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Abstract

This study compares the shadow price (marginal cost) and shadow value (total cost) of patent stock (as knowledge stock) in each of 92 countries between 1992 and 2010. Two specifications are considered in the data envelopment analysis approach. One specification considers population, capital, patent stock, energy use (four inputs), greenhouse gas (undesirable output), and gross domestic product (desirable output). The other uses human capital and natural capital instead of population and energy use. Under these two specifications, respectively, the shadow price of the patent stock (on weighted average) for the whole period is −0.106 and −0.054 million US dollars per patent in the entire sample. Similarly, the shadow value of the patent stock (by the ratio of gross domestic product) in the entire sample is −5.8% and −2.9%, respectively. As the standing position of patent stock, the patent stock is less valuable than human capital and (produced) capital but more valuable than population, energy use, and natural capital. The patent stock also is likely to be valuable in developing countries. In addition, the shadow value of the patent stock is relatively high in certain large countries and nearly flat in most of the countries.

Keywords: Data envelopment analysis; Patent stock; Shadow price; Inclusive wealth index
JEL codes: C14, O34, O44

1. Introduction

This study aims to discuss economic development policy on the value of patent stock as knowledge stock. Knowledge stock is not considered in traditional economic models (e.g., Solow residual) but has long been discussed as an element of economic development (e.g., Griliches, 1981, 1990; Cohen, 2010).

This study estimates and compares the shadow price and shadow value of patent stocks in each of 92 countries over the years from 1992 to 2010. This study introduces estimated results focusing on time and country heterogeneity. This study considers two specifications: base and inclusive wealth index (IWI) models in the data envelopment analysis (DEA) approach. The base model considers population, capital, patent stock, and energy use as four inputs, greenhouse gas (GHG) as the undesirable output, and gross domestic product (GDP) as the desirable output. In the IWI model, based on the idea of IWI (see UNU-IHDP and UNEP, 2012, 2014), human capital and natural capital are used instead of population and energy use.

The results of this study are briefly summarized as follows. In the entire sample, the shadow price of patent stock (on weighted average) (million US dollars [USD] per patent) over the whole period is −0.106 and −0.054, respectively, in the base and IWI models. The shadow value (which is shadow price times quantity) of the patent stock in the entire sample (on weighted average) is −5.8% and −2.9% of GDP, respectively, in the base and IWI models. As the standing position, the patent stock is less valuable than human capital and (produced) capital but more valuable than population, energy use, and natural capital. In addition, the shadow value of the patent stock is relatively high in certain top countries (such as the United States and China) and nearly flat in most of the countries.

The structure of this paper is as follows. Section 2 summarizes the knowledge measurement method at the macro level and confirms the trend of patent stock for the period. Section 3 explains the model and data. Section 4 shows and discusses the estimated results, and section 5 concludes.

2. Background

2.1 Measuring knowledge at the macro level

Before reviewing knowledge indicators, this study introduces recent literature on inclusive wealth as an alternative macro index, which is different from the concept of GDP. At the macro level, GDP has long been one of the major indicators for comparing countries. GDP is a flow variable and a major economic indicator. GDP is useful for comparing economic activities, but has been considered unsuitable as an indicator of national wealth for sustainable development. In recent years, inclusive wealth (as well as IWI, which means inclusive wealth per capita) has been proposed as a new substitute indicator of wealth (UNU-IHDP and UNEP, 2012, 2014). IWI is a stock variable, divided into human, produced, and natural capitals. Among recent literature about inclusive wealth, a major theoretical framework has been developed by Arrow et al. (2012, 2013). Various articles have used this framework to estimate inclusive wealth of the 20 countries (Yamaguchi, 2014), Southeast Australia (Walker et al., 2010), West Virginia in the United States (Ghadimi et al., 2015), groundwater in Kansas in the United States (Fenichel et al., 2016), Japan at the prefectural levels (Ikeda et al., 2017), the Seto Inland Sea in Japan (Uehara and Mineo, 2017), and the oil-exporting countries (Collins et al., 2017). In addition, Kurniawan and Managi (2017) use the DEA model to estimate the entire productivity change, considering inclusive wealth (human, produced, and natural capitals), GDP, and carbon damage (using UNU-IHDP and UNEP (2014)). The present study notes that the framework in Arrow et al. (2012, 2013) is popular but under debate; for example, Roman and Thiry (2016) raise certain limitations of the framework, in terms of its theoretical assumptions.

Measurement of knowledge is important for economic policy. Knowledge is not considered in the traditional economic models (e.g., Solow residual), which mainly consider labor and capital, but may be a key component of endogenous economic growth (e.g., Griliches, 1981, 1990; Cohen, 2010). In IWI, human capital was originally composed of human skills, education, health, etc., and can therefore be considered a measure of knowledge. UNU-IHDP and UNEP (2014) have estimated human capital, taking into account education and health; however, knowledge has not been considered in the current estimation. This study supposes that knowledge has a unique process, which consists of the

status of inflow (invented or newly acquired), stock (diffused/maintained), and outflow (obsoleted or forgotten). Based on this process, this study reviews three kinds of issues in measuring knowledge: knowledge flow, knowledge stock, and monetary evaluation.

Knowledge flow mainly considers the status of inflow and does not consider the status of stock. Logically, the status of outflow can be considered, but it is usually difficult to observe. Knowledge flow (knowledge inflow) is relatively easy to measure (e.g., the number of patent applications or grants). Usually, economic variables and numbers in accounting consist of flow variables (e.g., GDP and sales) and therefore are likely to be related to knowledge flow. On the other hand, knowledge stock represents well the characteristics of knowledge from the status of inflow to outflow; however, it is often more difficult to measure than knowledge flow. The perpetual inventory method is a popular method often used to estimate knowledge stock when information on knowledge flow is available. It needs data for some periods, assuming a certain discount rate (which is often exogenous) (e.g., Hall et al., 2005).

As the last issue, it is often difficult to estimate the monetary value of knowledge, mainly because there are usually few markets of knowledge itself (such as information products). Therefore, price or market of knowledge often does not exist. Thus, some assumptions are usually needed to estimate the monetary value of knowledge. As an example, with regard to human knowledge and experience (such as education and skill), wage information in a certain labor market can provide a hint about the monetary value of knowledge.

When estimating knowledge stock at the macro level, education, research and development (R&D), patents, and scientific articles are frequently referenced in the literature. Education is adopted within the human capital of IWI (UNU-IHDP and UNEP, 2014). One example indicator here is the number of years of schooling. Using this indicator, education can be stock indexed by multiplication with population size. Also, because it is likely to be related to wage in the labor market (at the macro level), its monetary value can be indirectly estimated. On the other hand, education represents mainly knowledge in educational institutions and is less likely to capture business and industry skills.

R&D and patents are representative indicators in the literature on industrial organization

(Cohen, 2010). R&D is one of the most popular indicators in business and industry. As a feature, it is already expressed in monetary value accordingly. However, some issues can be raised; for example, because R&D is a flow variable, it is difficult to evaluate as a stock variable. Furthermore, R&D is considered to represent innovation input rather than innovation output. Therefore, it is difficult to evaluate the quality of R&D.

A feature of patents is that a flow variable of patents is easy to access (e.g., the number of patent applications and grants). This is because large-scale databases such as European patent office (EPO) PATSTAT and NBER Patent Citation Database (Hall et al., 2001, 2005) have been developed. The availability of the technology classification for each patent application is an advantage. Measuring the quality of patents is also possible, often by using citation information (e.g., a fixed-effects approach, as in Hall et al., 2005; Park and Park, 2006). In measuring patent stock, it is common to use the perpetual inventory method with a 15% depreciation rate (Hall et al., 2005). Note that an issue here is the frequent difficulty of estimating the monetary value of patents. This is because market information (for patent licenses) is usually difficult to access. The renewal-based approach (Park and Park, 2006; Schankerman and Pakes, 1986) by using information on the patent fee is one method of gaining this information.

