IS SUSTAINABILITY A 17TH-CENTURY DUTCH PRONK TOLD THROUGH 19TH-CENTURY ENGLISH PIGMENT?

Toward a Transdisciplinary Endogenous Time-Window Analysis of Development

[WORKING PAPER]

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Abstract

As demonstrated by the 1987 report Our Common Futures, "sustainable development" is inherently complex across dimensions of demonstration—whether that be conceptually, semantically, mathematically, or expressionistically. The dimension of space-time is the highest of interest, when attempting to understand, model, and predict sustainability of anthropocentric development, since sustainable development goals (SDGs) are location-specific, and time is a finite resource manipulated based on the user's ambitions and agendas. Arrow and colleagues (2013)—while addressing whether economic growth can be symbiotic with sustaining well-being over time—implored that time be considered a capital asset (e.g.; thereby, an endogenous variable), for the sake of sustaining natural capital. This paper aims to explore time as a critical component of sustainable development, and how diverse disciplinary and philosophical lenses may use time, by means of endogenous and exogenous conceptual categorization.

Methods employed include a curated selection of the literature, which suggest the conclusions: economics would benefit from an endogenous time variable; sociology and human rights call for an exogenous approach; investigations through visual media suggest time is indeed endogenous, simply because of its finite and lagging nature; and furthermore, in the interest of coupling the well-being of terrestrial assets and the explorative freedom of aerospace innovation, endogenous time should be nested within an authoritarian philosophy. In conclusion, time

could be considered a social imaginary and—similar to the decreasing supply of granular sand in the concrete industry—an inevitably finite tool used for its endogenous and exogenous facets. Future directions could include borrowing temporal illustrations from other disciplines—even if seen as irrelevant or pedantically perverse. For example, the hyperboloid topology of a wormhole provides a useful paradox of the sustainable development goals with respect to time. Similar to an hourglass, time capital spent moving the sand is a function of the radius of the origin, or path.

1 Introduction

The 1987 report Our Common Futures provided a foundational framework for envisioning sustainable development. Over the last three decades, the literature has evolved from traditional nomothetic models to increasingly empirical and computational approaches. For instance, Biswas et al. (2021) proposed the α-Sustainable Development framework, where development (D) is sustainable until a threshold of uncertainty (α) is reached. This shift highlights a broader trend: sustainability, development, and complexity have become dominant problematics—concepts that impose questions rather than answers (Ferguson, 1994).

As sustainability goals proliferate across disciplines, the divergence of definitions and metrics has also grown. Complexity, often used to study adaptive systems, now structures and responds to knowledge production in diverse fields (Dan-Cohen, 2017). This paper argues that time—finite and universal—may serve as a unifying variable across disciplines. Whether endogenous (user-defined) or exogenous (pre-defined), time is critical for understanding and advancing sustainable development.

This paper explores time's role through four perspectives. First, economics examines time as an endogenous capital asset, building on Arrow et al. (2013). Second, sociology critiques endogenous time as a construct with potential for misuse, favoring an exogenous approach. Third, art illustrates time's dual nature, from Dutch still lifes that depict time capital to British pigment choices that document environmental change. Finally, space policy proposes a novel application of endogenous time for aerospace innovation. Together, these perspectives reveal time as the thread linking sustainability's complexities across disciplines, offering new insights for theory and practice.

2 An Economic Perspective – Capital Assets

2.1 The Temporal Component of Capital Assets in Sustainable Development

Understanding the temporal dimension of capital assets is essential to fostering responsible and sustainable development. Both monetary and non-monetary forms of capital must be evaluated in terms of their ability to contribute to long-term well-being across generations.

2.2 The Diversity and Complexity of Capital

Capital, broadly defined, encompasses any asset that enhances productivity, adds value, and provides strategic advantages. Beyond its traditional association with financial resources, capital includes intangible and visible forms such as:

1. *Human Capital (HC)*: The skills, experience, and productivity of individuals within a system.
2. *Social Capital (SC)*: The networks, relationships, and social trust that facilitate collective action.
3. *Natural Capital (NC)*: The finite resources and ecosystems that sustain life and economic activity.
4. *Intellectual Capital (IC)*: Innovations, knowledge, and intellectual property that advance progress.
5. *Cultural Capital (CC)*: Shared norms, traditions, and identity that define societal resilience.
6. *Experiential Capital (ExpC)*: The value derived from accumulated practical knowledge over time.

Goodwin (2003) and others have emphasized the critical relevance of these capital types to sustainable development. Notably, natural capital has historically been neglected despite its foundational role in sustaining other capital forms. Moreover, the emerging recognition of Ethics Capital (EthC), particularly in technology sectors, highlights evolving definitions of value in the sustainable development arena.

