Substitution chains

A prolegomenon for sustainable resource policy

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Abstract

Sustainability requires a non-declining stock of wealth assets to be maintained for future generations. To achieve this, the Hartwick rule posits that rents from non-renewable natural resources should be substituted for other forms of capital. However, most economic analyses posit that resource rents should be redistributed, not necessarily substituted, through taxation. This paper formalises the distinction between these two approaches- capital substitution versus resource redistribution. I argue resource policy is largely synchronic in orientation, emphasising intratemporal justice and redistribution. Conversely, sustainability exhibits a diachronic orientation, emphasising intertemporal justice, and wealth maintenance through substitution. The synchronic bias obscures the manifold ways that wealth is substituted. To characterise these diverse ways natural is substituted with produced capital, I advance the heuristic of transcapital substitution chains. *Presenting evidence that such chains operated during Australia's mining boom, I suggest that policy must either design hermetic rent taxes, or support economy-wide savings.*

introduction

How to manage non-renewable natural resource wealth is a key question of economic policy for many countries. In 2014, total global mining production was over 17 billion metric tonnes, with a value of US$5.4 trillion (Reichl et al 2016: 38). Of that, $3.8 trillion was traded internationally (WTO 2015: 84). How should governments go about exploiting mineral assets? If they grant concessions to private enterprises for access to mineral deposits, how should they charge for the use of those minerals and what share of the proceeds should go back to society at large? What policy instruments are best-placed to capture those proceeds? And, perhaps most importantly, what should those proceeds be spent on, and when? The irreplaceability and exhaustibility of mineral commodities present unique challenges that straddle the economic, political and environmental spheres. At the crux of the challenge is the notion of resource rent, wealth that is owned by the entire nation, that is unearned, and which in privatised mining industries must be retrieved from mining companies by the government and returned to the broader community.

A growing literature of sustainability economics frames natural resource commodities as 'natural capital', a wealth asset that can be liquidated and re-invested, but which ultimately belongs to the entire nation (Helm 2015). At the heart of the natural capital argument is the Hartwick (1977) savings rule, which posits that in order to achieve sustained prosperity, natural capital must be perfectly substituted with different kinds of capital. The Hartwick rule implies that resource rents must be reinvested. In response to the savings imperative of the Hartwick rule, many analysts have proposed increasingly sophisticated taxes to capture those rents, but given the limitations of rent taxation, no-one has persuasively demonstrated the viability of a Hartwick-accordant rent tax; in all instances, substantial resource rents flow straight into the private economy. This raises the question: is capital substitution possible in the absence of a hermetic rent tax? And then: why is there such disproportionate focus on rent taxation given its essentially insurmountable limitations? In this paper, I argue that the tax-myopia is due to an overemphasis on efficiency and equity, rather than a sustainability focus on capital substitution.

I distinguish these two contrasting approaches to resource management based on their divergent temporal emphases. The first posits that the objective of resource policy is the efficient and equitable (re)distribution of natural resource wealth. As the emphasis is on vertical justice, or a just distribution at a given point in time, in this paper, I call this approach the *synchronic* approach. The second approach posits that the objective of resource policy is the efficient substitution of natural capital for produced capital. Given the emphasis here is on horizontal justice, or a just distribution across time periods, I call this approach the *diachronic* approach. The synchronic-diachronic dichotomy echoes the vertical-horizontal dichotomy, but I suggest is a broader concept because it encapsulates not just the conceptualisation of justice, but the policy objectives, instruments and priorities they each entail. This is explored further in Chapter 2. I argue that the literature has overwhelmingly advanced synchronic arguments for the taxation and reinvestment of resource rents. From the sustainability viewpoint, this approach is inherently limited, because, first, it inevitably means the bulk of resource rents will remain in the private economy, and second, it is silent on the role of substitution.

The diachronic approach, with its focus on capital substitution, is fundamental to sustainability. To underscore this approach, I advance the heuristic of a substitution chain, an unbroken sequence of transmutations in the liquidation-capture-reinvestment nexus through which resource rents are converted from natural into produced capital. The theory posits that there are manifold plausible concatenations between natural capital and its infinite potential substituted forms, and, more forcefully, that no particular configuration is preferable to any other; it is the act of substitution that is relevant, not the process through which it takes place[1]. This conceptual repositioning allows rent taxation to be reframed as one of a variety of substitution chains, and suggests that more work must be done to compensate for the inability of taxes to completely capture rent. This argument therefore calls for an epistemological pivot in the economics of sustainable natural resource exploitation, positioning the concept of substitution chains as a prolegomenon- a preliminary discussion or treatise- for a genuinely sustainable resource economics. In essence, if the objective of resource policy is to sustain wealth across generations, then both the government and private sector are equally capable of investing resource rents, and the relevant question is whether it is possible or desirable to track and direct rent flows between

[1] Importantly, by 'substitution', I refer specifically to transcapital substitution, the liquidation of one form of wealth capital and equivalent reinvestment in another, as distinct from other uses of the term in economics such as product substitution, or investment-to-consumption substitution. This is following the 'sustainability as capital maintenance' approach detailed in Chapter 2.

them. Substitution chains draw attention to both the relevant outcome (transcapital substitution), and the processes through which that takes place (both public and private).

This paper is structured in four chapters.

Chapter 1 provides an overview of the analytical debate around sustainability, and positions my approach within that. I outline the notion of sustainability as intergenerational wealth transfer as laid out by Hamilton & Hepburn (2014). It explains the conceptualisation of resource rent implied by the Hartwick rule, and adopted by economists of sustainability, as a stock of capital assets capable of providing long-lasting income through its substitution for other forms of capital. I characterise this position as exhibiting a diachronic orientation, concerned as it with wealth maintenance over time.

Chapter 2 elaborates what I describe as the synchronic orientation of mainstream debates around resource policy. I will consider Australian resource policy through its recent mining boom to argue that non-renewable natural resources are conceptualised primarily through synchronic arguments around redistribution, and that this leads to an an overdetermination of the role of the state in managing resource rents, while obscuring the actual flow of rents through the private economy that is crucial to the substitution process.

Chapter 3 attempts to resolve this tension by introducing the notion of a substitution chain. I argue that since some rents inevitably end up as financial capital belonging to both investors and employees of mining companies, satisfaction of the Hartwick rule requires that those rents also be substituted. I lay out a positive conceptual model of substitution chains, and argue that the Hartwick rule can only be satisfied if the investment coefficients, which indicate the proportion of rent windfall received by all rent beneficiaries that is spent on investment in capital, are equal to one. In this chapter, I will provide some incipient evidence that private substitution chains have been in operation during the Australian mining boom.

Chapter 4 outlines the implications of my model, proposing three policy responses based on substitution chains. I assert that if a hermetic rent tax combined with a robust investment mechanism, can be designed, it is the preferable outcome as it satisfies both synchronic and diachronic priorities, by achieving redistributive capital substitution. I suggest that this would take the form of a system of reverse auctions for mining permits followed by a rigorous public investment scheme. A second policy response would be a tripartite rent tax, complementing a corporate rent tax with similar taxes on other recipients of rent flows (employees and shareholders). Thirdly, if it is impossible to directly track rent flows, the only option is articulating an aggregate savings target for an economy as a whole, indexed to fluctuations in rent windfalls.

Finally, I conclude. Philosophically, this paper rejects what I regard as the supererogatory ethical treatment of rent substitution in synchronic economics. That is, I reject the notion, implicit in synchronism, that reinvesting resource rents is a laudable policy goal, but it is not absolutely required and is secondary to redistribution. Rather, with its genesis in the perfect substitution imperative implied by the Hartwick rule, this paper advances a deontological ethic of rent management, that any substitution less than unity is a violation of the principle of diachronic justice. Therefore, by abnegating the accumulation of debts to be borne by future generations, I advance a form of fiscal conservatism, but one that applies not just to financial capital but to all forms of capital. This paper calls then for a political economy of natural resource management based on the notion of capital conservatism.

chapter 1.
sustainability as capital maintenance

1.1 Background to sustainability

Sustainability is fundamentally about the durability of systems and processes. In the context of human development, the meme of sustainability has come to encapsulate a generalised sense that economic development as it is currently unfolding is destroying the foundation upon which it relies and therefore cannot be trusted as a guide to improving human welfare in the long run (Dasgupta 2001). Environmental and ecological sciences have accumulated incontrovertible evidence of enormous and persistent market failures from climate change (Stern 2007), to catastrophic biodiversity loss (Cardinale 2009), to alarming disruptions of biogeochemical cycles (Rockstrom et al 2009). These deleterious phenomena stem from the proclivity of neoclassical economics to regard the natural environment as both an inextinguishable source of valuable materials, and an indestructible repository for all forms of waste (Dasgupta 2010; Pezzey & Toman 2005; Raworth 2012). Environmental economics has attempted to reconcile this tension by bringing the environment into the economic system as a form of wealth capital, and calling for economic activity that does not reduce aggregate natural capital (Bowen and Hepburn 2014: 409).

There are three broad views on this highly contested relationship between the environment and economic growth (Hepburn and Bowen 2012)[2]. The first posits that "green growth is almost tautologically required for global welfare to rise in the long run" (Bowen and Hepburn 2014: 407). This implies that destroying the environment, upon which all economic activity ultimately depends, will undermine long-term economic prospects, and by implication that it is both possible and necessary to 'decouple' economic growth from resource exhaustion. Various theorists have advanced visions of a post-material economy, specifically a "weightless economy" where exchanges are in non-material products and services (Coyle 1998); a "circular economy" whereby all material is recycled in a closed loop (Ellen MacArthur Foundation 2012); a "donut economy" whereby environmental degradation is permitted within prescribed ecological limits (Raworth 2012); and the "intellectual economy" whereby material consumption plateaus and the intellectual or creative economy is the source of growth (Hepburn and Bowen 2012). The second view is that economic growth can be indefinitely sustained because technological innovation overcomes environmental limitations and decreasing returns to capital (Bowen and Hepburn 2012: 7). The third view is that sustainable or green growth is oxymoronic, because economic growth is not possible without resource depletion and environmental degradation. This neo-Malthusianism has spawned notions of the steady-state economy (Daly 1992), and "prosperity without growth" (Jackson 2009) whereby the ineluctable limitations of the planet are purported to present a final barrier to growth. This thesis advances the first of these arguments, postulating that environmental limitations constitute a surmountable obstacle to economic growth, and therefore that stringent conditions must be adhered to in order to avoid resource depletion. More specifically, this thesis asks: what role do non-renewable natural resources play in achieving sustained improvements in human welfare? This is a central question of sustainable development.

1.2 Operationalising the Brundtland definition

The foundational definition of sustainable development is that of the Brundtland (1987) report: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This is the starting point for my discussion. The Brundtland

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[2] Bowen & Hepburn (2014) consider the debate around 'green growth' as distinct from 'sustainable development'. They follow the OECD (2011) in stating that green growth is a subset of sustainable development specifically concerned with the conditions under which economic growth can be reconciled with resilient ecosystems. However, the role of non-renewable natural resources is the same under both concepts, so the conceptual differences, which are highly debated, are not germane to my discussion.

definition has provided a broad philosophical anchor for the concept of sustainability, but is open to multiple interpretations (Pezzey 1992). It has variously been interpreted to mean that sustainability requires non-declining utility (Pezzey 1989), non-declining intertemporal welfare (Riley 1980), and maximum sustainable utility (Arrow et al 2004). Each of these iterations calls for slightly different policy prescriptions, but a single question underpins them all: how can we know whether or not we are compromising the ability of future generations to meet their needs? If we accept that Brundtland implies we should have at least non-declining utility[3], and therefore non-negative changes in the flow of consumption possibilities over time (Dasgupta & Maler 1999), how can we know whether this is being achieved? There are two problems here, the time-orientation, and the nature of needs. First, sustainability is intrinsically diachronic, it relates to successive points in time, and second, it is speculative, we cannot know in advance what the needs of future generations will be. Dasgupta & Maler (2001) frame each of these problems in terms of a dichotomy.