Scientific articles are also a useful indicator. One example of knowledge flow is the number of scientific articles. Similar to patents, the quality of each article can be evaluated by information on citations, scientific fields, and so on. Some indicators, such as journal impact factor (Thomson Reuters) and SCImago Journal & Country Rank (Scopus database by Elsevier B.V.), have been developed (Falagas et al., 2008) for this. As with patents, an issue is that it is difficult to estimate monetary value. One of the direct reasons for this difficulty is that no (or few) market exists for academic achievements. As an idea, however, wage information in academic labor markets may give the monetary value of scientific articles indirectly. Furthermore, if information on the budget or funding for academic achievements is available, it may show the monetary value of scientific articles. The literature has been working on new indexing for this purpose, such as third-party funding (e.g., Schmoch et al., 2010).

2.2 Patent stock

Patent stock has been measured since the 1980s, but mainly since the 2000s (since Hall et al. (2001)), based on the perpetual inventory method (Hall et al., 2005). To search for journal articles that use patent stock data, this study used the topic search at Web of Science (Thomson Reuters' Journal database; accessed in June, 2017). For keywords, this study used simply "patent stock" and "stock of patents". A total of 28 journal articles were found (21 including "patent stock" and 7 including "stock of patents"), and this study accessed 24 of them. Apart from those found in this search, this study also found three additional articles (Bottazzi and Peri, 2007; Lach, 1995; Schankerman and Pakes, 1986) and reviews of a total of 27 articles. Note that patent stock data have actually been measured in those 27 articles, except that by Yueh (2009). The articles' themes can roughly be divided into two groups: research on the value of patent stock, and miscellaneous other subjects. The former group of themes includes the valuation of patents (Park and Park, 2006; Schankerman and Pakes, 1986; Thompson, 2016) and productivity (Balasubramanian and Sivadasan, 2011; Blind and Jungmittag, 2008; Bottasso et al., 2013; Chen and Yang, 2005; Czarnitzki and Kraft, 2010; Lach, 1995; Madsen, 2008; Mahlich, 2010; Mukherji and Silberman, 2011). This classification is based on the following three approaches to patent valuation: a quality approach, a market value approach, and a hybrid approach (Wang and Hsieh, 2015). The latter group of topics includes innovating activity in international trade theory (Benz et al., 2014), innovating activity in knowledge transfer offices in universities (Berbegal-Mirabent et al., 2012), governmental venture capital (Bertoni and Tykvová, 2015), the relationship between R&D and patent stock (Bottazzi and Peri, 2007), innovating activity in university (Crespi et al., 2011), the labor market (Gera et al., 2001), the funding strategies of public sector scientists (Grimpe, 2012), innovative spell length (Jang and Chen, 2011), knowledge spillover (Streb et al., 2007), determinants of patents (Yueh, 2009), and open innovation (Zobel et al., 2016). Topics related to merger and acquisition were explored by Amess et al. (2016), Desyllas and Hughes (2009), and Lin and Jang (2010). A study of environmental efficiency (DEA) was done by Johnstone et al. (2017).

The literature attempts to estimate the value of patent stock by estimating the elasticity of

patent stocks to economic variables. It is popular to conduct a regression analysis, using certain size variables and productivity and/or profit ratio as the dependent variable(s). The elasticity of patent stock to a size variable tends to range from 0.04 to 0.3 (from 0.047 to 0.324 in Blind and Jungmittag (2008); from 0.05 to 0.108 in Bottasso et al. (2013)). Meanwhile, in terms of productivity and profit rate, some studies find a positive correlation between patent stock and productivity (Bottasso et al., 2013; Chen and Yang, 2005; Lach, 1995; Madsen, 2008; Park and Park, 2006). The elasticity to total factor productivity (TFP) or TFP growth ranges from 0.243 to 0.342 in Lach (1995) and from 0.049 to 0.303 in Park and Park (2006); it is 0.21 in Bottasso et al. (2013). However, other studies do not support this positive relationship (Balasubramanian and Sivadasan, 2011; Mahlich, 2010). Overall, therefore, studies suggest that patent stock may be not a perfect substitute for productivity and profitability.

In recent years, the legal status of patents has become available (van Zeebroeck, 2008, 2011a, 2011b), mainly in EPO PATSTAT. This made it possible to estimate living patents in a legal sense. Shadow price estimates for patent stock have seldom been made. Note that Johnstone et al. (2017) use the patent stock variable in the DEA model, but do not focus on efficiency or the shadow price of patent stock. This study aims to simply summarize and discuss the estimated results of shadow price/shadow value on patent stock, focusing on time and country heterogeneity. Shadow price means basically marginal cost (in a certain mathematical problem); because its sign is negative in this study, however, it refers to marginal profit. Note that shadow price is calculated by an allocation problem of GDP (value added); therefore, it can be called the marginal price of value added. In this study, shadow value refers to the shadow price multiplied by the corresponding quantity, which means total cost (or negative profit) or, equivalently, value added. Heterogeneity on the shadow price/value of patent stock is considered important for the economic valuation of countries. Countries with a higher shadow price/value of patent stock will face a higher price/cost of investment in technology development. At the same time, they are also likely to create high value added from the technology investment. In particular, this study considers that developing countries with higher shadow price/value of patent stock will need greater technology assistance and/or meet larger demand for knowledge stock.

The sample includes 92 countries. The 35 Organisation for Economic Co-operation and

Development (OECD) members are Australia (AU), Austria (AT), Belgium (BE), Canada (CA), Switzerland (CH), Chile (CL), the Czech Republic (CZ), Germany (DE), Denmark (DK), Spain (ES), Estonia (EE), Finland (FI), France (FR), the United Kingdom (GB), Greece (GR), Hungary (HU), Ireland (IE), Iceland (IS), Israel (IL), Italy (IT), Japan (JP), the Republic of Korea (KR), Luxembourg (LU), Latvia (LV), Mexico (MX), the Netherlands (NL), Norway (NO), New Zealand (NZ), Poland (PL), Portugal (PT), Slovakia (SK), Slovenia (SI), Sweden (SE), Turkey (TR), and the United States of America (US). The 57 non-OECD members are Albania (AL), the United Arab Emirates (AE), Argentina (AR), Armenia (AM), Bulgaria (BG), Bolivia (BO), Brazil (BR), China (CN), Côte d'Ivoire (CI), Cameroon (CM), Colombia (CO), Costa Rica (CR), Cuba (CU), the Dominican Republic (DO), Algeria (DZ), Ecuador (EC), Egypt (EG), Guatemala (GT), Honduras (HN), Croatia (HR), Haiti (HT), Indonesia (ID), India (IN), Iraq (IQ), Jamaica (JM), Jordan (JO), Kazakhstan (KZ), Kenya (KE), Sri Lanka (LK), Lithuania (LT), Morocco (MA), the Republic of Moldova (MD), Mongolia (MN), Malaysia (MY), Namibia (NA), Nigeria (NG), Pakistan (PK), Panama (PA), Peru (PE), the Philippines (PH), Paraguay (PY), Romania (RO), the Russian Federation (RU), Sudan (SD), Senegal (SN), El Salvador (SV), the Syrian Arab Republic (SY), Thailand (TH), Tajikistan (TJ), Tunisia (TN), Ukraine (UA), Uruguay (UY), Venezuela (VE), Viet Nam (VN), Yemen (YE), Zambia (ZM), and Zimbabwe (ZW). This study adopts the complete renewal approach (the shortest lifetime) (van Zeebroeck, 2011a), and the maximum lifetime is set as 20 years from the filing date.

Table 1 summarizes the average patent stock of the entire sample (92 countries), the 35 OECD members, and the 57 non-OECD members in three periods: 1992, 2010, and the entire period (hence 12 items in total). Supplementary Information Table S1 shows the period's average patent stock for each country (see Supplementary Information Figure S1 for total patent stock).

Total patent stock almost doubled in the 19-year period, from 16,024,637 in 1992 to 31,218,742 in 2010. Regarding technology classification, this study uses the weight of technology fields according to five classifications proposed by Schmoch (2008). Note that this weight is included in EPO PATSTAT ("TLS230_APPLN_TECHN_FIELD"). The five categories are as follows: (I) Electrical engineering (1. Electrical machinery, apparatus, energy; 2. Audio-visual technology; 3.

