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Accounting for the utilisation of geothermal energy resources within the genuine progress indicator—A methodological review

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ABSTRACT

The Genuine Progress Indicator (GPI) was initiated to mainly reflect strong rather than weak sustainability principles and embrace a 'Fisherian' understanding of income and capital. Prior to this review, neither existing calculation methodologies nor academic reviews of the GPI had considered the possibility that geothermal energy resources might not deliver sustainable yields. Although geothermal energy is renewable in the sense of the Earth's almost ubiquitous capacity to store heat, the resources are frequently utilised at a rate that is unsustainable. Pressure recovery and fluid-heat recharge periods typically endure for several decades or more. Whenever geothermal resources are utilised unsustainably, this paper contends that the GPI should deduct monetary costs for the excess depletion. This approach would maintain the GPI's methodological correctness as a measure of sustainable economic welfare in current time terms. Failure to do so is affirmative of the weak sustainability paradigm, inferring that overexploited energy resources can be either fully replaced or partially substituted when their yields begin to diminish. This paper sets out a new method for calculating GPI cost deductions for the unsustainable utilisation of geothermal energy resources. The outlined approach synthesises existing academic theory concerning geothermal production modes and levelised energy cost calculations.

Contents

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1. Introduction

In the field of economics, economic welfare refers to the sum of utility gained through the consumption of material goods and services [1]. It is the component of social welfare that is fulfilled via economic activity and is commonly measured through Gross Domestic Product (GDP). However, reality is more complex and GDP a deficient measure of economic welfare. GDP does not provide any indication of the sustainable nature of economic activity. GDP fails to acknowledge that the faster non-renewable resources are depleted to provide energy to fuel economic activity, the more pollutants that are likely to be emitted. National accounting measures count the loss of natural capital resources and their many non-market services as an economic gain. Repetto and Austin describe the problem in terms of "a country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared" [2] (p. 61). Viewed collectively, these effects carry negative implications for human health, social well-being and the sustainability of economic welfare itself.

In contrast, the Genuine Progress Indicator (GPI) is a comprehensive measure of sustainable economic welfare, and is designed to take full account of many environmental and social costs which are treated as income in GDP, including the utilisation of non-renewable energy resources [3,4]. Whereas GDP accrues on a twofold scale when pollution occurs (via the economic act itself causing pollution and the following costs of clean-up), the GPI methodology counts this damage as a cost deduction roughly equivalent to the monetary value of the clean-up activity [5]. GPI advocates claim that its measure can more reliably track economic progress by assimilating the ecological impacts of production into the equation [6].

The GPI methodology has emerged within the field of ecological economics, a modern movement which places emphasis on 'strong sustainability' values, those rejecting the idea that natural and human forms of capital are substitutes for one another [7]. The concept of welfare in ecological economics is differentiated from understandings of the term generally voiced by neoclassical economists [3]. Often ecological economists opine that neoclassical economists ignore the environment, viewing it as a subset of the human economy [8,9]. The field of ecological economics distinguishes itself from neoclassical interpretations of the value of nature by reinforcing the observation of economies embedded within environmental systems. The GPI has been developed with this perspective in mind, and thus factors in cost deductions for economic activities that result in welfare depletion such as inequality, pollution, environmental damage and non-renewable energy resource utilisation [3].

Energy is integral to the flourishing capacities of all life. Every activity on Earth is dependent on energy and economies cannot be sustained without energy inputs. However, the intensive use of energy, particularly when sourced from non-renewable resources, is also the cause of a number of environmental and societal ills to the detriment of economic and social welfare. Energy production and consumption activities have been linked to local health impacts, global climate change, air and water pollution, soil contamination, biodiversity loss, resource depletion, security implications and land-use conflicts [3,10]. Over the longer term, the potential for increased non-renewable resource scarcity represents an important argument in favour of shifting towards a sustainable energy system on a global scale. The issue of the remaining recoverable non-renewable resource stocks splits opinion, with optimistic perspectives [11] countered by more pessimistic viewpoints [12]. The GPI methodology rewards nations that increase their use of renewable energy—a relative increase in sustainable economic welfare is derived from a lower cost deduction for replacing non-renewable resource utilisation with renewable alternatives. This is generally a logical approach, not least because the greater use of renewable energy leads to the less rapid depletion of scarce non-renewable resource stocks and the point of absolute depletion is shifted into the future [13]. In addition, other 'negative externality' cost deductions (for example, air and water pollution) associated with fossil fuel and nuclear combustion are correspondingly lower, and therefore the final GPI value is higher.

Renewable energy forms are those obtained from the continuous or repetitive currents of energy recurring in the natural environment, and as such cannot be depleted [14]. Energy sourced from solar, wind and tidal sources are the ultimate forms of renewable energy due to their constant replenishment [15]. Another source of energy commonly considered to be renewable is geothermal [16,17]. In terms of the stock of the global energy source, this classification is valid. However, geothermal utilisation may not necessarily be sustainable when viewed as a flow resource, since this depiction relies on the sustainability of site-specific heat extraction and long-term replenishment rates. The maintenance of sustainable yields from geothermal power is greatly limited by the speed at which heat travels through solid rock [18]. After a certain time period, the process of extracting heat for utilisation in a geothermal power station may deplete the energy resource, at least temporarily. If unsustainable rates of utilisation occur, the geothermal resource cannot comprise a valid component of a sustainable energy system. This has important implications in terms of the GPI's set of cost deduction methodologies.

No academic studies have been published to evaluate how best to incorporate geothermal energy utilisation within the GPI methodology and arrive at a more precise calculation of sustainable economic welfare. The aims of this paper are twofold: (a) to consider and explain use-mode scenarios where geothermal utilisation undermines the sustainability of economic welfare; and (b) propose a cost deduction methodology for the GPI in order to account for cases of unsustainable geothermal utilisation.

This paper begins by providing a brief summary of the limitations of GDP as a measure of sustainable economic welfare. An analysis of the nature of strong and weak sustainability principles follows, with these considerations used to appraise the robustness of the GPI as a measure of sustainable economic welfare. In Section 3, the GPI's theoretical underpinnings are applied and expanded using existing academic theories of sustainable geothermal resource utilisation. Following this, an appropriate methodology for calculating the costs of unsustainable utilisation of geothermal energy resources is outlined and illustrated. Section 4 discusses the current limitations and constraints of the recommended approach, together with consideration of the steps needed to apply the methodology in practice.

2. Sustainable economic welfare

Over the last 30 years, major concern has been raised in relation to long-term rates of natural resource depletion and environmental degradation, and its perceived impact on sustainable development [19]. Seeking to address this in national accounting, proponents of alternative measures of economic welfare, which tend to incorporate wider quality of life considerations, generally consider the incorporation of an array of additions to and deductions from GDP [6,20]. At the core of 'green' national accounting approaches is the notion of netting out from investment in new durable capital goods the drawdown in items of natural capital [21]. Although there remains no single accepted interpretation of the term sustainable development, essentially the concept considers a single choice: should natural capital be