Firstly, in conceptualising the nature of needs, they distinguish between constituents and determinants of wellbeing (Dasgupta & Maler 2001). Constituents are the things which actually make up the wellbeing of an individual, for instance, health, freedom, happiness (Dasgupta & Maler 2001: 3). The determinants are the factors that *produce* wellbeing, for instance, food, clothes, resources (Dasgupta & Maler 2001: 3). One key obstacle in seeking to account for the welfare of future generations, is that it is impossible to predict what their needs will be. Logically, the ability of a generation to meet their needs is dependent not only on the nature of their needs, but their assets, and their ability to make use of those assets. This position draws on the idea that a just distribution of goods diverges from a formally equal distribution of goods insofar as it is modulated by the differing abilities of individuals to make use of those goods (Sen 1992). Therein, it echoes Kymlicka's (1995) multiculturalist critique of Rawlsianism to suggest that just as culturally distinct groups may need different goods in order to achieve the same ends, so too may temporally distinct groups need different goods to achieve the same ends. Dasgupta and Maler's distinction between the constituents and determinants of wellbeing is a resolution to this obstacle.

[3] As with the debate around the definition of green growth, each of these interpretations calls for the same role for non-renewable natural resources, so I will not dwell on defending a specific interpretation. I select the notion of non-declining utility (Pezzey 1989) because I regard it as the most conservative interpretation.

Instead of attempting to prophesise what the constituents of wellbeing will be in the future, sustainability should attempt to sustain the determinants of wellbeing, such that future generations can derive their own constituents of wellbeing as they see fit. Hence this approach emphasises self-determination, with each generation being empowered to make decisions about its own development, without constraining the set of possibilities available to the next generation. In that sense, it is not up to today's generations to ensure that future generations make good decisions, but to ensure that they are not prevented from making decisions at all because of actions of their predecessors. In practice, this is obviously impossible. The physical infrastructure we choose to invest in obviously constrains the possibilities for the future. If we do not build roads, people will be unable to drive. If we do build roads, people will be less able to do something else. So the idea that by focussing on the non-declining asset base is not constraining possibilities is clearly fallacious. However, it is a best approximation.

Second is the notion of current versus perpetual wellbeing. In essence, improvements in current wellbeing are not necessarily improvements in sustainable wellbeing, for instance if current consumption is being fuelled by the liquidation of, or underinvestment in, capital assets, such that future consumption and therefore wellbeing will decline. Therefore, any measure that focusses on economic (or any other kind of) performance at a given point in time, says nothing about the ability of that level of wellbeing to be sustained into the future. Sustainability suggests that "economic development should be evaluated in terms of its contribution to intergenerational wellbeing" (Arrow et al 2010). This means that "each generation should bequeath to its successor at least a large a productive base as it inherited from its predecessor" (Dasgupta & Maler 2001: 4). Measures such as GDP and the Human Development Index, both measure performance at a given point in time, that is, they are synchronic measures of progress. They measure a synchronic outcome, rather than the ability of a society to achieve the same outcome in the future. Sustainability therefore calls for a diachronic measure of the determinants of wellbeing. Diachronism calls then for a measure of stocks rather than flows, since it is the size of the stock of wealth from which the flow of income is derived, rather than the size of the flow itself, which indicates how long it can be sustained (Common & Stagl 2005: 88). This justification has been used to suggest that wealth is the "criterion for sustainability" (Dasgupta & Maler 2001), and therefore that a measure of the growth of capital assets is the appropriate metric for sustainable growth.

1.3 Natural resources as capital assets

In the sustainability lexicon, wealth is not simply financial wealth, but "also consists of physical capital, natural capital, human capital and its creative wealth" (Ploeg 2014: 146). Correspondingly, the value of consumption is function of this total wealth base. The key implication of this insight is that calibrating the progress of society through measures of output, specifically GDP, are not true representations of the wealth of a society because of the extent of the omissions. Rather, "genuine wealth" can be understood to consist of the current account, plus investments in all forms of capital, minus depreciation of all forms of capital (Ploeg 2014: 147). Accordingly, a country is said to become richer of the change in genuine wealth, or genuine savings is positive, and poorer if the genuine savings is negative (Arrow et al 2003). By extension, the status of the current account cannot in isolation be used to diagnose the health of an economy (Ploeg 2014: 147).

This 'capital assets' approach frames non-renewable natural resources as a form of natural capital, and "once nature is viewed as a set of assets it can be valued in economic calculations" (Helm 2015: 6). By conceptualising natural capital as a factor of production, both valuable and exhaustible, then depletion of resources constitutes a liquidation, rather than a generation, of wealth. This distinction means that instead of exploiting resources as fast as possible, we should do so under strict conditions, conditions which have been formalised in a series of rules. Hartwick (1977) showed that without technological change, sustainable consumption is possible despite resource exhaustibility if net saving everywhere is zero, (that is, capital accumulation compensates perfectly for resource depletion), which in turn requires that the elasticity of substitution between resources and capital is one (that is, they are perfectly substitutable). This model generated the Hartwick rule, which "achieves zero net savings in an exhaustible-resource-dependent economy by requiring that the scarcity rents from natural resource depletion be re-invested in reproducible capital" (Randall 2008: 79). The level of rent is determined by the Hotelling rule. Hotelling (1931) pointed out that leaving minerals in the ground entails an opportunity cost equivalent to the return that the illiquid mineral capital could be accruing in a substituted capital form. Similarly, extracting resources entails an opportunity cost because they cannot then be extracted in the future. As such, the "marginal revenue of natural resources sold on world markets should equal the sum of their marginal extraction cost, plus their Hotelling rent" which should grow at the market rate of interest (Ploeg 2014: 150). In short, then, the Hartwick rule posits that Hotelling rents from non-renewable natural resources should be reinvested in produced capital in order to sustain constant consumption over time. The simple premise of the Hartwick rule is that "the depletion of a natural resource is in effect the liquidation of an asset and therefore should not appear as a positive contribution to net income or net savings" (Hamilton & Clemens 1999: 334).

1.4 Substitution in the Hartwick rule

Critically, though, the Hartwick rule relies on assumptions about capital substitution elasticities that are highly contested. It is well documented that if the elasticity of substitution between natural and produced capital is less than unity, then the Hartwick rule fails (Dasgupta & Heal 1979; Hamilton 1995; Randall 2009; Pearce & Atkinson 1993). And yet "there is no empirical evidence that the relevant elasticities of substitution are zero" (Pearce & Atkinson 1993). The Hartwick rule has come under harsh critique for this assumption given that evidently there are intrinsic limits in nature that cannot be transgressed without significant fallout (Rockstrom et al 2009; Arrow et al 2004). In general "economists have too readily treated this substitution as straightforward and paid too little attention to the constraints of nature on man-made capital and labour" (Helm 2015: 8).

This debate over the limits to substitution can be characterised into two broad camps (Dietz & Neumayer 2007). Strong sustainability asserts that there are limits to capital substitution, and distinguishes critical from non-critical natural capital, arguing that the former cannot be substituted for any alternative form of capital (Brown et al 2005: 373). Weak sustainability posits that there are no such constraints on capital substitution, that the relevant factor is the total size of the capital stock, rather than its constitution (Brown et al 2005: 373). Common and Stagl (2005) demonstrate the difference algorithmically through production functions. Assuming zero substitution elasticity, they use a Leontief production function to simply illustrate that "with no possibilities for substitution, capital accumulation and technical progress cannot overcome the fundamental problems presented by the use of a non-renewable resource in production" (Common & Stagl 2005: 221). Equally, infinite substitution is clearly implausible; no share portfolio is worth the last tree on Earth. Conversely, they use a Cobb-Douglas production function to demonstrate that an economy can grow indefinitely despite a declining stock of non-renewable natural resources provided the non-renewable resources can be sufficiently substituted for other forms of capital (Common & Stagl 2005: 221). The reality, then, clearly involves some form limited asymptotic substitution between natural and produced capital, whereby, crucially, resources simply cannot be depleted. The simple conclusion is to restate two polar truisms: that some conversion of natural capital is essential to human development, but that there are intrinsic untraversable limits to that process. This model of sustainability recognises that "since some natural capital forms are irreplaceable or have critical levels, this means that, when near these critical levels, the marginal rate of substitution in production and the marginal utilities of consumers will tend to infinity" (Mota 2010: 1935).

Helm articulates a possible middle ground through an "aggregate natural capital rule" which rejects equally, on the grounds of ethics and practicality, the extremes of both infinite and zero substitution (Helm 2015). The aggregate natural capital rule posits that natural capital can be depleted so long as there is equivalent replenishment of natural capital elsewhere such that the aggregate is non-declining (Helm 2015: 64). This definition necessarily encapsulates the Hartwick rule, implying that economic rents from non-renewable resources must be reinvested, but goes beyond it, by asserting that renewable natural capital must indeed be renewed. It is important to note that substitutability of non-renewable natural resources is fundamentally different, to renewable or biotic resources. As inert, abiotic, subterranean substances, minerals provide essentially zero ecological function[4]. The renewable component of Helm's aggregate natural capital rule is therefore irrelevant to my analysis. As such, I will adopt a weak sustainability prescription for this thesis, assuming that the elasticity of substitution is indeed one, that mineral resources can be infinitely substituted for other forms of capital.

1.5 Measuring the Hartwick rule

If we accept the premise of the Hartwick rule, then, how do we know if our modes of mineral extraction are satisfying it? A variety of methodologies have been proposed to monitor capital maintenance, all of them centring on a basic identity that seeks to operationalise the Hartwick rule:

$$\Delta \text{ Wealth} = \Delta \text{ (physical)} + \Delta \text{ (natural)} + \Delta \text{ (financial)} + \Delta \text{ (human)} + \Delta \text{ (social)}$$

Since this approach was pioneered by Pearce & Atkinson (1993), over 600 indices of sustainability have been developed that employ variations of this identity to give a headline

[4] Obviously the process of mineral exploitation can involve significant environmental damage, and the refinement and manufacturing process, as well as combustion in the case of fossil fuels. Internalising externality costs is clearly a critical consideration for capital maintenance, but is beyond the scope of this paper, which is exclusively focussed on substitution of the minerals themselves. For this reason, I can adopt a weak sustainability approach.

macroeconomic indicator of the sustainability of an economy (Bohringer & Clemens 2007). The most prominent is the World Bank's "adjusted net savings" (ANS) approach which begins with gross national income, makes deductions for the depreciation of physical capital, depletion of non-renewable natural resources and damage from carbon dioxide and particulate emissions, and additions for public expenditure on education as an investment in human capital (World Bank 2015). ANS or genuine savings analyses exist for many countries (Brown et al 2005; Ferreira & Moro 2011; Gnègnè 2009; Hanley et al 1999; Nourry 2008; Pillarisetti 2005), but these approaches have a number of clear limitations.