Telecommunications; 4. Digital communications; 5. Basic communication processes; 6. Computer technology; 7. IT methods for management; 8. Semiconductors); (II) Instruments (9. Optics; 10. Measurement; 11. Analysis of biological materials; 12. Control; 13. Medical technology); (III) Chemistry (14. Organic fine chemistry; 15. Biotechnology; 16. Pharmaceuticals; 17. Macromolecular chemistry, polymers; 18. Food chemistry; 19. Basic materials chemistry; 20. Materials, metallurgy; 21. Surface technology, coating; 22. Micro-structure and nano-technology; 23. Chemical engineering; 24. Environmental technology); (IV) Mechanical engineering (25. Handling; 26. Machine tools; 27. Engines, pumps, turbines; 28. Textile and paper machines; 29. Other special machines; 30. Thermal processes and apparatus; 31. Mechanical elements; 32. Transport); (V) Other fields (33. Furniture, games; 34. Other consumer goods; 35. Civil engineering). Note that "unclassified" refers to the event that certain patent items are not weighted in this classification.

In terms of the trend of total patent stock, (I) electrical engineering tends to increase (from 19.8% in 1992 to 27.1% in 2010). (II) Instruments have slightly increased, but it is almost unchanged (from 13.1% in 1992 to 13.6% in 2010). (III) Chemistry is on a downward trend (from 25.0% in 1992 to 22.4% in 2010), and (IV) mechanical engineering also tends to decrease (from 28.8% in 1992 to 21.1% in 2010). (V) Other fields are decreasing, but they do not change much (from 8.0% in 1992 to 7.4% in 2010). As summarized, the period from 1992 to 2010 can be said to be the development era of (I) electrical engineering.

Regarding the OECD members, the average ratios of technology fields I to V are, respectively, 20.8%, 12.9%, 24.6%, 28.3%, and 7.9% in 1992 and 27.3%, 13.8%, 20.9%, 21.5%, and 7.6% in 2010. As a feature of the period, (III) chemistry and (IV) mechanical engineering were popular in 1992 but decreasing toward 2010. Instead, (I) electrical engineering tends to increase. Similarly, regarding the non-OECD members, the average ratios of technology fields I to V are, respectively, 10.4%, 8.6%, 37.1%, 29.0%, and 9.0% in 1992 and 25.0%, 12.2%, 33.1%, 20.0%, and 6.8% in 2010. In 1992, the non-OECD members were investing the most in (III) chemistry (37.1%), suggesting that the demand for agricultural technology was intense. In 2010, on the other hand, (III) chemistry was still popular but received less investment than previously (33.1%). Instead, (I) electrical engineering

has been increasing (from 10.4% to 25.0%), as among the OECD members.

Regarding the average patent stock for each country (Supplementary Information Table S1), the country with the largest patent stock is Japan (JP, 7,331,432.3). The countries with the largest ratios in each technology field are the Republic of Korea (KR, 40.3%) in (I) electrical engineering, Senegal (SN, 23.9%) in (II) instruments, Guatemala (GT, 73.5%) and Kenya (KE, 73.5 %) in (III) chemistry, Albania (AL, 66.7%) in (IV) mechanical engineering, and Côte d'Ivoire (CI, 27.3%) in (V) other fields. This implies that except for the Republic of Korea, the non-OECD members tend to specialize in a specific technology field.

3. Materials and methods

3.1 DEA model

An issue with patent stock is how to estimate its monetary value. Just the number of patent stocks (living patents) is not very useful as an economic development indicator. This study estimates the shadow price of patent stock by a DEA approach. The model of this study assumes variable returns to scale (VRS) with weak disposability of GHG as the undesirable output, following Leleu (2013). This study then estimates the shadow price of patent stock (Lee et al., 2002; Yagi et al., 2015) and calculates the shadow value, which is the shadow price multiplied by the corresponding quantity. To do this, the problem of GDP allocation considers how GDP is allocated to the four inputs, the undesirable output, and the remainder (as profit). In other words, the profit is calculated by GDP minus the sum of the cost of four inputs and one undesirable output (where the cost of undesirable output may be positive or negative, as in Leleu (2013)). Shadow price is estimated by solving the maximization problem of the profit using the Lagrange multiplier method.

The DEA model has had a 40-year history since its use by Charnes et al. (1978) (Cook and Seiford, 2009; Emrouznejad and Yang, 2018). In recent years, some studies have considered not only basic production factors such as value added (GDP), labor, and capital, but also environmental factors such as energy and GHG (Chung et al., 1997; Färe et al., 1996: Tyteca, 1996; for a survey, see Zhou

et al., 2008). In this context, undesirable environmental outputs (such as GHG) are often assumed to be weakly disposable. In addition, as a scale assumption, non-increasing returns to scale and VRS tend to be used rather than constant returns to scale. In particular, many studies assume weak disposability under VRS (Chung et al., 1997; Färe et al. 1996) (for recent discussion about weak disposability in the DEA model, see Kuosmanen and Matin, 2011; Leleu, 2013). In recent years, Leleu (2013) proposed a new formulation of weak disposability under VRS.

Following Leleu (2013), this study supposes that a production set is defined as $P_o^t(x^t)$, where input vector x can produce output vector (v, w) in time t (year t); v and w denote desirable and undesirable outputs, respectively. The Shephard output distance function $D_o^t(x^t, v^t, w^t)$ for each year is defined as follows:

$$D_o^t\left(x^t, v^t, w^t\right) = \inf\left\{\theta : \left(\left(v^t, w^t\right)/\theta\right) \in P_o^t\left(x^t\right)\right\} \tag{1}$$

Here, the following weak disposability is assumed:

$$\begin{aligned} &\text{If } \left(v^t, w^t\right) \in P_o^t\left(x^t\right) \text{ and } 0 \le \theta \le 1 \text{ then } \left(\theta v^t, \theta w^t\right) \in P_o^t\left(x^t\right) \\ &\text{If } \left(v^t, w^t\right) \in P_o^t\left(x^t\right) \text{ and } w^t = 0, v^t = 0 \end{aligned} \tag{2}$$

Instead of $D_o^t(x^t, v^t, w^t)$, the directional distance function $\overrightarrow{D_o^t}(x^t, v^t, w^t)$ is defined as follows:

$$\overrightarrow{D_o^t}\left(x^t, v^t, w^t; g^v, g^w\right) = \sup\left\{\beta : \left(v^t + \beta g^v, w^t - \beta g^w\right) \in P_o^t\left(x^t\right)\right\} \tag{3}$$

where g denotes the directional vector $g = (g^v, g^w)$. This study sets $g^t = (g^{t,v}, g^{t,w}) = (v^t, w^t)$, following Chung et al. (1997). The frontier direction of undesirable output (g^w) is usually equal to or more than zero in equation (3); therefore, undesirable output takes a maximum value at the current activity level (as discussed in Kuosmanen (2005)).

Suppose there are k-th peer decision making units (DMUs) from 1 to K, and k' is a certain evaluated DMU. Leleu (2013) has made a new formulation of weak disposability under VRS in the directional distance function. The primal problem is expressed as follows:

$$
\begin{aligned}
&\max_{\delta,\lambda,\sigma} \delta \\
&s.t. \quad -\sum_{k=1}^{K}\lambda_k\left(v_{m,k}-v_m^{k'}\right)+\sigma v_m^{k'}+\delta g_m^{v}\le 0 \quad m=1,...,M \\
&\sum_{k=1}^{K}\lambda_k\left(w_{j,k}-w_j^{k'}\right)-\sigma w_j^{k'}+\delta g_j^{w}=0 \quad j=1,...,J \\
&\sum_{k=1}^{K}\lambda_k\left(x_{n,k}-x_n^{k'}\right)\le 0 \quad n=1,...,N \\
&\sum_{k=1}^{K}\lambda_k+\sigma=1 \\
&\lambda_k\ge 0 \quad k=1,...,K \\
&\sigma\ge 0
\end{aligned}
\tag{4}
$$

Similarly, the dual problem is as follows:

$$
\begin{aligned}
&\min_{\phi,\pi^{v},\pi^{w},\pi^{x}} \phi \\
&s.t. \quad \left(\sum_{m=1}^{M}\pi_m^{v}v_{m,k}-\sum_{j=1}^{J}\pi_j^{w}w_{j,k}-\sum_{n=1}^{N}\pi_n^{x}x_{n,k}\right) \quad k=1,...,K \\
&\quad -\left(\sum_{m=1}^{M}\pi_m^{v}v_m^{k'}-\sum_{j=1}^{J}\pi_j^{w}w_j^{k'}-\sum_{n=1}^{N}\pi_n^{x}x_n^{k'}\right)\le\phi \\
&\sum_{m=1}^{M}\pi_m^{v}g_m^{v}+\sum_{j=1}^{J}\pi_j^{w}g_j^{w}=1 \\
&\sum_{m=1}^{M}\pi_m^{v}v_m^{k'}-\sum_{j=1}^{J}\pi_j^{w}w_j^{k'}+\phi\ge 0 \\
&\pi_m^{v}\ge 0 \quad m=1,...,M \\
&\pi_j^{w}\ unconstrained \quad j=1,...,J \\
&\pi_n^{x}\ge 0 \quad n=1,...,N
\end{aligned}
\tag{5}
$$

