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China's provincial exhaustible resources rent and produced capital stock—Based on Hartwick's rule

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ABSTRACT

Hartwick's rule, which concerns reinvesting resource rents in manmade capital, together with the concept of dynamic efficiency, dealt with by Hotelling's Rule, imply that locally constant consumption is sustainable. Based on Hartwick's rule, we have a hypothesis: if the 29 provinces in China (except Beijing and Shanghai) had invested their resource rents (from three energy resources: oil, natural gas, and coal; and nine mineral resources: iron, copper, lead, zinc, nickel, tin, antimony, molybdenum, and aluminum) in produced capital stock from 1995 to 2014, then the value of these assets should have grown commensurately over time. Using hypothetical estimates of capital stocks, the capital produced from a postulated series of historical investments, and a perpetual inventory model (PIM), the capital produced from exhaustible resources value reinvestment under Hartwick's rule is estimated. The empirical results prove that China's 29 provinces fare very well under Hartwick's rule from 1995 to 2014, and the results show that the provinces exhibit regional differences that are non-synchronous with local economic growth. Some provinces are striking: Xinjiang, Heilong, Shaanxi, Inner Mongolia, and Tianjin would have higher energy resources rent shares and lower levels of capital accumulation. Based on results, we provide managerial implications and suggestions for enhancing provincial performance under Hartwick's rule.

1. Introduction

In resource economics, there are two main intertemporal allocation rules: the Hotelling rule and the Hartwick rule (Asheim et al., 2002). This paper considers Hartwick's rule. Hartwick (1977) suggested that "investing all net returns from exhaustible resources in reproducible capital…implies intergenerational equity." Scholars have subsequently called this Hartwick's rule for reinvesting resource rents in reproducible capital (Solow, 1993). Together with and Hotelling's Rule covering dynamic efficiency, this implies locally constant consumption. Solow (1974) shows that exhaustible natural resource inputs can be substituted by the manmade capital in such a way that depleting these natural resources does not harm future generations. Thus, substitutability between natural and manmade capital, despite the exhaustibility of natural resources, may allow for equitable consumption for all generations. Hartwick (1977) seemed to have found the investment policy that would bring about sustainability in this way. Many scholars at that time, 40 years ago, established an extend proposition for Hartwick's rule. These are reviewed in the next section.

Based on Hartwick's rule, we have developed a hypothesis: if the 29 provinces in China (except Beijing and Shanghai) had invested their resource rents (from three energy resources: oil, natural gas, and coal; and nine mineral resources: iron, copper, lead, zinc, nickel, tin, antimony, molybdenum, and aluminum) in produced capital stock from 1995 to 2014, then the value of these assets should have grown commensurately over time. Using hypothetical estimates of capital stocks, the capital produced from a postulated series of historical investments, and a perpetual inventory model (PIM), the capital produced from exhaustible resources value reinvestment under Hartwick's Rule is estimated.

This paper is organized as follows: Section 2 reviews the literature and empirical cases; Section 3 gives the original propositions and the current hypothesis; Section 4 provides data and explains how these were obtained. Section 5 presents the empirical results and draws an initial conclusion regarding the implications for different provinces in China. The final section presents and discusses conclusions and discusses the most important managerial implications and suggestions in relation to policy-making.

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2. Literature review and empirical studies

Reviewing literature of Hartwick's rule on theory development for Hartwick's rule are three aspects. **First:** our paper draws on the literature extending the original rule. Hartwick (1977) proposed the original rule; Asheim (1986) and Hartwick (1995) expanded the Hartwick rule for open economies; and Cass and Mitra (1991) investigated the nature of a general production function that might support the constant consumption result; Hartwick (1996) analyzed and expanded the original proposition in "consumption is interest on capital"; Hartwick, Long and Tian (2003) showed a peaked time-path of consumption, wherein zero net investment occurred in advance of the peak; André and Cerdá (2005) extend the original rule in renewable resources. d'Autume and Schubert (2008) with the effects of technical progress; Martinet (2007) with the consumption and the price are not in the optimal path, and Amigues and Moreauxy (2008) consider a bisector model. Mitra et al. (2013) and Mitra (2015) under an additional assumption on the increasing of the initial resource stock, all non-trivial maximin paths are efficient. **Second:** our paper draws on the literature on established the converse to original proposed that under dynamic efficiency (Hotelling's Rule), constant consumption implies "investing exhaustible resource rents" (Dixit et al., 1980). Withagen and Asheim (2007) and Asheim (2013) offer a general proof of the converse of Hartwick's rule that includes positive discount factors; Cairns and Yang (2000) sought out this converse without "positive discount factors"; and Buchholz et al. (2005) show that, if a competitive path is equitable, it must satisfy Hartwick's rule. **Third:** the original rule implies the Instant consumption is zero, Hamilton (1995) offers the extended rule (invest resource rents) and dynamic efficiency, imply a positive constant (the Instant consumption is a positive); Sato and Kim (2002) prove Hamilton's extend proposed (by the Dasgupta and Heal)by the Cobb-Douglas model and consider relationships between Hartwick's rule and conservation laws; and Hamilton and Hartwick (2005) examined "maintaining capital intact" and locally unchanging consumption,and Bazhanov (2015) extends by inefficiency. Cairns (2006) considers relationships between Hartwick's rule and national-accounting prices. In China, the scholars just had the literature reviewed but not break through in the rule in theory. Lihong (2007) thinks the profound influence of Hartwick's rule on sustainability, population growth, intergenerational equity, and the system of national accounts. Bo et al. (2013) think Hartwick's rule is the important one research of human well-being, the derived on math is very precise, this rule brings an important measuring sustainable method to measure the human well-being. This method could measure the total well- being by total income which came from various consumptions multiply shadow price.