Firstly, most do not count all forms of natural capital depletion (Randall 2008). Second, they do not count all forms of depreciation in other capital assets e.g. human cap (Arrow et al 2004). Third they do not count all forms of re-investment in capital (World Bank 2015: 277). Fourth, they do not consider the quality of investments or returns on investments (Brown et al 2005). Fifth, they ignore technological change and population growth (Pezzey 2004). Sixth, there is no standardised methodology to normalise the various inputs (Bohringer & Jochem 2007). Seventh, even if you could properly measure the total wealth base, there is no inevitable link between aggregate consumption possibilities, and social welfare. We know that the welfare benefits of consumption follow a non-linear function, resulting in declining marginal utility of consumption, such that overall welfare will be heavily influenced by the distribution of access to the wealth, rather than just the size of the base itself. By emphasising merely the capital base, sustainability occludes this nuance. Eight, no indicator even attempts to estimate commensurability of capital, that is, whether the specific natural capital being depleted is sufficiently compensated for, or whether it constitutes unsubstitutable natural capital under a strong sustainability prescription. The ideal indicator would recognise that capital substitution is both the engine of, and the biggest threat to, economic growth. But we do not know how to do this. Clearly, the data limitations on these methods are manifold and non-trivial.

Because of the inherent limitations in how we measure capital stocks, and the uncertainties in the response of the natural world to perturbations, there are growing calls to consider sustainability indicators 'one-sided tests of sustainability', that is, negative genuine savings definitely indicates negative welfare growth, but positive genuine savings does not guarantee positive welfare growth (Pezzey & Toman 2002: 184-5). For instance, Hamilton and Hartwick (2005) posit that positive genuine savings is a component of a feasible weak sustainability prescription. Arrow et al (2004: 168) similarly conclude that "given the vast uncertainties associated with the estimates, even when point estimates are positive, there may remain significant possibility that genuine investment is negative". I disagree with this analysis.

Simply put, the notion that ANS-style measures can be used as one-sided tests assumes that the data limitations are only on one side of the equation. That is, they assume that greater granularity and availability of data could only ever reveal greater depreciation of capital assets than the algorithm currently asserts. But that could only be possible if the algorithm could categorically be assumed to have accounted for all forms of capital appreciation. Yet this is manifestly not the case. The data points nominated by the analysts are by no means a collectively exhaustive account of all possible investments in capital, in fact they are tiny proportion. Most consider government investment in education as the only source of capital appreciation (World Bank 2015). This ignores of course, all other forms of government investment, and many forms of private investment. In Section 3 I will return to this argument, but at this point I merely want to underscore that indicators of sustainability are not at all one-sided. Greater data availability on this side of the ledger could very plausibly reveal greater than expected investments in capital and therefore greater appreciation than depreciation of capital. Therefore, at best, such indicators of sustainability can be said to be extremely tentative.

1.6 Conclusion

To summarise the logic of the sustainability literature, the objective of non-renewable natural resource policy is the efficient substitution of natural with produced capital. Its temporal orientation is diachronic, implying an emphasis on horizontal justice, justified by the claim that resource rents are the possession of the nation itself, not the people who happen to be alive in a nation at a given moment, and the heuristic that this points to as the appropriate locus of analysis is the set of transmutations in the liquidation-capture- reinvestment nexus through which resource rents are substituted from natural into produced capital. I have argued that the prevailing methodologies for assessing whether substitution is taking place are significantly constricted in scope, since natural capital is inevitably converted into financial capital, which is distributed between governments and the private economy, and can then be invested in any form of capital, or consumed. Most capital accounting methods, based in the ANS identity, fail to account for the full variety of ways in which resource rents flow through an economy.

chapter 2.

synchronic resource taxation

2.1 Introduction to synchronism

In contrast to the diachronism underpinning sustainability economics, I argue that most literature on resource policy advances fundamentally synchronic arguments for the taxation and redistribution of resource rents. This basic approach, privileging the role of the state in taxing and saving through sovereign wealth funds, has reached the level of consensus, constituting the basis for the 'guidelines for exploiting natural resource wealth' (Ploeg 2014). The synchronic approach has four characteristics. First, it posits that the object of resource policy is the efficient and equitable redistribution of resource wealth. Second, its emphasis is on vertical justice (justice within a society at a given point in time). Third, its moral premise is that resource rents belong to all citizens of a country, and fourth, its preferred policy instrument is a redistributive rent tax.

In this section I outline how the debate over resource policy in Australia has developed in an almost exclusively synchronic framing, and therefore has limited currency in debates over sustainability. Central to my thesis is the distinction between synchronic and diachronic economic orientations, and the different policy prescriptions each of them suggest. In section 1, I extensively outlined the diachronic position. In order now to illustrate the synchronic rationale for resource policy, this section involves a detailed elaboration of the policies around the Australian mining industry. In elucidating how Australian resource policy is anchored in a synchronic orientation, I hope to underscore the drawbacks of that position from a sustainability perspective.

2.2 Background to the Australian case study

Australia has perhaps the most generous endowment of natural capital of any country in the world. Charlton (2014: 16-7) notes that:

> Australia has the largest demonstrated lodes of uranium, nickel, lead, zinc and brown coal of any country in the world; the second-largest demonstrated reserves of bauxite, copper and silver; and the fourth-largest reserves of iron ore. In all, Australia has a staggering 19 per cent of the world's total known mineral wealth.

Australia's economic development since colonisation in the 18th century can be seen as a process of "industrialising natural capital", converting natural into produced capital (Greasely 2015). In the 1880s, the discovery of gold near Ballarat and the subsequent goldrush made the fledgling British colony into the seventh-richest country on Earth (Charlton 2014: 13). In the late 1990s, skyrocketing demand from a rapidly growing China fuelled a second major mining boom, this time for construction and energy minerals such as iron ore, bauxite, coal and nickel. Chinese demand for iron ore increased 750 per cent, and the mineral price rose to 600 per cent above 2002 levels (Robson 2015: 307). As a key commodity supplier, the economic impacts on Australia were considerable. Over the period 2003-12 Australia's terms of trade rose 87 per cent (Robson 2015: 309) and across a similar period real per capita household disposable income rose 10 per cent (Downes et al 2014: 1). The government windfall has been estimated at anywhere between $180 billion (Hetherington & Prior 2012: 3), to $334 billion (Charlton 2014: 64).

Despite a century-long interstice, the taxation regime for the 21st century boom was fundamentally unchanged since the 19th century one. Australia's mining taxation regime retains significant state-based resource taxation regimes largely because of the significant revenues that were available to the colonial governments after the gold rush in the decades preceding Federation (Eccleston & Wooley 2014: 4). The state-based taxes are based on royalties, payments made by a contracted or licensed party (e.g. a miner) to another party (i.e. the government) who owns a particular asset, for the right to use that asset (MCA 2008: 8). This set of "laws and norms that hail from the 19th century colonial era" have been critiqued as "colonial baggage" ill-suited to the contemporary economy (Cleary 2016: 152). Garnaut and Brown (1983: 251), writing well before the current boom, argue that:

> This bewildering array of royalty arrangements has grown historically through large numbers of ad hoc decisions, and has no obvious economic rationale. Arrangements within each state have been unstable over time, with royalty rates often being raised at times of high profitability in the mining industries. The Australian system of mineral rent taxes is highly unstable, does not on the whole perform well on the criterion of revenue maximization, and is a significant source of distortion of investment and production decisions.

Royalties are levied as output-based taxes, one of two broad types of resource taxes identified in Hogan's (2012) taxonomy. Royalties can be either be ad valorem, whereby the royalty is calculated as a constant percentage of the value of a unit of output, or volumetrically, whereby a constant dollar amount is levied per physical unit of output (Hogan 2012: 250). Ad valorem royalties are seen to be preferable to volumetric ones as the latter bears no relation to the value of the commodity and is therefore inappropriately inelastic for a fluctuating commodity market (Cleary 2016: 153). Each state has its own royalty system, with a set royalty for each mineral, and often multiple royalties for the same mineral, sometimes different rates for different mines, and no interstate legislative uniformity (MCA 2008: 8). New South Wales has over 100 different royalties, including volumetric ones (Cleary 2016: 153).

2.3 Theory of resource taxation

There are generally five factors involved considering the merits of tax policies. First, efficiency involves levying taxes which involve the least distortions the economy. The Henry Tax Review articulates that "the efficiency cost depends on whether people change their behaviour in response to the change in price" (Henry 2008: 247). Second, equity refers to the extent that the tax burden is distributed fairly within society. This is usually taken to refer to progressive taxation systems whereby the level of tax increases with level of wealth. Third, is the extent of the revenue collection. A well designed and equitable tax is useless unless is delivers revenue to the government. Fourth is government risk, meaning the reliability and predictability of the revenue take. Fifth is administrative or compliance cost, the cost incurred by the government of designing and implementing the tax and the costs to investors of complying with it. In short, the objective of tax policy is generally seen to be raising sufficient revenue to cover legitimate government expenditures in the least costly way, with the tax burden equitably distributed across the economy.

It is against these criteria that royalties, both ad valorem and volumetric, are seen to be unpalatable. Firstly, they distort decisions about production volumes and investment and lead to early closure of mines by eroding profit margins (Kellow 2016: 143). Second, they impose a regressive cost on firms, because they are forced to pay the impost before, and often regardless of making a profit (Cleary 2016: 154). Thirdly, because the royalty rates are generally inelastic, "governments are likely to collect an inadequate share of the resource rent, particularly during periods of relatively high industry profitability" (Hogan 2012: 245). This leads to a situation in which unprofitable firms pay a disproportionately high and commercially unviable amount of tax, and super-profitable miners pay a disproportionately low and commercially negligible amount of tax. Royalties therefore are prone to capturing both too little and too much tax, in different market conditions.

Moreover, because they are state-based, and state governments are less able than the Commonwealth to leverage favourable agreements with miners, effective tax rates are well below statutory rates, and approval processes are generally weak (Cleary 2016: 155). For instance, in 2010, as against a 30 per cent statutory tax rate, the effective company rate for the Australian mining sector was 17 per cent, and only 13 per cent for large multinationals like BHP Billiton and Rio Tinto (McKnight & Hobbs 2013: 313). This is consistent with earlier estimates the effective tax rate for mining companies in Australia in 2008 was 16.4 per cent (up from 8.7 per cent in 2007, and the lowest of six major commodities exporters), and the average global effective tax rate for the mining industry was 23 per cent (Kerr 2009: 5). In short, royalty regimes are demonstrably ineffective at capturing appropriate returns to the public on mineral assets.

In light of these inadequacies, there is general agreement that resource taxes should be based on rents rather than output royalties. The concept of economic rent generally refers to "the excess payment received by a factor of production over the minimum required to induce it to do its work" (Wessel 1967). That is, it is a payment to a factor of production (i.e. capital or labour) beyond that which is necessary, or 'normal' and therefore constitutes an abnormal or 'super-profit' (Henry 2010: 171). Rent is therefore conceptually distinct from the normal risk-free component of profit, as well as the risk premium which is regarded as the compensation to capital for entrepreneurship. Rather, it is the difference between the risk premium, and the price. In commodities markets, mineral prices fluctuate drastically, meaning world prices can be substantially higher than firms' cumulative production costs and normal return to capital. As such, private firms are often the beneficiaries of significant windfalls of resource rent (Hogan 2012: 248-51).

There are two key implications of this theory. First, because natural resources belong to states themselves, and states contract private firms to extract those resources on behalf of the state, whilst firms are entitled to normal compensation for their efforts, the resource rents are understood to belong to the state itself. Secondly, since rent is by definition the returns in excess of what is needed to sustain factors of production, governments can theoretically appropriate the entire economic rent without distorting any investment or production decisions. In short, rents both can and should be appropriated by governments. This basic economic rationale for rent taxation been operationalised in a number of rent tax proposals.