The key feature of this formulation is that there is no constraint on the shadow price of w (π_j^{w}). Equations (4) and (5) follow weakly disposable Shephard's technology. Note that it has been argued that weakly disposable Shephard's technology is non-convex (Kuosmanen and Matin, 2011; Leleu, 2013), and thus basically unsuitable for linear programming. Furthermore, shadow price may be not only positive but also negative in this formulation when fully following weakly disposable Shephard's technology. Because the shadow price should usually take a non-negative value, Leleu (2013) proposes, apart from the assumption of weak disposability, the additional constraint that π_j^{w} be positive (for other recent applications of shadow price estimation, see Kumar et al., 2015; Tamaki et al., 2018).

Let λ^{*} be the weight of the (pseudo) reference DMU for DMU *k'*. Thus, *v*, *w*, and *x* of the pseudo reference DMU (denoted by *) are represented as follows:

$$
\begin{aligned}
v_m^{*k'} &= \sum_{k=1}^{K} \lambda_k^* v_{m,k} \quad m = 1,...,M \\
w_j^{*k'} &= \sum_{k=1}^{K} \lambda_k^* w_{j,k} \quad j = 1,...,J \\
x_n^{*k'} &= \sum_{k=1}^{K} \lambda_k^* x_{n,k} \quad n = 1,...,N
\end{aligned}
\tag{6}
$$

Here, let π^* be the shadow price of the pseudo reference DMU, estimated by equation (5). Because equations (4) and (5) are equivalent, the objective value ϕ of equation (5) is rewritten as follows:

$$
\phi = \left(\sum_{m=1}^{M} \pi_m^{*v} v_m^{*k'} - \sum_{j=1}^{J} \pi_j^{*w} w_j^{*k'} - \sum_{n=1}^{N} \pi_n^{*x} x_n^{*k'} \right) - \left(\sum_{m=1}^{M} \pi_m^{*v} v_m^{k'} - \sum_{j=1}^{J} \pi_j^{*w} w_j^{k'} - \sum_{n=1}^{N} \pi_n^{*x} x_n^{k'} \right) \tag{7}
$$

That is, the objective value ϕ indicates the difference in profit between the pseudo reference DMU (*) and DMU *k'* (Leleu, 2013; Yagi et al., 2015).

Following Lee et al. (2002) and Yagi et al. (2015), shadow prices p^v, p^w, and p^x of desirable outputs *v*, undesirable outputs *w*, and inputs *x*, respectively, are calculated in the following maximization problem:

$$
\begin{aligned}
&\max_{x,v,w} \sum p_m^v v_m + \sum p_j^w w_j + \sum p_n^x x_n \\
&s.t. \quad \overrightarrow{D_o}\left(x_n, \sigma_m^v v_m, \sigma_j^w w_j; v_m, w_j \right) = 0
\end{aligned}
\tag{8}
$$

The subject condition refers to the productivity of (pseudo) reference DMU, which hence takes zero (on the frontier). σ^v and σ^w are inefficiency parameters of *v* and *w*, respectively, converted to the frontier values. Therefore, $\sigma^v v = v^* \geq v$ and $\sigma^w w = w^* \leq w$.

According to the first-order conditions in the Lagrange multiplier, p^x and p^w are expressed as follows:

$$
\begin{aligned}
p_n^x = \frac{p_n^x}{p_m^v} &= \frac{\partial \overrightarrow{D_o}\left(x_n, \sigma_m^v v_m, \sigma_j^w w_j; v_m, w_j \right) \Big/ \partial \left(x_n \right)}{\partial \overrightarrow{D_o}\left(x_n, \sigma_m^v v_m, \sigma_j^w w_j; v_m, w_j \right) \Big/ \partial \left(\sigma_m^v v_m \right)} \cdot \frac{1}{\sigma_m^v}, \\
&= -\frac{\pi_n^{*x}}{\pi_m^{*v}} \cdot \frac{1}{\sigma_m^v}
\end{aligned}
\tag{9}
$$

$$p_j^w = \frac{p_j^w}{p_m^v} = \frac{\partial \overrightarrow{D_o}\left(x_n, \sigma_m^v v_m, \sigma_j^w w_j; v_m, w_j\right) \Big/ \partial\left(\sigma_j^w w_j\right)}{\partial \overrightarrow{D_o}\left(x_n, \sigma_m^v v_m, \sigma_j^w w_j; v_m, w_j\right) \Big/ \partial\left(\sigma_m^v v_m\right)} \cdot \frac{\sigma_j^w}{\sigma_m^v}$$
$$= -\frac{\pi_j^{*w}}{\pi_m^{*v}} \cdot \frac{\sigma_j^w}{\sigma_m^v}$$

Again, this study assumes $p^v = 1$ (monetary unit) because of GDP. Inefficiency score σ^v is 1 at the frontier and larger than 1 when leaving the frontier. On the other hand, inefficiency score σ^w is 1 at the frontier but less than 1 when leaving the frontier. For this reason, the shadow prices p^x and p^w are largest on the frontier and decrease when away from it (see Yagi et al., 2015).

This study uses two models for sensitivity analysis: the base and IWI models. The base model considers four inputs (population as labor, capital, patent stock, and energy use, GHG as the undesirable output, and GDP as the desirable output. On the other hand, following the concept of three capitals in IWI, the IWI model uses human capital and natural capital instead of population and energy use (which are traditionally used in the economics literature), respectively.

Note that (produced) capital is already used in both models. As in Chung et al. (1997), the directional distance function sets its frontier direction to a 1% increase in GDP and a 1% decrease in GHG. By comparing the two models, it is possible to judge how sensitive the model is to change in the variables.

The difference between the two approaches depends only on whether to use labor (population) and energy use, or human and natural capitals. The base model arises from the context of the literature, because many studies use population and energy use (Zhou et al., 2008). On the other hand, the IWI model is built on the discussion of IWI rather than DEA literature, and considers the three capitals with patent stock. Kurniawan and Managi (2017) also use these three capitals in the DEA model, albeit without considering patent stock. Note that this study cannot truly detect which model is better; however, it will be possible to decide which is more intuitive, based on the estimated results. One indicator would be the value of a patent stock. In the sample period of this study (1992 to 2010), the country that invested the most in R&D was, intuitively, the United States. For this reason, this study considers the model in which the United States owns the largest value of patent stock as more intuitive.

The IWI model also shows which capital is important among the three. Note that the three capitals are stock-based, whereas shadow price (marginal cost) is a flow variable estimated from a problem of GDP allocation. For this reason, the shadow price of each capital represents how much annual cost is required for stock usage (USD per 1 USD of capital). This study considers the shadow price as equivalent to its depreciation cost/rate. Higher shadow price of the three capitals means higher marginal cost for their usage and a larger depreciation rate, and thus faster deterioration. Similarly, patent stock is a stock variable, and hence its shadow price denotes the depreciation cost for 1 USD of patent stock.

3.2 Data

Table 2 shows the descriptive statistics for the data in this study. Data on GDP, population (million people), (produced) capital, human capital, and natural capital are obtained from UNU-IHDP and UNEP (2014). The monetary unit is billions of USD at a constant 2005 price. The patent stock is measured from the EPO PATSTAT (2016a version). Energy use (million tonnes of oil equivalent [TOE]) and GHG emissions (million tonnes) are obtained from the International Monetary Fund World Economic Outlook Database (October 2016 edition). Sample countries are 92 countries (35 OECD and 57 non-OECD members) from 1992 to 2010.

4. Results

4.1 DEA score

This section mainly focuses on patent stocks. Appendix A discusses the difference between the base and IWI models.

