainfully be distinguished from, while at the same time embedded within, the universal metabolism of nature itself. Mitchell (2015), in a notable blog entry, has argued that MMT is closer to Marx than to Keynes. And numerous commentators, who might otherwise be sympathetic towards Keyes, have noted that he was more conservative when it came to policy than he was in strictly theoretical terms. One obvious sticking point for Bill Mitchell was Keynes's view that fiscal deficits should be balanced over the business cycle to pay back debt!

Some ecological economists approach the question of sustainability by examining historical developments in the relationship between endosomatic and exosomatic forms of energy. For example, Common and Stagle (2005) note that by 1900 the average human used about 14 extrasomatic human energy equivalents (i.e. an amount equivalent to each person on Earth possessing, on average, 14 human slaves. Moreover, by the end of the 20th Century this had risen to the equivalent of about 19 slaves)! Giampietro and Mayumi (2000) explain how this conception can be further developed for use in multi-scale integrated assessments of societal metabolism. The resulting sustainability assessment

provides for a range of multi-dimensional representations across a profile of human activity, by household, services, and production sectors at a hierarchy of scales including country, province, and region. The kernel of their approach is based on a notion of a dynamic balancing of the exosomatic energy budget (i.e. in energetic terms, consumption per capita multiplied by population is related to labour productivity multiplied by labour supply). The constraint on equilibrium may be expressed by using two intensive variables, (1) Bioeconomic Pressure (which equals the ratio between "total exosomatic energy metabolised by the whole society" divided by "working time in the productive sector of the economy); and, (2) the Strength of Extrasomatic Hyperycle (which equals the ratio between "total exosomatic energy that can be supplied to the whole society" divided by the "requirement of working time" in the productive sector).

To inform their Eco-Socialist research and political activism, Paul Burkett and Bellamy-Foster introduced the key notion of "metabolic rift" by focusing on Marx's discussions about the Soil Science of his day (Foster, 2000). For these natural scientists, agricultural productivity was seen as effectively "going down the drain", in large part due to the invention of the flushing toilet (which was taking the nutrients in human waste out to sea rather than back onto the land to preserve its fertility. However, this raises the question of whether the notion of "metabolic rift" be a convincing metaphor for all of our environmental ills. Is it required to carry too much weight, and if not, how can it, too, be operationalised?

Jason Moore (2017), the "Ecological Historian", has complained about the concept-indicator approach (eco footprints, rifts). He also insists that much of "Green Thought" (including Eco-Socialism) preserves modernity's dualisms between human organisation on the one hand, and the "web-of-life" on the other hand, along with a spurious notion of unidirectional causality. Nevertheless, I would insist that we need to come up with better ways to inform policy-makers (as well as better ways to focus on activist interventions). For his part, John Bellamy-Foster (2016) has responded by observing that anything Jason Moore doesn't like is labelled '*Dualistic'*. Moreover, he cautions that Moore is too close to the bland and somewhat tame politics of Bruno Latour's *New Economic Sociology*. To demarcate his own approach from that of Moore, Foster quotes from Marx's *Grundrisse*:

> It is not the unity of living and active humanity with the natural, inorganic conditions of their metabolic exchange with nature, and hence their appropriation of nature, which requires explanation or is the result of a historic process, but rather the separation between these inorganic conditions of human existence and this active existence, a separation which is completely posited only in the relation of wage labour and capital.

However, Moore does provide a valuable historical analysis of how colonisation abroad and exploitation at home ensured that capital could take advantage of the "four cheaps" (cheap food, cheap labour, cheap energy, and cheap raw materials). For Moore, all of capitalism's environmental problems all relate to difficulties in obtaining the "Four Cheaps". Accordingly, for him, there are no ecological crises, as such, only economic crises caused by the ecological scarcity that can be solved by "shifts" — by obtaining resources or labour elsewhere or in other ways, rather than efforts to overcome implacable "rifts". In fact, Foster (2016) has questioned the value of this principle on the basis of its naivety.

Alternative Approaches to the Development of Useful Metrics based on Labour Time

For me, then, the fundamental question is how we can come up with metrics based on labour time that accounts for the extent to which nature has been "short-changed". Classical Political economy is grounded in the analysis of socially necessary labour time. This conception of "reproduction price" (prices that must obtain if the economy as a whole and each industry within it can reproduce on an expanding scale). This Classical conception of value still survives in two contemporary spheres of economic analysis: input-output modelling and national income accounting.