The benchmark in rent taxes is a variation on income-based taxation known as the cash-flow method or, eponymously, Brown taxes (Brown 1948). In Brown taxes, the government acts as a silent equity partner for mining projects and therefore "shares equally in losses and profits" (Kraal 2013: 860). Brown taxes reserve for the government a constant proportion of annual cash flow of a resource project, and in years of negative cash flow, cash payments are made to private investors (Hogan 2012: 250). An amended version of a Brown tax avoids the accumulation of public liabilities for cash payments, by stipulating that the rent tax can be levied only on positive cash flows, where negative cash flows are offset against future net cash flow (Garnaut & Ross 1975). That is, in years of negative profit, costs are carried forward with interest "in order to preserve value" (Kraal 2013: 860). Furthermore, the notion of an "allowance for corporate capital" (ACC) retains the basic approach of a Brown tax, but deducts a predetermined ACC from net profit before the rent tax is applied (Boadway & Bruce 1984). The ACC, also known as the 'uplift rate', represents an "imputed return on a firm's entire asset base", and is often linked to the government bond rate (Hogan 2012: 250). It is designed to insulate a proportion of profit from tax liabilities to reflect a reasonable payment for the extraction itself, before rent taxation kicks in.

There is general consensus that rent-taxes are superior to output-based royalties, and there have been calls for decades to transition towards rent taxes on the grounds of efficiency and equity (Freebairn & Quiggan 2010). Comparison of actual resource tax revenue in Australia with outcomes under two hypothetical rent-based taxes, a classic Brown tax and a Resource Rent tax (each levied at 40%, applied to industry net cash flow before royalties and taxes and assuming no supply response) show that for the 1999-2007 period, $31 billion (2007 dollars) of tax revenue was forgone (Hogan & McCallum 2010; Hogan 2013). Similar studies show similar revenue gaps in other resource-rich countries. For instance, the Mongolian government has been shown to be receiving just 10 per cent of its due share of mining proceeds, even assuming profit margins of 10-20 per cent for mining firms, due to the failure to implement an effective rent tax (Thampapillai 2014: 175). Similarly, between 2002-08, commodity price increases multiplied total natural resource rents in Africa by 2.3, yet resource revenue flows to African government increased by only 1.5 (Mansour 2014).

2.4 The Australian experience of rent taxation

In light the compelling economic rationale, after a sweeping review of the tax system known as the Henry Review (Henry 2010), the Australian government announced in 2010 that it would implement a tax on "super profits" of firms exploiting all non-renewable natural resources, except low value minerals (Hogan 2012: 247). The tax, originally known as the Resource Super Profits Tax (RSPT), imposed a 40 per cent impost on profits that were above the government bond rate, implying that anything in this zone constituted an abnormal profit, and therefore economic rent (Gilding et al 2016: 131). The tax was in essence a modified Brown tax, applying only in years of positive cash flow, and stipulating an ACC at the government bond rate (Hogan 2012: 248). However the tax was politically toxic, and after a backlash from the mining industry, the government watered down the proposed tax such that in its final form, known hence as the Mineral Resources Rent Tax (MRRT), it applied to just one tenth of the companies that would have been affected by the RSPT, it applied only to coal and iron ore, and was levied at a lower rate, all of which meant it collected just $126 million in its first year of operation, barely 7 per cent of its projected revenue take, and barely covering its administrative costs (Passant 2012: 111). After a change of government, the MRRT was repealed in 2014 and the pre-2010 tax arrangements persist.

The tax failed because of a popular perception that it constituted an unfair impost on the mining industry and that it would drive away investment and destroy jobs. This impression was actively fomented by an aggressive and well-resourced industry campaign against the tax (McKnight & Hobbs 2013) that contributed to a public impression that the tax would be economically destructive (Bell & Hindmoor 2014). The government was also accused of failing to publicly articulate the rationale or generate sufficient stakeholder support for the reform (Kraal 2013). Moreover, the tax proposed by the government was seen to conflict with a submission by the mining industry itself to the Henry tax review which actually called for a rent tax based on a Brown tax model that recognises the government and firms are engaged in a "joint venture" (MCA 2008: 7). However the RSPT differed from a classic Brown tax in three important, and ultimately fatal, ways. First, it was to be levied as an additional impost, on top of output royalties, not to replace them. Second, the premise of the Brown tax is that the government collects profit proportionate to its equity contribution, however the RSPT applied not only to new but also to existing projects, where "the government has incurred none of their development costs or those of any unsuccessful projects" (Kellow 2016: 137). It therefore was seen to be "taxing the winners without funding the losers, as the Brown tax requires" (Ergas 2010). Thirdly, following Garnaut and Ross (1975) the RSPT "would not reimburse losses at the time they were incurred, but promised investors that those losses, compounded at the bond rate, could be deducted from future tax liabilities" (Kellow 2016: 137). This model of compensation was seen to disadvantage small and medium size firms for whom capital scarcity is the chief obstacle to their operations (Gilding et al 2016: 26).

The debate around the mining tax is instructive for what it reveals about the synchronic orientation of resource policy in Australia, which, I argue, fundamentally mischaracterises the policy imperatives for capturing rent. In essence, the debate around the RSPT was a debate about tax policy, how to redistribute the proceeds of a one-off mining boom to the entire country without destroying the industry in the process. The Australian consensus is that "the objective of resource taxation policy is to enable the government to collect a reasonable return on the extraction of the community's non-renewable resources (that is, to collect a major share of the resource rent), while ensuring the costs of the policy are not excessive" (Hogan 2012: 245). The public nature of resource rents is central to this framing, such that rent taxation both "has lower economic costs than other forms of taxation; and it represents the value of public property that is being transferred to private ownership" (Garnaut 2010). In this articulation, tax reform is a necessary evil needed to sustain revenue-raising capacities of the state in the face of fluctuating economic and political conditions (Eccleston 2013: 103).

The Henry Tax review in general argued for "shifting the tax mix from mobile to immobile factors of production" (Freebairn 2012: 54) in light of the criteria of tax policy. Segal (2012: 340) buttresses this normative claim by arguing that because natural resources belong to all citizens of a country, "resource revenues have not been appropriated from anyone" and that through taxation they are "distributed, but not redistributed". These arguments exemplify the synchronic vision of rent, as the shared property of everyone alive in a country at a given moment, that must be redistributed to those people, and animate a discourse than any rent not captured by the government is wasted. But how does this differ from a diachronic framing, and what is the significance?

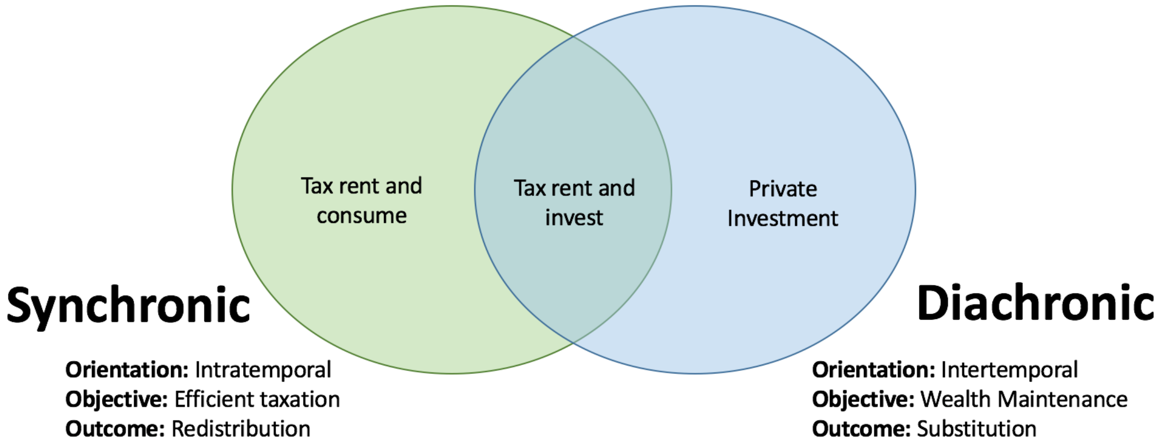
2.5 Shortcomings of the synchronic frame

In section one I argued that diachronically oriented economics take as its objective intertemporal wealth maintenance, and therefore aims to achieve substitution of different forms of capital. In this section, I have demonstrated through the Australia case study, that debate around resource policy is framed synchronically, taking as its objective intratemporal justice, and therefore aiming to achieve a redistribution of wealth as efficiently as possible. As figure 1 illustrates, these are overlapping but fundamentally different approaches to the management of natural resources and they point to different policy objectives. In fact, in distinguishing the two approaches, I hope to elucidate two significant shortcomings of the mining policy debate in Australia.

Firstly, from a diachronic perspective, a rent tax that only captures 40 per cent of the rent would be a disaster. If taxation and public investment was the only way through which substitution takes place, then an instrument that only captures 40 per cent easily fails to satisfy the Hartwick rule. From a synchronic perspective, this is somewhat irrelevant so long as some redistribution is achieved. But for diachronism, it represents a haemorrhaging of wealth. Yet in reality, rent taxes never capture 100 per cent of rents. As Hogan (2013: 249) concedes: "in practice, it is difficult to estimate economic rent and to distinguish between resource rent and other types of rent" and that "to reduce negative distortions of a mineral resource taxation policy on industry investment and production decisions, governments should target substantially less than 100 per cent of estimated economic rent". However, the second insight of diachronism renders this redundant.

The second insight is that taxes are not the only way that substitution can take place. The synchronic orientation makes a category mistake by assuming sustainability is synonymous with the level of public rent capture, whereas in fact the diachronic orientation tells us that sustainability is synonymous with total rent substitution. Therefore, analyses of sustainability that focus exclusively on synchronic measures are likely to be ignoring significant flows of rent outside government revenue flows, and therefore underestimating the extent of substitution, and by consequence, the extent of sustainability. The vertical distribution of wealth in an economy at a given point in time is entirely irrelevant to the satisfaction of the Hartwick rule, what counts is

Figure 1. Conceptual illustration of the difference between synchronic and diachronic orientations in the treatment of resource rents



aggregate substitution, not the diversity of agents engaged in it. The synchronic orientation misses this, because rent flows into the private economy are seen to be "wasted" whereas from this view they are just as valuable as any other rent flows. Therefore the partiality of rent taxes is overcome because capital need not be taxed for it to be substituted. Private agents are equally capable of doing this as governments are. As distinct from the synchronic focus on collecting resource rent for the public in the form of tax, for diachronism, "the fundamental economic problem faced by resource-rich economies is how to transform sub-soil assets into a portfolio of other assets- human capital, domestic physical capital (both private and public) and perhaps also foreign financial assets- that yield a continuing flow of income to citizens" (Ploeg & Anthony 2011). The synchronic and the diachronic orientations point to overlapping but distinct policy imperatives, conceptually illustrated in Figure 1 above.

In fact, there are many ways that rents can be kept inside an economy beyond taxes. For instance, governments can impose investment controls on firms, legal restrictions specifically on the resource sector to preserve ownership (and therefore rent capture) for certain economic actors (Wilson 2016: 113). For example, restrictions on foreign direct investment (which ensure a minimum local ownership), and production-sharing contracts (in which a firm is allowed to recover its extraction and operation costs after which point the profit is shared with the government according to a predetermined formula), both constitute "de facto profits taxes" (Wilson 2016: 115) by securing revenue for the state at the cost of an indirect impost on firms. Moreover, export controls restrict operational activities of resource companies to maximise benefit to the domestic economy. Export taxes and quotas, local processing requirements and domestic price controls all function to sequester rents within the domestic economy, whilst artificially inflating costs to firms. The combination of taxes, investment and export controls collectively constitute "sovereign risk", the demands made by governments on resource extractors. But outside of government intervention, rents will naturally flow to labour and capital as excess payments. In the context of mining firms, this is in the form of investor returns, employee wages, and corporate capital.