Tables 3 and 4 show (weighted) average DEA scores in the entire sample, OECD members, and non-OECD members from 1992 to 2010, respectively, in the base and IWI models. GDP is used as a weight for the weighted average, controlling for economic scale. Supplementary Information Table S2 shows the average DEA scores for each country in the period.

Regarding the DEA score, the simple average (standard deviation) values are 0.173 (0.232), 0.127 (0.172), and 0.202 (0.258) in the base model and 0.127 (0.187), 0.094 (0.158), and 0.148 (0.201) in the IWI model for the entire sample, OECD members, and non-OECD members, respectively. Similarly, the weighted average values (by GDP) are 0.045, 0.030, and 0.119 in the base model and 0.036, 0.019, and 0.117 in the IWI model, respectively. These values represent the potential increase in GDP and decrease in GHG (compared to the current situation, considered as 100%). The IWI model has a smaller value (more efficient) than the base model, indicating that there is less heterogeneity among countries in the IWI model.

4.2 Shadow price of patent stock

This subsection checks the shadow price of patent stock. Again, shadow price refers to marginal cost for the usage of patent stock. Because the sign is reversed (negative) in this study, however, it is indeed marginal profit. Tables 5 and 6 show the weighted average values of shadow price over the years in the base and IWI models, respectively. Similarly, Supplementary Information Tables S3 and S4 show the average shadow price in each country. Supplementary Information Figures S2 and S3 show the transition of the shadow price of patent stock in the base and the IWI models, respectively

This study supposes that the weighted average presents a more realistic picture than the simple average, considering the scale factor. Regarding the base model, the weighted average of patent stock over the whole period (million USD per patent) is −0.106, −0.054, and −0.821 in the entire sample, OECD members, and non-OECD members, respectively (Table 5). In the non-OECD members, the simple average is much more expensive than the weighted average, suggesting that the patent stock is very expensive in a few countries. In the entire sample, the weighted average has slightly increased from −0.075 in 1992 to −0.106 in 2010 (peak at −0.170 in 2003; bottom at −0.047 in 2007). The OECD members have little fluctuation, from −0.045 in 1992 to −0.044 in 2010 (peak at −0.092 in 1994; bottom at −0.023 in 2002). The non-OECD members experienced a large drop from −0.950 in 1992 to −0.245 in 2010 (peak at −2.175 in 1996; bottom at −0.151 in 2007).

On the other hand, regarding the IWI model, the weighted average of patent stock over the whole period (million USD per patent) is −0.054, −0.032, and −0.355, respectively, in the entire sample, OECD members, and non-OECD members (Table 6). The values are approximately half those of the base model. Note that this tendency is similar to (produced) capital. This decrease may be because the IWI model considers human capital; that is, considering the value of education (in human capital) may discount the value of knowledge in patent stock accordingly.

In the base model, the top five countries with the most expensive shadow price of patent stock (million USD per patent) are Paraguay (PY, −1126.191), Pakistan (PK, −913.545), Cameroon (CM, −764.592), Nigeria (NG, −664.634), and Kazakhstan (KZ, −450.028) (all non-OECD members); the shadow price is zero in 11 countries (Supplementary Information Table S3). Similarly, in the IWI model, the top five countries are Cameroon (CM, −1039.077), Nigeria (NG, −421.556), Yemen (YE, −234.875), Senegal (SN, −209.555), and Armenia (AM, −150.809) (all non-OECD members); the shadow price is zero in 16 countries (Supplementary Information Table S4). A shadow price of zero means extra one unit of patent stock can be used for free, according to the DEA problem.

4.3 Decomposition of GDP and shadow value

This subsection calculates the shadow value (total cost), multiplying the shadow price by the corresponding quantity. Because the shadow price is estimated by the GDP allocation problem, GDP (value added) consists of the sum of each shadow value and its remainder (as profit). Supplementary Information Figures S4 and S5 decompose GDP with costs (shadow values) and profit (as the remainder) in the entire sample for the period in the base and IWI models, respectively. In these figures, the shadow values are basically represented as positive, inverting the sign. Tables 7 and 8 show the shadow value (the entire sample, OECD members, and non-OECD members) over the years for the base and IWI models, respectively. Similarly, Supplementary Information Tables S5 and S6 show the shadow value for each country in the base and IWI models, respectively.

Regarding the base model (Table 7), the shadow values of population (by GDP ratio) are at 2.1%, 1.9%, and 2.8% in the entire sample, OECD members, and non-OECD members, respectively.

Similarly, those of capital are 24.6%, 18.2%, and 55.9%; those of patent stock are 5.8%, 3.3%, and 18.2%; those of energy use are 5.1%, 4.8%, and 6.4%; those of GHG are 48.8%, 58.9%, and −1.5%; and those of profit (as the remainder) are 13.7%, 12.8%, and 18.1%.

Comparing the OECD and non-OECD members, the four inputs for the OECD members have a lower proportion of GDP than for the non-OECD members. On the other hand, the shadow value of GHG is much higher for the OECD members than for the non-OECD members, resulting in lower profit among the OECD members. Regarding the trend in the entire sample, there are slight fluctuations over the years. The shadow values of population, capital, and patent stock increased from 1.8%, 22.4%, and 3.6% in 1992 to 2.3%, 29.9%, and 4.2% in 2010, respectively. On the other hand, the shadow values of energy use, GHG, and profit decreased from 4.4%, 51.0%, and 16.7% in 1992 to 2.4%, 48.3%, and 11.2% in 2010, respectively.

Regarding the IWI model (Table 8), the shadow values of human capital (by GDP ratio) are 15.1%, 12.2%, and 29.6% in the entire sample, OECD members, and non-OECD members, respectively. Similarly, those of capital stock are 15.1%, 11.6%, and 32.2%; those of patent stock are 2.9%, 2.0%, and 7.9%; those of natural capital are 1.2%, 1.0%, and 2.1%; those of GHG are 54.0%, 61.9%, and 14.5%; and those of profit (as the remainder) are 11.7%, 11.3%, and 13.8%.

Compared with the base model, in the entire sample, the sum of the shadow values of the four inputs increased slightly, whereas the shadow value of GHG remained almost unchanged. As a result, the profit decreased approximately 0.85 times (= 11.7% / 13.7%) compared with the base model. Regarding each factor of the entire sample, the shadow value of human capital (15.1%) is much higher than that of the population (2.1%) in the base model, which indicates that human capital (considering education and health) is worth much more than the population size itself.

On the other hand, the shadow prices of the other three inputs are lower than those of the base model. The shadow values of capital and patent stock are lower by approximately 0.6 (= 15.1% / 24.6%) and 0.5 times (= 2.9% / 5.8%), respectively, compared with the base model. The decreases imply that the value of education (captured in human capital) cancels out the value of patent stock (as knowledge stock), to some degree. This study supposes that the consideration of education captures a

kind of premium of (human) management in resources. Perhaps for a similar reason, the shadow value of natural capital in the IWI model is 0.24 times (= 1.2% / 5.1%) smaller than energy use in the base model. Note that this implies that natural capital has a low depreciation rate and hence does not deteriorate much over the years (see Appendix A). In terms of the low shadow value of natural capital, this study believes that this low value does not mean natural capital is less important than other capitals. Rather, it means that the value contributed by natural capital to the annual GDP is underestimated; in other words, each country could use natural capital cheaply in the sample period. In addition, the shadow value of GHG in the non-OECD members is not negative but positive (hence cost), unlike in the base model. This sign is more intuitively adequate than that in the base model (Kuosmanen and Matin, 2011; Leleu, 2013).

4.4 Shadow value of profit: country heterogeneity

To check country heterogeneity, it is useful to see shadow values. In particular, this study considers profit (which is GDP minus the total costs) as the first index. If profit is positive, there is a surplus in the model; otherwise, the cost is excessive. Then, depending on the excess of profit, each shadow value will show which part is a cost (or the potential for improvement through policy and international support).

Supplementary Information Tables S5 and S6 show shadow values (period average) in each country in the base and IWI models, respectively. Among the 92 countries analyzed, average profit is negative in 42 countries in the base model (12 OECD members and 30 non-OECD members) and 33 countries in the IWI model (7 OECD members and 26 non-OECD members). The worst three countries in terms of average profit (by GDP ratio) in the period are Tajikistan (TJ, −1503.1%), Mongolia (MN, −818.6%), and the Republic of Moldova (MD, −297.0%) in the base model and Mongolia (MN, −305.4%), the Republic of Moldova (MD, −182.2%), and Tajikistan (TJ, −138.7%) in the IWI model. For these worst outliers, therefore, the IWI model has milder profits (−305.4%, −182.2%, and −138.7%) than the base model (−1503.1%, −818.6%, and −297.0%).