Input-Output (I-O) modelling, which was introduced to Western economics by Wassily Leontief, was first developed in Russia on the basis of Classical political economy (see Belyck, 1989, and Clark, 1984 for more historical background to these developments). It was subsequently applied in a variety of forms to support the planning apparatus in the Soviet Union. One helpful way of thinking about I-O modelling is that it represents a multi-sectoral generalisation of the Keynesian multiplier relationship, with aggregate demand expressed as a column vector with each entry representing the amounts that are required from each of the industries in the economy (Kurz, 1985; Goodwin, 1949)[1].

[1] See Leite (2018) for a comprehensive and up-to-date review of the literature on macroeconomic applications of multi-sectoral I-O multipliers and so-called Sraffian "super-multipliers".

While I-O models have been applied by development economists, a branch of ecological economists—who are usually called "industrial ecologists" are also major users of this modelling methodology.

Schmelev talks about industrial ecology in Chapter Five of his 2012 Ecological Economics textbook, where he states that "In industrial ecology, an industrial system is viewed as a complex organism that processes energy and materials under its own metabolic rules". The question of "How industrial systems are structured and how they transform, use and discard natural resources is, therefore, the major focus of industrial ecology." To this end, "[i]ndustrial ecology aims at closing material cycles within the industrial system by developing symbiotic relationships among industries." In this Chapter, Schmelev distinguishes between (i) Life cycle analysis; (ii) Material flows analysis; and, (iii) Environmentally extended input-output analysis. While the first of these frameworks is oriented towards the level of product, a production line or region, and has already firmly been enshrined in the ISO-14,000 set of environmental management standards developed by the International Organization for Standardization; the second of the frameworks is usually directed at the level of the national economy or a region and has been formalised by the United Nations System of Environmental and Economic Accounting and the 2003–2004 development of the Global Material Flows Database (which has largely followed European guidelines).

Significantly, Integrated Product Policy (IPP) was advocated by the EU's sixth Environmental Action Programme, observing further that the product-oriented life-cycle approach recommended in an EC Directive in 2003 required firms to quantify the "environmental impacts of various products in an economy" while "investigating further the identified target products". In this context, Input-Output based Life-Cycle Analysis (IO-LCA) "has been recognised as one of the approaches well suited to IPP analyses". The third framework is one that routinely employs environmentally extended input-output models for dealing with a range of topics, including energy and the environment, materials balance and materials flows, water, waste, environmental policy analysis and key sector analysis.

When applied to global production and international trade, a multi-national I-O approach can also account for the environmental impact associated with exported and imported products and services. As such, it complements work by contemporary geographers and historians on global commodity chains and can therefore be deployed in calculating such things as the Carbon footprint[2]. The fact that all this work is grounded in Classically-motivated I-O analysis implies that it would be relatively straightforward to convert findings into a form based on socially necessary labour time.

The United Nations approach to National Income Accounting, which provides the framework for economic analysis, macroeconomic policy interventions, and a basis for meaningful international comparisons, also owes more to Classical Political Economy than it does to its Neoclassical counterpart. Here, I can draw on Peter Flaschel's authoritative 2010 research on the development of national income accounting, highlighting, in particular, the important role of Richard Stone.

> In my investigation of the United Nations' Systems of National Accounts, I have come to the opinion that this system is more Classical than Neoclassical in nature, where Classical here simply means that its concepts stress more the evolution of average magnitudes than of marginal ones obtained under the assumption of perfect competition. (Flaschel, 2010: 12)

Flaschel (2010: 21) also observes that the so-called *New Interpretation* of Marx's value theory (Duménil and Foley, 2006) is "similar to Keynes' (1936) approach who considered the working of the economy from the perspective of prices normalised by the wage unit". It is important to reflect on the fact that GDP, a concept heavily criticised by ecological and feminist economists, can be viewed as entirely "fit for purpose", when that purpose is interpreted in accordance with the benchmark of achieving full employment.