Consider two analyses of Australian resource policy during that country's recent mining boom. One suggested that from 2002-08, the mining boom delivered a windfall of $180 billion to the Federal government, of which $36 billion was used to pay down Commonwealth debt, $69 billion was invested in a sovereign wealth fund to service future public sector pension liabilities, and, in a "missed opportunity", the remaining $75 billion was returned to the private economy in the form of tax cuts and increased social spending (Hetherington & Prior 2012: 3). By contrast, Charlton (2014: 64) argues that the boom added a windfall from 2004-07 of $334 billion to the Federal budget, of which only 6 per cent was saved. Firstly, the vast disparity between these two analyses- 50 per cent of $180 billion over six years saved in the first, and 6 per cent of $334 billion over three years in the second- serves to underscore the difficulty of identifying precisely what qualifies as 'windfall' and what qualifies as a proper use for it. In either analysis, it is entirely possible that the increase in income that was not substituted by the government, did in fact go into long-term productive investments. Both of these analyses illustrate the statist bias inherent in discussion of rent management, stemming from their orientation in a synchronic vision of efficient revenue-raising, and vertical resource redistribution. The synchronic framing then was at once too flexible in that it allowed the majority of rents not to be captured, whilst being simultaneously too inflexible, in that it articulated tax as the only option to achieve the desired policy objective.

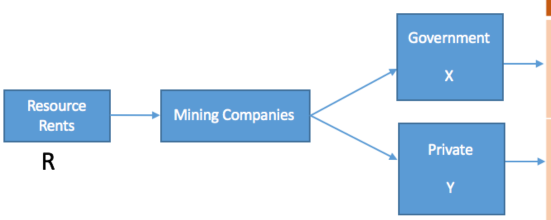
It is well established that the free allocation of land to European settlers appropriated from Indigenous Australians, and the generous granting of mining concessions during the 19th century goldrush, "Australia's institutions allowed gold rents to spread widely" (Greasely 2016: 173). That is, the economic rents flowed into the private economy. Given the basic policies are still in operation, much the same process operates today. We can therefore legitimately concede that "the record of Australia's economic development highlights its success in utilising or extracting natural resources. Less clear-cut is the achievement surrounding the utilisation of resource rents" (Greasely 2016: 176). In this section I have argued that this is the fundamental question for resource policy, and that conventional sustainability measures that only focus on the role of the state in achieving substitution systematically underestimate the extent of substitution and therefore the level of sustainability. In the next section, I argue that we we need to broaden our analytic focus on the manifold ways that substitution takes place.

chapter 3.
substitution chains

3.1 The model of substitution chains

In this section I elaborate my concept of the substitution chain, as a resolution to the theoretical constraints of synchronic approaches to resource rent. Figure 2 (below) is a positive (as opposed to normative) description of the ways in which rent flows through an economy. The model of substitution chains is based on two foundational claims. Firstly, that rents flow into both public and private hands. As noted earlier, if the definition of rent is a payment to a factor of production above what is needed to keep it in operation, then employees and investors are theoretically capable of receiving rents, through inflated wages or above normal returns (Segal 2012). If we assume that the government is not receiving all of the rent, then eventually it must be going to either of these two. Certainly some is held by the companies themselves, but that is eventually spent in investments which entails a return to investors or indeed improvements in physical or other capital for the nation. The second central claim is that rents can either be consumed, or invested in any form of capital.

Figure 2. Conceptual Diagram of Substitution Chains



Consumption	Natural Capital	Physical Capital	Human Capital	Financial Capital	Social Capital	TOTAL
C(R*gov*)	N(R*gov*)	P(R*gov*)	H(R*gov*)	F(R*gov*)	S(R*gov*)	X
C(R*prv*)	N(R*prv*)	P(R*prv*)	H(R*prv*)	F(R*prv*)	S(R*prv*)	Y
Consumption Coefficient: 0	N	P	H	F	S	Investment Coefficient: 1

Hence the substitution chain model asserts that resource rents can be substituted with other forms of capital in a multitude of ways and is an attempt to conceptually taxonomise those ways. Analysis of the extent to which the Hartwick rule is being satisfied, would theoretically have to consider the extent to which each of these substitution chains is taking place. To that end, the proportion of rent (R) which flows to each of the government and the private sector (through investors, and employees) which is then consumed (C) constitutes a direct reduction in national wealth. As such, the consumption coefficients for each group must be 0 such that:

$$C(R_{gov}) + C(R_{prv}) = 0$$

Equally, then, the investment coefficients for each actor must be 1 for the same to be true. This is essentially a restatement of the Hartwick rule, yet, as I have demonstrated above, such restatement is necessary because of the obscurantism surrounding the flow of rents through the private economy inherent to both synchronic and diachronic renditions of resource policy. To illustrate the importance of these flows, and therefore of the need for a diachronism based on a comprehensive substitution chain model, in what follows, I intend to demonstrate that private capital investments have increased throughout the Australian mining boom. I do not attempt to suggest that the consumption coefficients are zero, indeed it seems almost certain that they are not. Rather, I want to demonstrate the existence of rent flows neglected by conventional analyses. In doing so, I hope to demonstrate the analytical utility of substitution chains as a productive heuristic for understanding resource management.

3.2 Methodological approach

Following Brown et al (2005), I adopt a data-driven approach to assessing the role of substitution chains using a variety of data sources. To do so, I make a series of assumptions that I will detail presently. Firstly, in contrast to measures such as ANS which start from measures of GNI and make corrections for resource depletion and other environmental costs, I will attempt a 'marginal analysis', to test whether a windfall of resource rents has altered capital investment at the margin. This involves two steps: first, calculating the value of resource rents for a given year, and second, calculating the value of capital investments (for the same year) that diverges from the expected historical or normal trend. I adopt this approach because the Hartwick rule only makes sense at the margin. Some brief elaboration is required.

Even in the absence of resource rents, private and public actors will engage in some combination of consumption and investment. A rent windfall comes on top of that pre-existing consumption-investment split. Essentially there is some theoretical optimum between consumption and investment, though “no-one can seriously claim to pinpoint the optimal level of current consumption for an economy” (Arrow et al 2004: 155). It may, for instance, be that a country is saving more than is ideal, and when a rent windfall arrives, it gets spent. Viewed in isolation as the Hartwick rule, that might look to be a squandering of resources, but in the broader picture of the economy, it may in fact be a corrective to a historical pattern of underconsumption. For instance, a recent study found that several countries, including Malaysia and China, had “invested far more than the Hartwick rule requires” (World Bank 2011: 11). Assessing the satisfaction of the Hartwick rule is therefore somewhat irrelevant unless the broader context of consumption-investment settings are interrogated. An economy which consumes its resource rent may be underconsuming elsewhere in which case Hartwick-discordance could be economically advantageous. Attempting to estimate whether Australia has an ideal underlying consumption trend is far beyond the scope of this thesis. But in order to neutralise the impact of this confounding factor, I will make the almost certainly fallacious, but analytically necessary assumption that Australia already had an optimum level of consumption-investment, and that, therefore, any rent windfall should constitute an *additional* saving on top of that pre-existing mix. The objective is to identify whether capital investment rates are sensitive to rent windfalls, not whether rent flows compensate for other imperfections in the economy.

However, since rents disappear into the private economy and government coffers and it is impossible to trace individual dollars, this means I can only measure capital investment based on its deviation from a historical pattern, and the co-incidence of those deviations with rent windfall. To do this, in each case I have calculated first an expected ‘normal’ value of each investment for the year 2011-12, based on the compound annual growth rates (CAGR) for the immediately preceding years for which there is data available. Then I have subtracted the actual investment from the ‘normal expected’ investment to identify how much capital investments deviated above or below the historical trend. It is this deviation from historical trend that I argue constitutes a rent substitution. Importantly, it is the co-incidence of rent windfall and deviation from historical trend that is important here. Since it is impossible to track individual dollars, and what matters is the level of the economy, if the *equivalent* of the rent windfall has been invested then Hartwick rule has been satisfied. Necessarily then, the deviations from ‘normal’ trend are aggregated, and compared to the dollar value of resource rent windfall. If the two figures are equal, then the Hartwick rule is satisfied. The above caveats mean that my results should be interpreted extremely conservatively. However, my intention is not to offer a definitive diagnosis of the sustainability of the Australian economy, but merely to underscore the deep limitations in pre-existing attempts to do precisely that. I now turn to my choice of indicators, and data sources.

There are many ways of estimating resource rents, none of them beyond critique. For instance, Hetherington & Prior (2012: 9) arrive at a figure of $180 billion for Australia for the period 2001-07 by summing the additional government revenues from: above-average GDP growth, growth in the tax/GDP ratio, and forgone revenue from cuts to income tax and the fuel excise. But this is of course not a calculation of rent but of government resource revenue. Hogan (2012: 254) considers resource rents to be any profit accrued by mining companies above the government bond rate, arriving at a figure of $185 billion for the period 1999-2006. For the sake of simplicity, I will assume a reasonable return for mining companies of 10 per cent, and infer that profit above that amount constitutes a resource rent. Defining methodologies for capital investments is similarly problematic.

The literature on calculating and and investing in social capital is nascent. Social capital can be defined as "the sum of resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalised relationships of mutual acquaintance and recognition" (Bourdieu and Wacquant 1992: 119). More simply, I follow the OECD definition of "networks together with shared norms, values and understandings that facilitate co-operation within or among groups" (OECD 2001: 41). Accordingly, "increasing social capital will require investment of resource- an example would be building institutions that foster trust" (Hamilton et al 2016: 4). Leigh's (2010) seminal analysis of social capital in Australia, considers such institutions to include trade unions, churches, and sporting and cultural associations. Following this approach, I consider private financing of not-profit institutions as defined by the Australian Bureau of Statistics. Certainly, financing of organisations imputed to generate 'social capital' is a relatively poor proxy for the creation of social capital itself. It has been widely noted that many institutions have improved their finances whilst actual volunteering or participation has declined, such as political parties in the United States which have increasing revenues but decreasing memberships (Putnam 1995). However most theorists agree that it is at least a determinant of social capital and so has analytical value (Halpern 2005: 206). Moreover, I am not presenting my findings as a precise empirical assessment, but rather as a directionally correct algorithm, to illustrate the analytical merit of a broader set of substitution chains.

Human capital can be defined as "the total present value of the expected future labour income that could be generated over the lifetime of people currently living" (Hamilton and Liu 2014: 75). Since education investment is a chief determinant of earning capacity, this is used as an indicator for human capital. The World Bank's ANS methodology excludes private investments in education solely on the grounds of data insufficiency (World Bank 2002: 277). Others have noted that health expenditure could also qualify as an investment in human capital. As such, I am considering both public and private investments in education and health.

For private financial capital, I consider household savings, both through the ratio and absolute figures. The household savings ratio (HSR) is the proportion of disposable household income that is saved; that is, savings equals income minus consumption. If we assume that given the absence of resource rent taxation in Australia, that most of the resource rents are flowing either to foreign or domestic investors and households through higher wages, superannuation, and share portfolios, the HSR is an important indicator of the extent to which the resource windfall has accumulated as net financial assets at the household level.

For physical capital I consider investments in capital and housing infrastructure. For private physical capital I look at purchases of residential dwellings (ABS 2016d) and private investments in capital expenditure (ABS 2016e). For public investment in physical capital I use the OECD International Transport Forum statistics on public investment in transport infrastructure. This includes roads, railways, airways etc, so is a non-exhaustive but significant component of public infrastructure.