In Tajikistan, the average shadow values (by GDP ratio) are population (378.1%), capital

stock (606.7%), patent stock (12.5%), energy use (505.8%), and GHG (100.0%) in the base model and human capital (94.4%), produced capital (28.7%), patent stock (10.1%), natural capital (5.7%), and GHG (99.7%) in the IWI model. Similarly, in Mongolia, they are population (197.3%), capital stock (622.9%), patent stock (3.3%), energy use (0.0%), and GHG (95.1%) in the base model and human capital (166.3%), produced capital (154.3%), patent stock (11.3%), natural capital (0.0%), and GHG (73.5%) in the IWI model. In the Republic of Moldova, they are population (38.9%), capital stock (204.5%), patent stock (35.7%), energy use (18.0%), and GHG (100.0%) in the base model and human capital (164.4%), produced capital (1.5%), patent stock (0.2%), natural capital (41.5%), and GHG (74.4%) in the IWI model. The values in the base model therefore seem to be outliers compared to the IWI model. In a consistent way, however, it shows that patent stock is less valued than population, capital, and human capital in the economies of these countries. Thus, the patent stock is not so important, but more likely to be needed than energy use and natural capital. In addition, the shadow value of GHG is high, indicating that it has much cost at the time of production.

On the other hand, the best three countries in the period in terms of average profit (by GDP ratio) are Venezuela (VE, 102.5%), Thailand (TH, 95.6%), and Indonesia (ID, 36.2%) in the base model and Venezuela (VE, 76.7%), Indonesia (ID, 30.6%), and India (IN, 29.8%) in the IWI model. Therefore, on average, Venezuela is the most economically successful country in this study. The shadow values in Venezuela (by GDP ratio) are population (1.9%), capital stock (0.0%), patent stock (7.7%), energy use (2.2%), and GHG (−14.3%) in the base model and human capital (10.9%), produced capital (6.0%), patent stock (6.4%), natural capital (0.0%), and GHG (0.0%) in the IWI model. Although all input factors are relatively cheap, patent stock and human capital are relatively expensive. Venezuela also benefits from GHG emissions, implying that production cost is low. After the period of this study, however, Venezuela entered an economic crisis due to domestic mismanagement and the recent reversal in oil prices (see Vera, 2017). In other words, the model of this study is limited because it cannot capture the risk of such future financial issues and oil prices.

The second most successful country in this study is Indonesia. The shadow values in Indonesia (by GDP ratio) are population (7.7%), capital stock (77.1%), patent stock (8.9%), energy

use (0.0%), and GHG (−29.8%) in the base model and human capital (42.5%), produced capital (39.2%), patent stock (8.8%), natural capital (0.0%), and GHG (−21.1%) in the IWI model. In Indonesia, capital stock and human capital are more expensive than other shadow values. Similar to Venezuela, Indonesia also benefits from GHG emissions.

4.5 Shadow value of patent stock

Supplementary Information Figures S6 and S7 show the average shadow value of patent stock (in absolute value) from 1992 to 2010 (top 30 countries) in the base and IWI models, respectively. In these figures, each of the shadow values is divided simply by the ratio of technical classification (exogenously). That is to say, this study exogenously decomposes the value of the patent by the technology proportion of the patent stock. The value of a patent is essentially considered different for each technology (Fujii and Managi, 2016, 2018). Thus, as a limitation, the model used in this study does not estimate the value of each technology.

The 10 countries with the largest shadow value of patent stock (billion USD) are China (CN, 529.5), the United States of America (US, 266.7), the Russian Federation (RU, 188.4), Mexico (MX, 155.5), Italy (IT, 146.9), Brazil (BR, 143.5), India (IN, 126.0), the Netherlands (NL, 117.3), Belgium (BE, 80.3), and Germany (DE, 65.3) in the base model, and the United States (US, 287.4), China (CN, 154.6), India (IN, 132.5), the Russian Federation (RU, 79.0), Mexico (MX, 64.2), Belgium (BE, 49.3), Turkey (TR, 45.4), the Netherlands (NL, 43.9), Italy (IT, 29.4), and Spain (ES, 28.8) in the IWI model. On average, the shadow value in the IWI model is approximately half that of the base model; however, there is country heterogeneity. This finding implies that in the IWI model, educational value in human capital (as a premium of management in patent stock) is discounted from the value of patent stock (compared with the base model).

The countries listed above have a higher cost of patent stock (knowledge stock) than others. Given the allocation problem of GDP, this means higher value added. Basically, countries with higher GDP tend to have higher shadow values. Intuitively, the United States (which has the largest GDP for the period) should be at the top in the base model, as it is in the IWI model. However, China is the top

in the base model. Perhaps, because China has a large population, the educational effect (in human capital) is thought to cancel out the value of patent stock. Thus, this study considers the IWI model to likely be more intuitive than the base model.

An exceptional case is Japan. Japan has the largest patent stock for the period and a relatively large GDP; however, the shadow price of patent stock is zero. Furthermore, the shadow price of the other inputs is zero in both models. On the other hand, the shadow price/value of GHG is relatively high, which indicates that each of the input elements (in one extra unit) is available for free, but production cost is high. Note that the DEA score itself in Japan is zero (efficient), which implies that when DMUs (countries) are most efficient (or inversely most inefficient), estimated shadow prices may tend to be outliers.

5. Conclusions

This study estimates the shadow price/value of economic factors in 92 countries from 1992 to 2010, focusing on patent stock (as knowledge stock). From the estimated results in the non-parametric approach (DEA model), overall, fluctuations in the time series are not very large, and the country heterogeneity is relatively large. Thus, naturally, when discussing the whole picture, the weighted average of the results will reflect the reality better than the simple average.

This study considers two specifications. In the entire sample, in consideration of population and energy use as (traditional) input factors, the shadow price of patent stock is −0.106 million USD per patent, whereas its shadow value (total cost) is −5.8% of GDP. Similarly, in consideration of human and natural capital instead of population and energy use, the shadow price in the entire sample is −0.054 million USD, whereas its shadow value is −2.9% of GDP.

The standing position of the value of patent stock is clear in the entire sample. The patent stock is less valuable than human capital and (produced) capital but more valuable than population, energy use, and natural capital. The patent stock is much cheaper than the value of GHG (as a production cost of undesirable output). In addition, the patent stock is more valuable in the non-OECD

members than in the OECD members. These results are consistent in this study and imply which kinds of support are effective for developing countries. As may be intuitive, the most effective supports are, in order, human capital, (produced) capital, and patent stock. On the other hand, population (increase), energy use, and natural capital tend to be less important than patent stock. This is almost true for the OECD countries in this study. A difference is that when considering population and energy use in the model, the patent stock is less valuable than energy use in the OECD members.

The shadow value of patent stock is relatively high among certain top countries, such as the United States and China. This finding indicates that certain economic powers have a large need for knowledge stock (technology development) in their economies. On the other hand, the shadow value of patent stock is nearly flat in most of the sample countries, which implies that it is difficult for economically small countries to invest in knowledge stock on their own. This trend may continue in the future.

Regarding technical assistance, the non-OECD countries have a high proportion of (III) chemistry for the period, implying that this field has been required because of the great size of the agricultural industry. Looking to future developments, as the overall (I) electrical engineering grows, the non-OECD countries are expected to further increase the technical demand in this field. Thus, the electronics industry may further develop among the non-OECD members.

Appendix A. shadow price and value in the IWI model

Regarding the IWI model (Table 6), the weighted average shadow price of human capital (USD per 1 USD capital) for the period is −0.019, −0.015, and −0.035 in the entire sample, OECD members, and non-OECD members, respectively. In the entire sample, this means that an annual cost (depreciation cost) of 0.019 USD will be required to prepare a stock of 1 USD for human capital, thus implying that the depreciation rate is 1.9%. A point here is that the shadow price is higher in the non-OECD members than in the OECD members. This contrasts with the base model.