2.3 The Endogeneity of Time in Capital

Central to these discussions is the role of time as a dynamic and interconnected component of capital. Time is both a constraint and an enabler of capital accumulation and utilization, and its value has been analyzed in economic literature as a productive stock (Weitman, 1997; Pezzey, 2004). Scholars such as Arrow and colleagues (2011, 2018) have presented compelling frameworks to measure sustainability by incorporating time into assessments of inclusive wealth. Their model acknowledges the influence of population growth, technological innovation, and environmental quality on well-being over time:

$$W(t) = r(t)t + \pi_i(t)K_i(t) \tag{1}$$

Here, $r(t)t$ represents the shadow price of time, distinct from $K_i(t)$, the stock value of other capital assets. This differentiation positions time as a unique, endogenous variable central to understanding intergenerational sustainability.

Arrow and colleagues' work also emphasizes the recursive nature of time-dependent variables in complex systems, challenging conventional economic models that treat time as an exogenous linear progression. Instead, time is conceptualized as an abstract "finite bin" encompassing history, present dynamics, and future possibilities.

2.4 Sustainable Development Goals (SDGs) and Capital Across Time

In the context of Sustainable Development Goals (SDGs), Arrow et al. (2011) developed models to address intergenerational well-being:

$$V(T) - V(0) = \int_0^T r(s)\, ds + \sum_i \Big[\pi_i(T)K_i(T) - \pi_i(0)K_i(0)\Big] - \int_0^T \sum_i \frac{d\pi_i(s)}{ds} K_i(s) ds \qquad (2)$$

This equation highlights the interconnectedness of foresight, legacy effects, and feedback loops. It underscores the need for decision-making frameworks that prioritize dynamic interactions between capital assets and time.

2.5 Challenges of Temporal Capital

Although Arrow's models offer robust mathematical representations of sustainable well-being, they caution against numerical reductionism. Time, like other forms of capital, is subject to socio-political hierarchies and inequities. Its effective integration into sustainable development requires not only technical precision but also an ethical commitment to inclusivity and justice.

By recognizing time as an endogenous variable, sustainable development frameworks can better address the complexities of intergenerational equity, ensuring that the value of all capital assets is preserved and enhanced across temporal scales.

3 A Sociological Perspective: Time and Timing

3.1 Time as an Exogenous Variable

While Arrow and colleagues (2011; 2012) initiated an intellectual debate that shaped the discourse on time as a capital asset, their work continued to resonate through later contributions, including the 2018 Inclusive Wealth Report. In this report, total factor productivity (TFP) was expanded to incorporate natural capital, treating it as a key input in the production process. Managi (2018) observed that by integrating natural capital into this equation, TFP would be more accurately assessed.

This approach highlighted a critical issue: without a nuanced understanding of time as a capital asset, TFP calculations risked overestimating progress, conflating environmental degradation with improvements in knowledge and institutional development. Arrow and colleagues (2012) emphasized that neglecting the temporal aspect of natural capital would distort the economic understanding of sustainability and lead to faulty regression models that misinterpret ecological degradation as a positive shift.

3.2 Time Capital: The Malevolent Cousin of Human Capital

The concept of "time capital" offers a sociocultural perspective on how time is leveraged and extracted from marginalized groups. Anderson (2014) explores this idea in the context of migration, shifting the focus from spatial migration control to the temporal constraints imposed on migrants. In this view, migrants' time is framed as an abstract form of capital that is withheld for future gains, particularly as it is transferred to the broader economy. Anderson notes, "Migrant time was... constantly transferred across to the 'real economy' via the distribution of funds for camp management" (Anderson, 2014, p. 806). This framing positions time as a form of capital, specifically withheld and managed to benefit institutions rather than the migrants themselves.

Further elaborating on this idea, Anderson (2018) highlights the economic exploitation of migrants' time capital within immigration processing camps, where the time spent waiting becomes a valuable commodity. This process exemplifies what he terms the "bioeconomy," where migrants are reduced to their human capital, extracted and utilized for institutional and economic gains. As Anderson states, immigration functions as a form of exploitation that extracts value from marginalized groups, "...at the expense of their time capital asset" (Anderson, 2018, p. 435).

Building on this framework, Achtnich (2021) adds depth to the understanding of time capital within migration contexts. He argues that time capital is not an intrinsic or given asset but rather a product of social relations—shaped through care, labor, and endurance. Time capital, in this sense, is a resource created by those subjected to marginalization, extracted by higher powers in the social hierarchy. Achtnich's analysis underscores the abstraction of time as a capital asset, one that is created through struggle and often siphoned off for the economic benefit of more powerful actors. He states, "'time capital' held by migrants... is produced through social relations of care, labour, and endurance, the very fabric that constitutes vitality, from which a suite of actors profit" (Achtnich, 2021, p. 12).