For natural capital, I consider money flows towards protecting or enhancing "elements of nature that provide value or benefits to people (directly or indirectly), such as the stocks of forests, rivers, land, minerals and oceans, as well as the natural processes and functions that underpin their operation" (Natural Capital Committee 2013: 1). On the public side I consider public funding for environmental protection taken from the Australian Parliamentary Budget Office. For private investments, I consider private contributions to environmental causes, however these contributions are aggregated into the same data set as I use for social capital, as donations to not-profit institutions under the ABS definition. Therefore, my data for private natural capital investment is undifferentiated. This is unfortunate for clarity reasons but does not affect the actual result which only matters in the aggregate.

The data sources I have selected are, of course, arbitrary. An alternative set of choices would yield different results. My intention though is not to categorically argue for this particular conception of ‘investment in capital’, but rather to illustrate the existence of diverse substitution chains. Indeed, this tentative analysis does suggest that some of these substitution chains might indeed be in operation; in each of these cases, the data demonstrate that the period of the mining boom coincided with significant increases in private financing of each form of capital, often well in excess of GDP growth itself. The Hartwick rule only posits that during times of resource rent windfalls, greater capital investments must be made, at the aggregate level of the entire economy. This analysis demonstrates that Australia’s mining boom did coincide with significant uptick in investments in a variety of forms of capital. These trends are not adduced as evidence of a direct causal relationship, but that is somewhat irrelevant to the Hartwick rule. Whether the increase in investment was because of, or coincident with, the rent windfall is not therefore germane to my argument. What is important is the unity question- whether or not the investments in capital perfectly offset depletion of non-renewables. This I will address later.

3.3 Results

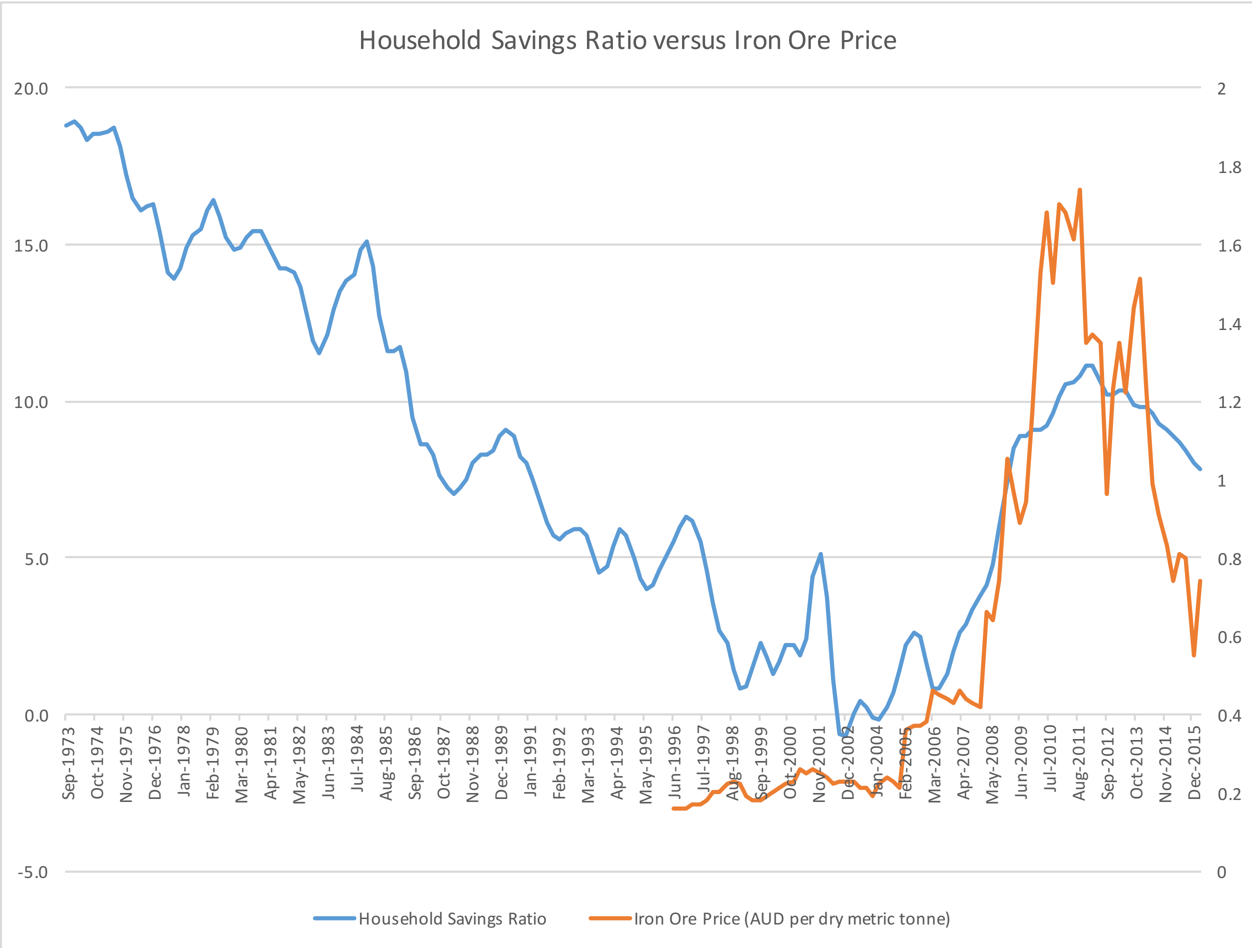
I will consider my results first for resource rents, then the value of each form of capital in turn. All results that I do not cite can be assumed to my own analysis. For the sake of simplicity, and data constraints, I consider just one year, financial year 2011-12. All my results relate to this period. All monetary figures are in 2015 Australian dollars.

Resource Rents

Resource rents, defined as return on resource investments above 10 per cent, for Australia for the period 2011-12, were $73 billion (ABS 2016a). In this period, the mining industry had an operating profit before tax of $82 billion, representing a return of 52 per cent. Of that margin, assuming $8.2 billion (10 per cent) should have been paid out as normal profit, that leaves an economic rent of $73 billion (with rounding). That same financial year, according to estimates from the mining industry itself, $22.2 billion was paid in company tax and royalties (Hooke 2013) meaning $51 billion, or 70 per cent of the economic rent, flowed directly into the private economy via mining companies[5]. This suggests that capital investment for the same year must be $73 billion above historical trend in order to satisfy the Hartwick rule.

Financial Capital

Graph 1[6] below shows that over the course of the increase in iron ore prices that underpinned Australia's mining boom, the HSR, which had been in sharp decline since the 1970s, reversed trend, and in 2011 just as iron ore prices peaked, so did the HSR. Across a similar time period,



between 2003-12, Australia's terms of trade rose 87 per cent, lead by an increase in GVA in iron ore by 182 percent (Robson 2015: 309). (Corporate savings, profits not paid out as shareholder

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[5] Of the industry 'tax' bill, $11.5 billion was royalty payments (ABS 84150). Technically, royalties represent a factor payment, not a tax on profits, and therefore should be excluded from the calculation of rent in the same way that labour expenses are. However, since royalties are popularly framed as taxes, and because a theoretical rent tax should replace royalty payments altogether, and in order to be conservative in my analysis, I will include royalty payments as a rent flow to the government. This should be interpreted to mean that if anything my analysis overestimates the flow of rent to the government.

[6] Data for the graph are sourced from indexmundi (2016) and the Australian Bureau of Statistics Australian National Income Accounts (2016b) datasets.

dividends, but used to finance capital investments, have also risen since the mid-2000s, "largely due to the strong growth in mining profits associated with record high commodity prices" (Bishop & Cassidy 2012: 12)). A number of theories have been advanced to explain this reversal (see Lowe 2011; Stevens 2011). It could be normal equilibrated deleveraging after a period of sustained high debt, a response to the "large negative wealth shock and volatility of asset prices since 2008", or a response to rising household incomes partly due to resource rent windfalls (Bishop & Cassidy 2012: 11). The private savings rate reversal certainly coincided with the onset of the Global Financial Crisis and the Australian government's announcement of a significant stimulus package financed by public borrowing (Megalogenis 2015). The prospect that the two phenomena are coupled would be consistent with the notion of Ricardian equivalence that private savings are a function of government borrowing, such that in times of negative fiscal imbalance, private savings rise in anticipation of higher future taxes and therefore decreased consumption possibilities in the future (Barro 1974). However, the fastest spike in private savings occurred during 2006-09, before the announcement of the major stimulus package.

Understanding the influences of private savings rates is notoriously difficult because "experiments to check divergent hypotheses cannot be deliberately performed, so economists must rely upon the often dubious evidence from the limited experiments with which nature and history have endowed us" (Carrol and Summers 1987: 249). The multiplicity of potential influences precludes any firm conclusions about the cause of the spike in private savings rate in Australia since 2005. Furthermore, "private savings rate are determined by processes too complex to represent by any sort of formulation embodying the preferences and budget constraint facing a 'representative consumer'" and that an alternative strategy is to "relate differences in private savings rates to a variety of factors that seem plausibly related to savings behaviour" (Carrol & Summers 1987: 250).

I concur with this analysis that multiple conceivable explanations exist for the rise in private savings, and I do not venture that the rent windfall was principally causative, simply that the two processes were coincident and that therefore some depletion in resource rents was offset through the accumulation of private finance. This would be consistent with Ploeg's (2011: 19) observation that "in practise, there may also be forward looking private agents who own assets and adjust savings and consumption decisions in response to current and future resource revenues" and that "this raises the possibility that Ricardian consumers may, in some sense, negate the effect of government policy". Ploeg in fact made the reverse argument for Ricardian equivalence, that if a government increases it savings, it may be “undermined by a private consumption boom fuelled by private borrowing” (2011: 20). But the knife cuts both ways. Just as government policies can be undermined, so too can government failings be ameliorated through increases in private savings. The evidence from Australia suggests precisely this substitution chain has been in action.

But what was the dollar value of increased savings? To calculate this, we need to estimate a ‘normal’ savings rate for 2011-12, and subtract it from the actual savings rate, in order to identify the ‘windfall’ savings, the amount of savings that occurred beyond the historical rate. From 1960-2010, the savings rate grew at an average CAGR of 7.22 per cent, reaching $121 billion in 2010-11. If we assume that the CAGR, as the historical average, represents a normal savings growth rate, then we would expect 2010-11 to have savings of $127 billion. In fact, household savings in that year were $142 billion. This represents a $15.6 billion increase over the historical trend and I will therefore count this as a rent substitution.

Human Capital

Investments in human capital have also increased. First, public investment. Australian government investment in all forms of education in 2010-11 was $75.6 billion (ABS 2016c). The normal expenditure, based on the 2005-09 CAGR of 8%, would be $67.3 billion. This represents a positive deviation of $8.3 billion above the ‘normal’ baseline, which I attribute to rent substitution. In the same year, Australian government health expenditure was $59.0 billion. The normal expenditure, based on the 2002-10 CAGR of 4.85%, would be $58.9 billion. This represents a deviation of $0.1 billion, which I attribute to rent substitution. This equates to $8.4 billion of rent substituted with human capital via public substitution chains. A similar picture emerges with private investments. Private expenditure on education in Australia for 2011-12 was $34.9 billion. Normal expenditure based on the 2005-09 CAGR of 8%, would be $33.0 billion. This represents a positive deviation of $1.9 billion, which I attribute to rent substitution. In the same year, total recurrent private expenditure on health, including from private health insurers, out-of-pocket expenses incurred by individuals, and payments made by industry compensation insurers, was $42.9 billion. The normal expenditure, based on the 2002-10 CAGR of 5.99%, would be $42.9 billion. There was therefore no deviation from the historical average on health investment.