However, there is another form of planning based on the labour theory of value, which Ecological Economists and activists can benefit from. This formal approach was pioneered by Soviet Mathematical Economists such as Kantorovich and Novozhilov and was actively promoted and applied in the period after the Post-Stalinist thaw, shortly before the Soviet Union collapsed into the "free-for-all" of Petro-baron politics and Casino Capitalism[3]! In 1965, after a whirlwind visit to the Soviet Union by Tjalling's Koopmans, then Director of the Cowles Commission (a prominent US research centre and "think-tank" that did much to advance modern

[2] Also see Sangwon and Kagawa (2005) for a detailed survey of I-O applications in this field.

[3] The cybernetic context for the rise of the mathematical economists is articulated in Leeds (2016), Boldyrev and Kirtchik (2017). See Vucinich (2002) for a more philosophical discussion.

techniques of mathematical economics and econometrics), Koopmans himself published an influential report, which ultimately influenced the awarding of the 1975 Swedish Bank Prize in Economics (often, *erroneously* referred to as the Nobel Prize in Economics) jointly to Leonid V. Kantorovich and Koopmans[4]. Regarding this event, Boldyrev & Düppe (2020: 20) have made the following observation[5]:

> In 1965, Novozhilov, Nemchinov and Kantorovich ultimately jointly received the Lenin Prize. The prize was a symbol of clear success in the ideological struggle over legitimate forms of economic knowledge in Soviet socialism. The prize put the dormant confrontation between political economists and mathematicians on hold, as the division of expertise was officially drawn.

The significance of this symbol of political approval cannot be overestimated. As Adam Leeds (2016:346) has observed of the Soviet economic milieu,

> […] mathematical economics had two centers of gravity, two communities, one based around input-output modelling, and the other around optimisation techniques […] The optimisers were more closely connected to the Academy of Sciences, to the applied mathematics profession and to military cybernetics and computing institutes. The input-output modellers were more closely connected to the planning apparatus—Gosplan and its institutes, and the Central Statistical Administration—and to the institutes of applied industrial science.

On purely technical grounds, Roy Gardner (1990) and Montias (1961) observe that subsequent Western advances in linear programming complemented Kantorovich's initial 1939 study, most notably in computational terms, aided by Dantzig's discovery of the simplex algorithm. Montias describes Kantorovich's original method of solution as one making use of "implicit prices" or "resolving multipliers", to use the terminology favoured by the Russian author, "to improve allocation, prices and activity levels" by being "successively adjusted until an optimal solution was achieved". Montias observes, however, that as "the algorithm was not fully described in the 1939 paper, it is not clear whether the method would necessarily always converge toward an optimum in a finite number of steps". He further noted that, in an appendix, the Russian mathematician, "anticipating the later work of Koopmans and others, used geometric methods to prove the existence of the 'multipliers' for the machine-assignment problems he was investigating". Gardner (1990: 643) summarises the matter at hand as follows,

> We are now at Kantorovich's fundamental economic insight: An optimal plan is inseparable from its prices. Even if a plan was entirely in quantities and said nothing about prices, if that plan was optimal, it would imply the existence of resolving multipliers that function just like prices.

Nevertheless, some care is need when reviewing the Western literature on Kantorovich and Novozhilov, especially in cases when their work is interpreted as an anticipation of marginal and neoclassical approaches. This is because both grounded their analysis firmly on Marx's labour theory of value.

For his part, Hagerberg has put a lot of effort into trying to integrate Marx's value theory with neoclassical notions of optimisation. The key to all this is the insight that at an optimum (which, ironically, can be a feasible goal for planners even though it is unlikely to be realised within a capitalist economy) output would be located at the point of intersection between the demand curve and the marginal cost curve, at the point where the latter cuts through the average cost curve at its minimum point. Accordingly, Hagerberg insists that there would be no transformation problem for an economy whose industries were each located at this optimum point because the price would have equal marginal cost while also being equal to average cost. In this, Hagerberg would seem to be mirroring Alfred Marshall's claim that he was a marginal theorist in the short run but a Classical theorist in the long run. [6]. Gardner goes on to summarise Kantorovich's economic contributions, highlighting the importance of his attention to resource problems,

> Between the discovery of resolving multipliers and the decision to give up economics four years later, Kantorovich solved a large number and a great variety of optimisation problems. Among these were transportation problems and other network problems central to linear programming and intertemporal optimisation problems, including problems in resource economics. In intertemporal problems, he found a resolving

[4] Details on Koopman's 1965 visit to the Soviet Union are provided by Düppe (2016).