There is a considerable body of literature presenting empirical studies of Hartwick's rule. Vincent et al. (1997) study the case of petroleum depletion in Indonesia and suggest that, to sustain their consumption levels, resource-rich countries will need to invest more than previously expected. Pearce and Atkinson (1993) measured 18 countries on the basis of a weak sustainability rule that allows for unconstrained elasticities of substitution between natural and manmade capital. Genuine saving (a positive constant)is the Hartwick rule's transform for empirical (Hamilton, 1994; Hamilton and Clemens, 1999; Hamilton and Hartwick, 2005). Hamilton et al. (2006) construct three alternative estimates of produced capital stock for the year 2000, using data covering 1970–2000. Genuine saving estimates were calculated by the World Bank (2005), based on Atkinson and Hamilton (2003). With negative genuine saving, a nation loses wealth, and social welfare falls (Dasgupta and MÄLer, 2000).

In China, the empirical studies focus on three facts. **First,** Chang and Yan (2011) evaluated the elasticity is two of the energy consumption and the manmade capital and would decline with technical progress. **Second,** Guoxia et al. (2009) evaluated the contribution of mineral resources to genuine savings in 31 provinces of China. Their results found that the value of genuine saving is negative in Shanxi, Guizhou, and Qinghai, which indicates that the development of the economy is not sustainable. Na and Yunyan (2008) compared the Jeffrey model and the Hamilton model to estimate the efficiency of China's genuine saving rate from the year 1960–2006, based on data provided by the World Bank, and found out that the main reason that is China's genuine saving by the World Bank does not conform to reality is difference in data formation method and being not suitable for China's data. **Third,** Some scholars focused on substitutions between exhaustible resources' capital and manmade capital (Angang and Yahua, 2005; Na, 2011; Qingyou and Xinfa, 2013).

3. Methodology and data

3.1. Generalizing the Hartwick rule

We assume that a simple economy with an exhaustible resource is essential for Hartwick's rule. The original "invest exhaustible resource rents" result, which was (a) investing resource rents: $\dot{K}=RF_R$, and (b) dynamic efficiency (Hotelling's Rule: $\dot{F}_R=F_K F_R$), implies constant consumption ($\dot{C}=0$) (Hartwick, 2003).

This can be deduced as follows: assume current output Q = F(K, R, N), where K is produced capital from current stock;R is an explored exhaustible resources flow from current stock $S(t)$, i.e.,$R(t)=-\dot{S}(t)$; and N is a constant for human resources. we set out a simple economy,with satisfied Dasgupta–Heal model (Dasgupta and Heal, 1980) and the Pezzey–Withagen model (Pezzey and Withagen, 1998), where

$$Q = F(K, R, N)=C + \dot{K} \tag{1}$$

Transform expression (1)

$$C=F(K, R)-\dot{K}$$

Consider the time-derivative $\dot{C}$:

$$\dot{C}=F_K\dot{K}+F_R\dot{R}+F_N\dot{N}-d\dot{K}/dt$$

We should prove $\dot{C}=0$, that is

$$\dot{C}=F_K RF_R+F_R\dot{R}-\dot{R}F_R-RF_R=[F_K F_R-\dot{F}_R]R=0 \tag{2}$$

This produces a proposition:

Proposition (Hartwick's Rule). if human capital N is constant, in Hotelling Rule ($\dot{F}_R=F_K F_R$) and reinvesting exhaustible resource rents into other capitals implies constant consumption.

Hartwick (2003) notes that this original rule did not make use of constant returns to scale. Cass and Mitra (1991) support the Solow (1974) constant consumption result for "enough" substitutability between produced capital and exhaustible resources rents, and show that produced capital should be more productive than are exhaustible resources rents to maintain constant consumption.

3.2. The hypothetical methodology

3.2.1. A review of our hypothesis

Based on Hartwick's rule, we present a hypothesis: if the 29 provinces in China (except for Beijing and Shanghai) had invested their resource rents (from three energy resources: oil, natural gas, and coal; and nine mineral resources: iron, copper, lead, zinc, nickel, tin, antimony, molybdenum, and aluminum) in produced capital stock from 1995 to 2014, then the value of these assets should have grown commensurately over time.

Hartwick's rule concerns reinvesting exhaustible resources' rents into other assets, including production capital, human capital, and renewable resource capital. Hamilton et al. (2006) consider the scenario that most resource-rich countries were investing little resource value either in human or in foreign financial assets, and,