Physical Capital

Analysis of Australian housing market data shows that the value of all dwellings (that is, excluding commercial properties) purchased in 2011-12 was $145.7 billion (ABS 2016d). Based on a CAGR of 2.36 per cent between 2004-10, normal expenditure would be $143.1 billion, leaving a positive deviation of $2.6 billion, which I will attribute to rent windfall as private investment in physical capital. Secondly, analysis of ABS industrial data shows that the value of all industrial capital expenditure in 2011-12 was $158.8 billion (ABS 2016e). Based on the CAGR of 7.21 per cent between 1987-2010, normal expenditure would be $127.9 billion. This represents a positive deviation of $30.9 billion which I attribute to rent windfall. This brings total deviation in private investment in physical capital to $33.5 billion. On the public side, OECD (2016) data shows that Australian government investment in transport infrastructure was $26.0 billion in 2011. Based on a CAGR of 9.8 per cent from 1995-2010, the normal expenditure would be $23.4 billion. This leaves a positive deviation of $2.6 billion, which I will attribute to rent windfall. This means total deviation in physical capital investment was $36.1b.

Social Capital

Based on comparison of ABS Satellite Accounts for non-profit institutions from 2006-7 (ABS 2007) and 2012-13 (ABS 2015), I estimated that private funding of social capital amounted to $91.5 billion in 2011-12. Because only two data points are available for this analysis, it is impossible to use the trend deviation method I have used above. Instead, I use as a proxy the amount that social capital funding has changed compared to the GDP growth rate for the same period. Between 2010-11 and 2011-12, private social capital funding increased by 4.43%, whilst GDP grew by around 3 per cent (ABS 2016b). The difference suggests a positive deviation of around $1.3 billion, which I attribute to rent windfall. Based on the same analysis, I estimate that public funding of social capital amounted to $16.2 billion in 2011-12. Between 2010-11 and 2011-12, public social capital investment grew by 7.59 per cent. Using the differential between 3 per cent GDP growth I estimate a positive deviation of around $0.7 billion, which I attribute to rent windfall.

Natural Capital

Government funding for environmental protection in 2011-12 was $2.3 billion (PBO 2016). Based on a CAGR from 2002-11 of 15 per cent, the 2011-12 normal expenditure would be $1.0 billion. This represents a positive deviation of $1.3 billion which I attribute to rent windfall. Private investment, as discussed, has already been included in the private social capital account.

Summary Table

The results of my analysis are summarised in Table 1 below.

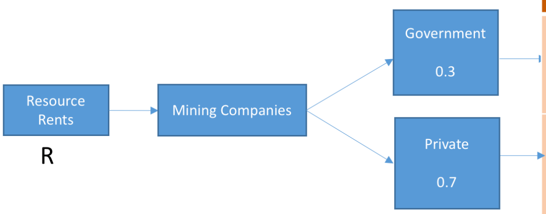
Table 1. Summary of transcapital substitution flows and data sources, Australia, 2011-12

	Actor	Indicator	Data Source	CAGR	2011-12 Normal	2011-12 Actual	Deviation
Resource Rent	N/A	Profit accruing to mining companies above 10% profit margin	ABS 84150 Mining Operations, Australia 2014-15	N/A	N/A	$73b	N/A
Natural Capital	Public	Public funding for the environment	Parliamentary Budget Office, Australian Government Spending, Part 1: Historical trends from 2002-03 to 2012-3	15%	$1.0b	$2.3b	$1.3b
	Private	Private financing of environmental organisations	ABS Australian National Accounts: Not-Profit Institutions Satellite Account 2012-13 (&the same one 2006-07)	N/A	N/A	N/A	N/A
Financial Capital	Public	Government debt repayments, contributions to sovereign wealth fund	Parliamentary Budget Office, Australian Government Spending, Part 1: Historical trends from 2002-03 to 2012-3	0	0	0	0
	Private	Household savings	ABS 5206.0 Australian National Accounts: National Income, Expenditure and Product	7.22%	$127.1b	$142.7b	$15.6b
Human Capital	Public	Public expenditure on education	ABS 5518.0.55.001 Government Finance Statistics	8.00%	$67.3b	$75.6b	$8.3b
		Public expenditure on health	Australian Institute of Health and Welfare, Health and Welfare Expenditure Series No. 51	4.85%	$58.9b	$59.0b	$0.1b
	Private	Private expenditure on education	ABS 5518.0.55.001 Government Finance Statistics	8.00%	$33.0	$34.9b	$1.9b
		Private expenditure on health	Australian Institute of Health and Welfare, Health and Welfare Expenditure Series No. 51	5.99%	$42.9	$42.9	$0
Physical Capital	Public	Public infrastructure investment	OECD International Transport forum, public investment and maintenance spending	9.8%	$23.4b	$26.0	$2.6
	Private	Private expenditure on property	ABS 5609.0 Housing Finance	2.36%	$143.1b	$145.7b	$2.6
		Private new capital expenditure	ABS 5625.0 Private New Capital Expenditure and Expected Expenditure	7.21%	$127.9n	$158.8b	$30.9b
Social Capital	Public	Government funding of social institutions	ABS Australian National Accounts: Not-Profit Institutions Satellite Account 2012-13 (&the same one 2006-07)	7.59%	$15.5	$16.2b	$0.7b
	Private	Private funding of social institutions	ABS Australian National Accounts: Not-Profit Institutions Satellite Account 2012-13 (&the same one 2006-07)	4.43%	$90.2	$91.5	$1.3b

3.4 Analysis

Capital investment across all categories increased over the duration of the mining boom, as *Figure 3* (below) shows. My analysis suggests that around 89 per cent of Australian resource rents in 2011-12 were substituted for other forms of capital, leaving 11 per cent to fund increased consumption. As predicted, then, this investment coefficient of 0.89 was less than unity and the Australian economy was Hartwick-discordant over this period. Interestingly, the private economy received 70 per cent of the resource rents, and yet substituted 72 per cent of the total rent in the economy. This means there was a private substitution rate of 103 per cent (they substituted 103 per cent of the rent they received). Importantly, this is not to say that a rent windfall suddenly made capital available for a series of investments that would not have otherwise happened and which resulted in overinvestment of rent. Rather, it suggests simply that in 2011-12, private investment increased faster than private rent windfall. Given the tiny negative consumption coefficient, and a standard margin of error around my figures, I would impute this figure to be effectively zero. Conversely, the government received 30 per cent of the rent, and substituted just 18 per cent. This means there is a government substitution rate of just 59 per cent (the

Figure 3. Actual Resource Rent Flows, Australia 2011-12, Coefficients



Consumption	Natural Capital	Physical Capital	Human Capital	Financial Capital	Social Capital	TOTAL
0.12	0.02	0.04	0.12	0	0.01	0.18
-0.02	0	0.46	0.03	0.21	0.02	0.72
Consumption Coefficient **0.11**	0.02	0.49	0.14	0.21	0.03	Investment Coefficient **0.89**

government substituted just 59 per cent of the rent it received). These figures suggest two things. Firstly, they corroborate my claim that focussing exclusively on public rent flows is substantially inadequate from a sustainability (read: substitution) perspective. Secondly, they suggest that the private economy may be significantly better at substituting rent flows than the government is.

However the analysis also highlights some potential causes for concern. Most substitution occurred in private investments in physical and financial capital, which together accounted for 80 per cent of total substitution across the private and public sectors. The relatively low investments in natural, social and human capital raise important questions around the limits to substitution discussed in Chapter 2. It is not clear whether the increasingly asymmetrical constitution of the national capital base, from underinvestment in natural (and other forms of) capital, can be sustained. Secondly, the overwhelming reliance on just two substitution chains (private physical and financial capital) suggests these processes are not robust; if household savings dry up or the housing market stumbles we would see a very different picture. In general, though, these findings buttress my claim that private substitution chains are a significant and overlooked aspect of sustainability, because they constitute not only the bulk of the rent recipients but the majority of capital reinvestment.

I have flagged multiple critical limitations to my analysis. The decision to use marginal analysis, the choice of indicators of capital investment, data availability constraints, the rent calculation methodology, the calculation of 'normal' expenditures using CAGRs and GDP deviations— all of these are highly contestable assumptions, and alterations in any of them can drastically affect the results. However my key point is not the precise figures that I have calculated, but more fundamentally the fact that I have figures at all. This preliminary analysis supports my assertion that tests of sustainability such as ANS are not simply "one-sided tests", because they are missing data on the capital re-investment side, and therefore are delivering overblown conclusions about the extent of unsustainability. For instance, in contrast to Charlton's (2014: 64) claim that "Australia saved only 6 per cent of [its resource rent windfall]" between 2004-07, it appears that in 2011-12, Australia saved almost 90 per cent. If these conclusions are correct, this point has significant implications for how we manage our non-renewable natural resources. In this final section, I turn to consider how policy can respond to these findings.

chapter 4.
policy implications

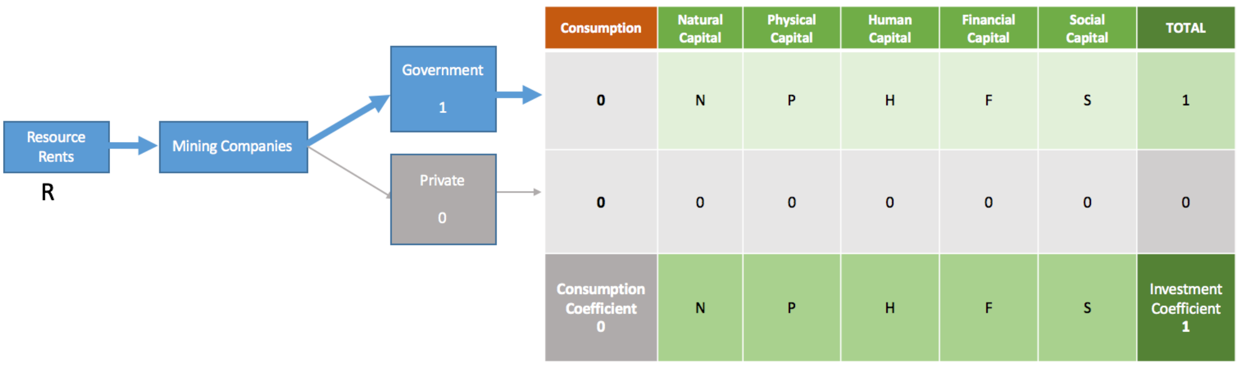
4.1 Three Policy Implications

Thus far I have argued three propositions. Firstly, that sustainability requires that resource rents be substituted for other forms of capital. Second, that resource policy focussed simply on capturing rent for the government is ill-conceived for this purpose. And third, that substitution chains more broadly defined, are not only a useful heuristic for considering the flow of resource rents through an economy, but have been demonstrated to be in action in the context of the Australian mining boom. If the above propositions are correct, in order to satisfy the Hartwick rule for diachronic justice, a number of potential policy responses present themselves.