[5] Kantorovich's contribution to planning is discussed in Boldyrev and Düppe (2020), Gardner (1990), Montias (1961), and Ward (1960), and an English translation of his important book on "The Best use of Economic Resources" is to be found in Kantorovich (1965).

[6] Nevertheless, Hagerberg distances himself from mainstream marginal analysis by insisting that non-labour resources make no contribution to the creation of value.

multiplier which for all intents and purposes is a rate of interest. In resource problems, he found resolving multipliers for resources such as land, water, and forests, which planners had previously taken to be free goods. (Gardner, 1990: 644)

Holubnychy makes it clear that, in Novozhilov's approach to accounting for resource scarcity, the opportunity cost of using scarce non-labour inputs is expressed not in terms of previous output but rather in terms of additional labour cost incurred elsewhere. Therefore, the labour spent in the production of the good must be added labour increments incurred in the production of other goods without the use of the scarce resource[7]. For Novozhilov, this was entirely in accord with Marx's argument that only labour is creative of value, while non-labour resources merely create differential conditions for the application of living labour, which can modify actual labour inputs per unit of output and therefore raise money prices.

Without going into too much technical detail, in Novozhilov's approach to economic planning, shadow prices are calculated by taking the minimand of a linear programming problem, in which it is assumed that the bill of final products is given by the national economic plan. What results is a fulfilment of the plan with minimum total labour costs. He refers to the maximum for the dual problem as national income. In this dual setting, final-production targets can then be calculated on the basis of forecasts of consumer demand and government preferences. Novozhilov deploys the well-known Goldman-Tucker saddle-point theorem to calculate socially necessary labour time. However, he acknowledges that product demand will also vary with price so that an iterative solution technique will be required to determine optimal prices and quantities[8]. Thus, Holubnychy insists that Novozhilov's approach to planning was entirely consistent with Marxist principles in his adherence to the labour theory of value, explaining that he also followed Marx in recognising the differences in marginal cost associated with differing levels of efficiency, differing degrees of obsolescence, and the relative advantages of operating in different locations given the location of relevant markets.

Conclusion

The major aim of this paper has been the development of techniques that could achieve a workable reconciliation between the policy objective of ecological sustainability and that of full employment. The policy context has been provided by the fact that many ecological economists and environmental activists alike, have criticised the use of GDP (and per capita GDP) as a measure of economic performance while advocating 'degrowth' strategies designed to achieve a transition towards a steady-state economy. Instead, I have argued, provocatively, that GDP is fit for purpose, in that both its definition and its deployment within the national income accounting framework—is motivated by the requirement to relate changes in value-added (and equivalently, effective demand) to levels of employment in the economy as a whole.

However, I have also encouraged ecological economists to develop a range of new metrics frameworks based on measures of resource efficiency. After this paper was written, the author came across the work of a Computer Science Professor at Glasgow University, Paul Cockshott (2020) and one of his PhD students, Jan Dapprich (2020), which considers improvements in linear optimisation since Kantorovich and the implications these have for economic planning (the latter author describing applications of these techniques to environmental sustainability). These would account for the extent to which we are "short-changing" nature by focusing on the way that the scarcity of factors other than labour-power create differential conditions for the application of living labour, as Novozhilov would have it), and by considering the allocation of labour-time to activities that are designed to promote conditions of sustainability. The fact that many industrial ecologists already work closely with I-O analysis should facilitate these technical efforts. These labour-based metrics could then serve as guides for policies of public investment (e.g. in sources of renewable energy, water and sewerage treatment or improved transport infrastructure), and other environmental projects, in ways that would be both less demanding than mainstream techniques of Cost-Benefit-Analysis and more defensible in theoretical terms. Of course, it must be acknowledged that not all desirable environmental policies and initiatives could be evaluated in this way. A good example of this is the promotion of biodiversity, which is extremely difficult to define in the first place, let alone to evaluate in a policy setting!

[7] For an English translation of the most influential of the works cited by Holubnychy (1982), see Novozhilov (1970).

[8] For details see the discussion in pages 454-456 in Holubnychy (1982).

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