Regarding (produced) capital, the weighted average shadow price (USD per 1 USD capital) for the period is −0.050, −0.039, and −0.102 in the entire sample, OECD members, and non-OECD members, respectively. These values are smaller than in the base model. For example, in the entire sample, it is 0.6 times (= −0.050 / −0.082) lower than in the base model. This difference, by replacing just the two input variables, indicates how unstable this model is.

Regarding patent stock, the weighted average shadow price (million USD per patent) for the period is −0.054, −0.032, and −0.355 in the entire sample, OECD members, and non-OECD members, respectively. Similar to capital stock, the price is approximately half that of the base model (see section 4.2).

Regarding natural capital, the weighted average shadow price for the period (USD per 1 USD capital) is −0.007, −0.014, and −0.003 in the entire sample, OECD members, and non-OECD members, respectively. The −0.007 value implies that the depreciation rate is 0.7% per year. Among the three capitals, the lowest depreciation rate in the entire sample is found for natural capital (0.7%), human capital (1.9%), and (produced) capital (5.0%), in that order. In other words, natural capital is harder to amortize compared with other capital. The OECD members' cost is 4.7 times (−0.014 / −0.003) higher than that of the non-OECD members, indicating that natural capital is more likely to be amortized and valuable in the OECD members.

Regarding the GHG, the weighted average shadow price (thousand USD per tonne) for the whole period is −0.569, −1.209, and −0.047 in the entire sample, OECD members, and non-OECD members, respectively. The entire sample and OECD members have almost the same value as in the

base model. As a point, the non-OECD members have a negative value; thus, GHG production is a cost (although the value remains small). This contrasts with the positive value in the base model (where GHG production is profit). As a summary, compared with the base model, the cost ratio in the IWI model has changed within the inputs and has been almost same for GHG.

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Table 1. Total patent stock in 1992 and 2010

Year	Countries	Patent stock	Technology field					
			1	II	III	IV	V	unclassified
1992	Total	16,024,637	19.8%	13.1%	25.0%	28.8%	8.0%	5.2%
1992	Entire sample (92)	14,338,523	20.5%	12.8%	25.0%	28.3%	7.9%	5.6%
1992	OECD (35)	13,861,753	20.8%	12.9%	24.6%	28.3%	7.9%	5.6%
1992	Non-OECD (57)	476,770	10.4%	8.6%	37.1%	29.0%	9.0%	5.9%
2010	Total	31,218,742	27.1%	13.6%	22.4%	21.1%	7.4%	8.4%
2010	Entire sample (92)	30,050,149	27.0%	13.6%	22.3%	21.3%	7.5%	8.2%
2010	OECD (35)	26,487,316	27.3%	13.8%	20.9%	21.5%	7.6%	8.9%
2010	Non-OECD (57)	3,562,833	25.0%	12.2%	33.1%	20.0%	6.8%	2.9%
Avg	Total	22,628,516	23.8%	13.6%	23.6%	24.3%	7.7%	6.9%
Avg	Entire sample (92)	21,252,237	24.2%	13.5%	23.5%	24.1%	7.7%	7.0%
Avg	OECD (35)	19,808,816	24.5%	13.7%	22.6%	24.2%	7.7%	7.3%
Avg	Non-OECD (57)	1,443,421	20.0%	11.3%	36.0%	22.3%	7.4%	3.0%

Notes: “Total” means total patent stock in EPO PATSTAT (2016a version), including out of sample. The entire sample consists of 92 sample countries (35 OECD members and 57 non-OECD members).

Table 2. Descriptive statistics

Variables	Unit	Obs	Mean	SD	Median	Min	Max
Entire sample							
GDP (constant 2005)	Billion USD	1,748	421.6	1303.6	69.0	1.2	13144.4
Population	Million people	1,748	57.2	173.9	12.1	0.3	1341.3
Produced capital	Billion USD	1,748	1263.8	3611.6	211.0	3.7	35543.1
Patent stock	Thousand	1,748	231.0	925.3	4.9	0.001	8790.9
Energy use	Million TOE	1,748	100.6	289.0	20.9	0.8	2469.1
Greenhouse gases	Million tonne	1,748	400.0	1072.8	80.2	3.6	11183.8
Human capital	Billion USD	1,748	3391.2	10337.2	585.3	11.4	99641.2
Natural capital	Billion USD	1,748	689.9	1713.1	116.5	0.5	10553.9
OECD members							
GDP (constant 2005)	Billion USD	665	922.0	1975.3	270.6	6.8	13144.4
Population	Million people	665	33.2	53.0	10.3	0.3	310.4
Produced capital	Billion USD	665	2734.5	5413.9	796.0	29.9	35543.1
Patent stock	Thousand	665	566.0	1427.3	117.0	0.003	8790.9
Energy use	Million TOE	665	148.6	367.5	33.9	2.0	2337.0
Greenhouse gases	Million tonne	665	472.4	1130.7	96.3	3.6	7244.3
Human capital	Billion USD	665	7338.4	15751.4	2190.5	90.3	99641.2
Natural capital	Billion USD	665	652.6	1672.8	156.4	1.1	9326.0
Non-OECD members							
GDP (constant 2005)	Billion USD	1,083	114.4	311.8	25.0	1.2	3883.5
Population	Million people	1,083	72.0	215.6	14.3	1.5	1341.3
Produced capital	Billion USD	1,083	360.6	948.3	68.6	3.7	11734.0
Patent stock	Thousand	1,083	25.3	137.7	0.6	0.001	2374.6
Energy use	Million TOE	1,083	71.2	222.6	9.8	0.8	2469.1
Greenhouse gases	Million tonne	1,083	355.5	1032.6	65.1	5.2	11183.8
Human capital	Billion USD	1,083	967.5	2141.8	243.1	11.4	13446.8
Natural capital	Billion USD	1,083	712.7	1736.2	106.7	0.5	10553.9

Notes: USD denotes US dollars at a constant 2005 price. TOE in energy use denotes tonnes of oil equivalent.

Table 3. DEA score in the base scenario (simple and weighted average)

	(1) Entire sample			(2) OECD			(3) Non-OECD		
Year	Avg	SD	Weighted avg	Avg	SD	Weighted avg	Avg	SD	Weighted avg
Entire period	0.173	0.232	0.045	0.127	0.172	0.030	0.202	0.258	0.119
1992	0.175	0.236	0.037	0.110	0.158	0.023	0.215	0.266	0.121
1993	0.182	0.242	0.036	0.120	0.171	0.025	0.220	0.272	0.105
1994	0.201	0.251	0.041	0.134	0.178	0.027	0.242	0.281	0.125
1995	0.197	0.262	0.036	0.129	0.180	0.026	0.239	0.295	0.092
1996	0.196	0.257	0.035	0.131	0.182	0.026	0.236	0.289	0.088
1997	0.205	0.252	0.051	0.135	0.182	0.029	0.248	0.279	0.179
1998	0.199	0.259	0.047	0.135	0.185	0.025	0.238	0.289	0.170
1999	0.191	0.253	0.049	0.140	0.189	0.029	0.223	0.283	0.168
2000	0.193	0.249	0.051	0.138	0.188	0.028	0.228	0.276	0.177
2001	0.178	0.240	0.051	0.134	0.184	0.031	0.205	0.267	0.163
2002	0.179	0.236	0.054	0.131	0.180	0.030	0.209	0.262	0.180
2003	0.168	0.223	0.041	0.130	0.177	0.033	0.191	0.246	0.082
2004	0.167	0.221	0.053	0.129	0.175	0.034	0.191	0.243	0.147
2005	0.162	0.215	0.053	0.128	0.170	0.036	0.184	0.237	0.134
2006	0.156	0.207	0.054	0.120	0.161	0.035	0.178	0.229	0.143
2007	0.148	0.199	0.050	0.120	0.158	0.035	0.164	0.221	0.109
2008	0.131	0.188	0.036	0.112	0.152	0.031	0.143	0.207	0.056
2009	0.131	0.192	0.037	0.121	0.166	0.033	0.137	0.207	0.049
2010	0.134	0.192	0.043	0.117	0.158	0.031	0.144	0.211	0.083

Table 4. DEA score in the IWI model (simple and weighted average)