4.2 Reverse Auctions for Mining Permits

The first possibility is an improved resource rent tax that can functionally capture 100 per cent of the revenues followed by a public investment mechanism. This latter point has been argued for extensively in the Australian context (cf. Cleary 2016), so I will focus on the former, the design of rent taxes. A hermetic rent tax would involve a synthesis of two approaches, the government as equity partner (Brown 1948) and reverse auctions for permits (Segal 2012). Under such a policy, the government would abolish royalties and uniform corporate and rent taxes for the mining industry, and commit to becoming an equity partner in all mining exploitation. Licences would be awarded under contracts that allow companies to recoup their production costs, after which point a rent tax kicks in, which apportions profits according to a pre-determined formula chosen through a reverse auction. Allowing firms themselves to essentially choose their own tax rate, under a competitive process, is attractive because “in practice it is very difficult to identify what counts as resource rents because it is very difficult to specify precisely how much the relevant costs should be” (Segal 2012: 341). The successful bidder would be the company than can commit to the highest return to the government, involving both the lowest production costs, and the most favourable profit-sharing arrangement. Competition would theoretically bid down costs and bid up government revenues until the point at which the venture no longer becomes viable for a mining company (Segal 2012: 341). This is the theoretical rent margin. Under a system such as this, a successfully designed rent tax would negate the need for other substitution chains, because it would be capturing all the rent by itself. This would, combined with savvy investment, satisfy both the synchronic priority for redistribution and the diachronic priority for substitution. Ordinarily, in designing auctions, “the two issues that really matter are attracting entrants, and preventing collusion” (Klemperer 2001: 3). Whilst both of these fully apply to the mining industry, a third confounding factor also applies, which is the uniquely stochastic conditions of mining. This point needs elaboration.

Figure 4. Idealised flow of rent in a reverse auction rent tax, coefficients



There are three main phases to mineral exploitation (Garnaut & Clunies-Ross 1983). Firstly, prospecting is the initial stage of geological analysis, and involves determining the presence of ores. Secondly, exploration involves the identification of commercially viable ore concentrations to mine. It is a much more intensive process than prospecting, and involves the evaluation of ore grades and tonnage, usually via drilling, to investigate and sample mineralisation. Thirdly, once commercially viable deposits have been extensively mapped, mining involves the right to work and extract minerals from the land. Each of these three stages involves separate licences issued by governments and each phase is inherently unpredictable (Chambers (2010). Most speculation and exploration does not result in commercially viable deposits suitable to mine, and it is impossible to know what price commodities will command on unstable world markets. Moreover, both early processes are costly, and yet the flow of income is ex post facto. Therefore, it is crucial for licensing schemes to grant priority progression from prospecting through to mining, in order to create the commercial incentive for each stage. Australia has separate licences for each of these stages, and a clear priority progression schemes. As Chambers (2010: 15) states:

> The Australian mining sector has developed and grown in the context of an open and transparent licensing system. Of significant importance is the ability for participants to move from exploration to mining phases with certainty…having spent considerable monies on exploration activities, a miner then has certainty that it will be able to extract deposits to enable a return on its investment.

Most policy environments provide priority licence progression from prospecting to exploration to mining in order to generate commercial incentives for prospecting and exploration. Certainly, the loss of commercial incentives was a key reason for the recent failure of India's proposed ascending auction scheme (Bhubaneswar 2015). Evidently, simply conducting reverse auctions for mining licences, without addressing the chain of commercial incentives, is insufficient. However, the status quo of granting exclusive or even priority licensing for firms who undertake prospecting, removes the incentive for firms to compete for lower costs and higher returns to government at the later stages, for if one firm has licensing priority, they essentially have a monopoly. But is it really a choice between returns to government, and commercial incentives? Since, "an auction's design must be tailored to both its environment, and to the designer's objectives" (Klemperer 2001: 3), the unique conditions of the mining industry call for a uniquely designed auction system. There are two models of reverse auctions that could resolve the tension between public return and private incentive.

The first is to retain the flow of priority licensing but to conduct an initial auction for the entire set of licences according to pre-determined conditions that come into effect as the mining process unfolds. When applying for a prospecting licence, firms would be required to submit bids for the eventual mining licence. But instead of projecting a specific estimated production cost (which is impossible without having explored), they stipulate estimated projected production costs under a range of exploration scenarios including different ore grades, quantities, market conditions, infrastructural requirements etc, as well as specifying their profit-split with the government. That way, the government can award prospecting licences based on both the ability of firms to efficiently exploit mineral deposits and their relative willingness of to surrender rents. This system protects the commercial incentive for prospecting and exploration whilst creating a countervailing incentive to reduce costs and maximise return to the government. Its key drawback is the sheer complexity of creating cost projections for the full range of scenarios which may transpire over the life of a mine.

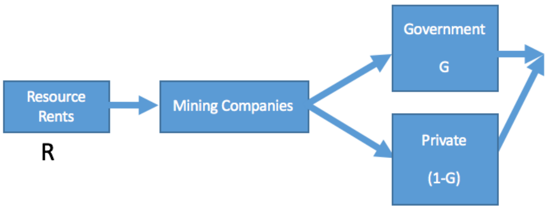
The second potential solution is to abolish priority licensing progression and replace it with retrospective compensation in the mining phase. Since the returns made in the mining phase, entail rent that has accrued at each of the three stages of the exploitation process (Laporte 2015: 240), policy can ensure compensation schemes for the early phases to be paid for with profits from the lucrative third phase. In this model, there would be reverse auctions at each of the three stages of the process, with each firm submitting two key pieces of information at each stage: estimated production costs, and the proportion of final mining proceeds they would be willing to accept as compensation. In this way, the rent paid to the government is ultimately the total amount of revenue, minus the production costs and predetermined profit margin for each step of the process. This model would introduce more competition at each stage, meaning that the returns from the mineral deposit are split between the firms that conduct each phase of its exploitation, but that each of those firms is the participant that was willing to accept the lowest return on their investment. Indeed, it may be the same firm for each phase, but in a transparent and competitive auction, such a situation would arise if that firm had been the most competitive bidder at each phase, not because they had monopoly rights to the deposit. Significantly, if the firm that wins the right to prospect does not subsequently win the right to explore or mine, it still receives its predetermined return from the proceeds of the mining, whichever firm is awarded the licence.

Such a system would be a radical departure from the current process. The Henry tax review suggested "a cash bidding system could also be adopted to supplement the resource rent tax and promote the efficient allocation of exploration rights (2010: 48). However, this referred only to the allocation of initial exploration (prospecting) licences, did not consider the entirety of the mining process, and besides, was not taken up by the government.

4.3 Tripartite Rent Tax

The second possibility is to retain a traditional partial rent tax on profits, but complement it with subsidiary rent taxes on other rent flows, namely, rent flows to investors and to employees. If we assume that some rent is flowing to both groups, and there is political-economic justification for imposing a sector-specific tax on rent accruing to companies, then it follows that there is justification for a sector-specific tax on rent accruing to other direct beneficiaries. This would involve a special impost on capital gains from shares in the mining industry, and an additional levy on top of income tax for people who work for mining companies directly. The tripartite rent system would essentially involve establishing three substitution chains. However, such a tax system would likely be politically impossible, certainly unprecedented, and have significant economic distortions. Therefore, though the substitution chain model logically points to it, I disregard it for these broader reasons.

Figure 5. Idealised flow of rent in a tripartite rent tax, coefficients



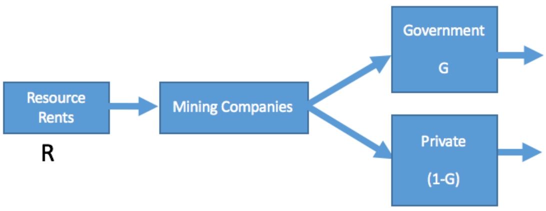
Consumption	Natural Capital	Physical Capital	Human Capital	Financial Capital	Social Capital	TOTAL
0	N	P	H	F	S	1
0	0	0	0	0	0	0
Consumption Coefficient 0	N	P	H	F	S	Investment Coefficient 1

4.4 Aggregate Savings Target

The third possibility is articulating an aggregate savings target for the entire domestic economy based on the fluctuations in rent income. This proposition requires some elaboration. Firstly, given the fungibility of different income streams, it is functionally impossible to delineate income from resource rents versus income from other sources. Moreover, the notion of hypothecating income streams for specific purposes, i.e. legislatively ensuring a proportion of resource income for capital investments, is undermined by the implication of general equilibrium theory, that if one form of income is artificially quarantined for specific investments, non-hypothecated income is likely to shift its own savings-consumption mix to restore the pre-hypothecation equilibrium.

Significantly though, the Hartwick rule only applies at the level of the whole economy; it does not require necessarily that income directly derived from resource rents be re-invested, it simply requires an amount equivalent to resource rents. It follows that what matters from a diachronic justice point of view, is not whether an economy consumes its resource rent but ends up saving more of its non-rent income, what matters is that the aggregate proportion of savings increases. This provision means the inability to directly trace resource rent flows is circumvented. It instead would require the government to calculate resource rents for a given year, and determine a national savings target by combining the long-term savings trend with the resource windfall, and developing policies to achieve that level of saving, for instance, one-off tax concessions for investment in certain kinds of capital that have a positive multiplier effect. This proposition also

Figure 6. Idealised flow of rent with a savings target, coefficients



Consumption	Natural Capital	Physical Capital	Human Capital	Financial Capital	Social Capital	TOTAL
0	Ngov	Pgov	Hgov	Fgov	Sgov	G
0	Nprv	Pprv	Hprv	Fprv	Sprv	(1-G)
Consumption Coefficient 0	N	P	H	F	S	Investment Coefficient 1

brings back into focus the broader question about the government's role in influencing savings rates. The question of rent management is in effect subsumed as one component of a broader savings policy aimed at ensuring capital maintenance. In Australia, there is strong precedent for the technocratisation of economic policy through the creation of independent statutory bodies: the Reserve Bank controls monetary policy, the Parliamentary Budgetary Office costs policy proposals from all parties, the Productivity Commission advises on micro-economic policy. An institution to represent the interests of future citizens via targets for capital maintenance would sit alongside these bodies in contributing independent advice to governments. Satisfying the Hartwick rule would necessarily, then, constitute a core part of such an institution's operations in a country such as Australia, whose wealth of non-renewable natural resources is likely to flow for some time, but not forever.

conclusion

It is undeniable that "the case for relying on the economic revenues from the depletion of non-renewable resources automatically compensating future generations is not a convincing one" (Helm 2015: 149). Certainly, the preliminary evidence I have presented above is far from a compelling case that private substitution chains are effective, Hartwick-accordant, wealth maintenance mechanisms. Similarly the policy proposals I have presented are inchoate. However, I hope also to have demonstrated that nor have rent taxes historically constituted a compelling mechanism to achieve capital substitution. My aim has been bifold. First I hope to have reconfigured the debate about resource policy in Australia from a synchronic to a diachronic temporal orientation, and second, to have broadened its scope reimagine the Hartwick rule as a network of substitution chains.

Therein I hope to have challenged the statist bias in arguments in favour of taxing resource rents. In light of the persistent failure of governments to capture resource rents, I offer the heuristic of a substitution chain, to draw attention to the manifold ways in which capital substitution can occur, and the Hartwick rule can be satisfied, that diverge from the tax-and-invest consensus. Certainly, I hope to have buttressed the case for rent taxation as an indispensable component of natural resource policy, and assuredly, synchronic distributive justice is a separate and important aim that similarly needs policy attention. But ultimately I hope to have situated those discussions as one part of a broader picture.

Many have argued that Australia's mining boom is 'over' and so the moment has passed. But that misses the point. For one, commodities are cyclical and the minerals boom will return, and secondly, Australia is about to become the world's largest exporter of liquid natural gas (LNG) so the critical questions of resource rent will re-emerge. But more importantly, the lessons expand beyond Australia; all resource-rich countries must consider the role of private substitution chains when grappling with how to transform their natural capital from ephemeral to enduring wealth.

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