4 An Artistic Analysis: Time and Climate Change through the Brush

4.1 17th Century Dutch Still Lifes: Time as a Capital Asset

The 17th-century Dutch still life, or pronk (meaning "show"), reflects the economic revolution of its time, where artists became increasingly aware of their labor as a valuable commodity. These works were expected to be not only exquisite and pious but also lavish, as they depicted the opulence of the Dutch Golden Age. Trentmann's Empire of Things: How We Became a World of Consumers (2016) details how only a select few Dutch artists, such as Vermeer and Dou, had the skill, patronage, and access to the rich objects that populated their studios. These artists became keenly aware of the time spent on each piece, and this labor contributed significantly to the pricing of their works. The concept of "time capital" emerged as a central element in their craft.

As Tokumitsu (2016) observes, "Dou's real-life timekeeping indicates that at least in his own practice, the hours of the day were capital assets, essential to his enterprise, and, like tobacco,

candles, and his fastidiously finished paintings, they were for sale." Dou's still lifes, including vanitas depictions, subtly comment on the dual nature of time: it is both eternal and immeasurable, yet it is also finite and not to be wasted. By integrating time as a capital asset into his artwork, Dou offered a nuanced moral commentary on the way time was valued in society.

Artists like Davidsz and Dou further symbolized this concept of time capital in their works by incorporating precise time indicators such as exquisite clocks, hourglasses, and candles—each serving as a representation of the limited nature of time within the production of commodities. This use of time as a marketable asset reflected an emerging consciousness among artists, who were starting to factor the "shadow price" of time into the value of their work, thereby developing an endogenous time variable within their pricing structure.

4.2 Pollution and Time in English Pigment Choice

While Dutch still life painters were focused on incorporating time as a capital asset, 19th-century British artists, though perhaps unaware, were capturing the influence of anthropocentric time on natural capital, particularly through their use of pigments. British painter J.M.W. Turner, known for his depictions of sunsets and sunrises, painted ethereal glowing orbs of light that changed in their hue over time. Around 1853, viewers began to notice a shift in the pigments Turner and other artists used, a change that coincided with the volcanic eruption of Mount Tambora in 1815, whose atmospheric sulfate pollution significantly impacted air quality.

Zerefos and colleagues (2007) explored the effects of volcanic eruptions on the work of famous artists by examining the correlation between volcanic events and the pigments used by painters. In their study, they tracked the annual mean aerosol optical depth (AOD)—a measure of solar voltage through polluted air—and the Dust Veil Index (DVI), a qualitative measure of atmospheric residue. The data revealed a strong correlation between these two variables over time, particularly after major volcanic eruptions like Tambora in 1803.

In a follow-up study (Zerefos et al., 2014), the researchers found that AOD levels continued to rise during the 19th century even outside of volcanic events, suggesting that anthropogenic factors, such as industrial pollution, were increasingly influencing the atmosphere. These findings indicate that the shift in pigment choice by British artists like Turner was not only a result of natural events but also the beginning of the visible impact of industrial pollution on the natural environment, a change that can be traced through the brushstrokes of artistic history.

5 Conclusion and Future Directions

In conclusion, time can be understood as a social imaginary—a construct that is inherently finite, much like the dwindling supply of granular sand in the concrete industry. It is both a tool and a constraint, shaped by both endogenous and exogenous forces. As such, the question arises: is sustainability akin to a 17th-century Dutch pronk, told through the changing pigment choices of 19th-century British artists? This metaphorical parallel underscores the evolving ways in which time, as a concept and a resource, influences both human action and environmental impact.

Looking ahead, future research could benefit from an endogenous time-window analysis of development, which would offer insights into the temporal limits of sustainability. Luukkanen et al. (2015) suggest that "the use of different indicators and different base years for the dynamic analysis of the Sustainability Window can yield information on the limiting factors of sustainability as a function of time, shedding more light on the complex development process and related synergies and trade-offs." Such an approach could provide a more nuanced understanding of how time constraints shape sustainable practices, and how these constraints might be mitigated through deliberate planning.

One possible direction for future exploration is borrowing temporal frameworks from other disciplines—even those that might initially seem tangential or overly abstract. For instance, the hyperboloid topology of a wormhole presents a paradox that could offer a fresh perspective on the Sustainable Development Goals (SDGs) with respect to time. Much like the sands in an hourglass, time capital is spent moving through a system, where the radius of origin—or path—determines how that capital is distributed. Time, in this framework, is neither purely endogenous nor an asset to be capitalized on; rather, it is an exogenous variable that is manipulated by social power dynamics and coded into dependent variables that shape policy decisions.

As we move forward in both research and policy development, it is crucial to account for the role of time—particularly how time preferences, whether consistent or inconsistent, influence decision-making. The temporal frameworks discussed throughout this paper highlight the complex relationship between time, sustainability, and power, offering new avenues for understanding and addressing the challenges of sustainable development in an ever-changing world.

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