	(1) Entire sample			(2) OECD			(3) Non-OECD		
Year	Avg	SD	Weighted avg	Avg	SD	Weighted avg	Avg	SD	Weighted avg
Entire period	0.127	0.187	0.036	0.094	0.158	0.019	0.148	0.201	0.117
1992	0.108	0.177	0.029	0.091	0.151	0.017	0.118	0.191	0.106
1993	0.117	0.180	0.029	0.098	0.163	0.018	0.129	0.190	0.098
1994	0.140	0.205	0.033	0.123	0.196	0.020	0.151	0.211	0.115
1995	0.145	0.215	0.030	0.113	0.193	0.017	0.164	0.227	0.111
1996	0.149	0.214	0.034	0.111	0.189	0.017	0.172	0.227	0.133
1997	0.152	0.215	0.041	0.110	0.177	0.020	0.178	0.233	0.161
1998	0.157	0.217	0.045	0.101	0.168	0.021	0.191	0.237	0.185
1999	0.158	0.221	0.044	0.100	0.173	0.018	0.194	0.240	0.196
2000	0.157	0.219	0.046	0.102	0.174	0.019	0.191	0.238	0.201
2001	0.139	0.201	0.039	0.094	0.167	0.016	0.166	0.217	0.167
2002	0.138	0.195	0.039	0.096	0.163	0.018	0.164	0.210	0.154
2003	0.136	0.188	0.039	0.086	0.151	0.019	0.166	0.202	0.144
2004	0.121	0.170	0.038	0.083	0.143	0.020	0.144	0.182	0.123
2005	0.111	0.160	0.036	0.083	0.140	0.021	0.128	0.171	0.107
2006	0.110	0.154	0.037	0.081	0.131	0.022	0.128	0.166	0.106
2007	0.106	0.153	0.034	0.081	0.129	0.022	0.121	0.165	0.082
2008	0.092	0.136	0.030	0.076	0.121	0.020	0.102	0.144	0.070
2009	0.095	0.148	0.029	0.081	0.134	0.020	0.103	0.157	0.062
2010	0.091	0.142	0.026	0.077	0.131	0.018	0.099	0.149	0.056

Table 5. Shadow price: the base model

Year	(1) Population		(2) Capital		(3) Patent stock		(4) Energy use		(5) GHG	
Unit	Thousand USD per person		USD per 1 USD of capital		Million USD per patent		Thousand USD per TOE		Thousand USD per tonne	
	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg
Entire sample										
Avg	−0.627	−0.155	−0.211	−0.082	−59.116	−0.106	−0.404	−0.213	−0.516	−0.514
1992	−0.657	−0.111	−0.162	−0.077	−165.492	−0.075	−0.313	−0.166	−0.475	−0.462
1993	−0.740	−0.134	−0.181	−0.081	−131.949	−0.112	−0.330	−0.259	−0.444	−0.472
1994	−0.809	−0.118	−0.165	−0.069	−55.248	−0.144	−0.325	−0.212	−0.475	−0.505
1995	−0.823	−0.148	−0.174	−0.070	−39.282	−0.159	−0.436	−0.293	−0.451	−0.479
1996	−0.691	−0.170	−0.177	−0.064	−33.854	−0.169	−0.483	−0.373	−0.458	−0.474
1997	−0.489	−0.103	−0.190	−0.074	−32.602	−0.131	−0.429	−0.283	−0.470	−0.470
1998	−0.602	−0.232	−0.209	−0.071	−69.013	−0.159	−0.378	−0.325	−0.457	−0.461
1999	−0.253	−0.042	−0.203	−0.068	−98.536	−0.139	−0.348	−0.432	−0.475	−0.486
2000	−0.385	−0.100	−0.209	−0.079	−121.729	−0.112	−0.383	−0.405	−0.473	−0.490
2001	−0.384	−0.077	−0.207	−0.078	−49.155	−0.106	−0.357	−0.175	−0.498	−0.564
2002	−0.318	−0.125	−0.219	−0.083	−48.890	−0.093	−0.327	−0.158	−0.504	−0.533
2003	−0.670	−0.173	−0.324	−0.080	−42.728	−0.170	−0.826	−0.111	−0.523	−0.545
2004	−0.652	−0.170	−0.270	−0.091	−39.583	−0.065	−0.595	−0.156	−0.543	−0.541
2005	−0.585	−0.162	−0.222	−0.088	−38.224	−0.082	−0.287	−0.072	−0.560	−0.546
2006	−0.634	−0.150	−0.231	−0.095	−39.885	−0.066	−0.314	−0.137	−0.574	−0.540
2007	−0.661	−0.137	−0.230	−0.099	−39.513	−0.047	−0.412	−0.177	−0.592	−0.542
2008	−0.944	−0.293	−0.223	−0.093	−32.405	−0.055	−0.413	−0.189	−0.603	−0.548
2009	−0.664	−0.267	−0.201	−0.078	−23.281	−0.161	−0.383	−0.136	−0.615	−0.527
2010	−0.957	−0.188	−0.211	−0.094	−21.834	−0.068	−0.346	−0.105	−0.607	−0.542
OECD										
Avg	−1.284	−0.541	−0.165	−0.061	−0.442	−0.054	−0.436	−0.298	−0.967	−1.150
1992	−1.347	−0.380	−0.146	−0.073	−0.864	−0.045	−0.304	−0.201	−0.794	−0.973
1993	−1.565	−0.536	−0.152	−0.067	−0.754	−0.088	−0.406	−0.361	−0.716	−1.002
1994	−1.741	−0.433	−0.145	−0.067	−0.585	−0.092	−0.378	−0.273	−0.781	−1.038
1995	−1.770	−0.543	−0.152	−0.067	−0.446	−0.085	−0.624	−0.388	−0.728	−0.996

1996	−1.461	−0.640	−0.148	−0.059	−0.522	−0.084	−0.671	−0.523	−0.755	−0.999
1997	−1.036	−0.422	−0.168	−0.065	−0.408	−0.077	−0.500	−0.386	−0.801	−1.044
1998	−1.332	−0.997	−0.172	−0.060	−0.406	−0.089	−0.384	−0.428	−0.871	−1.000
1999	−0.349	−0.105	−0.179	−0.062	−0.376	−0.048	−0.526	−0.613	−0.895	−1.003
2000	−0.764	−0.254	−0.181	−0.062	−0.329	−0.052	−0.436	−0.555	−0.927	−1.023
2001	−0.785	−0.266	−0.179	−0.068	−0.390	−0.027	−0.304	−0.171	−1.001	−1.159
2002	−0.561	−0.308	−0.189	−0.068	−0.248	−0.023	−0.313	−0.195	−0.999	−1.139
2003	−1.204	−0.551	−0.174	−0.062	−0.362	−0.075	−0.293	−0.106	−1.048	−1.253
2004	−1.195	−0.623	−0.171	−0.060	−0.360	−0.036	−0.398	−0.210	−1.066	−1.193
2005	−1.222	−0.581	−0.163	−0.055	−0.504	−0.052	−0.234	−0.091	−1.136	−1.276
2006	−1.260	−0.600	−0.176	−0.063	−0.345	−0.033	−0.388	−0.221	−1.128	−1.272
2007	−1.498	−0.544	−0.173	−0.058	−0.381	−0.037	−0.465	−0.288	−1.163	−1.290
2008	−2.013	−1.104	−0.166	−0.053	−0.353	−0.035	−0.515	−0.291	−1.158	−1.350
2009	−1.267	−0.598	−0.155	−0.055	−0.338	−0.063	−0.612	−0.225	−1.232	−1.378
2010	−2.027	−0.729	−0.156	−0.055	−0.432	−0.044	−0.526	−0.185	−1.169	−1.391
Non-OECD										
Avg	−0.224	−0.045	−0.239	−0.177	−95.144	−0.821	−0.385	−0.103	−0.239	0.005
1992	−0.233	−0.030	−0.172	−0.097	−266.580	−0.950	−0.318	−0.117	−0.280	−0.029
1993	−0.233	−0.015	−0.199	−0.148	−212.507	−0.776	−0.282	−0.112	−0.276	−0.002
1994	−0.237	−0.026	−0.177	−0.077	−88.812	−1.518	−0.293	−0.121	−0.287	−0.024
1995	−0.241	−0.033	−0.188	−0.080	−63.129	−2.038	−0.320	−0.155	−0.280	−0.006
1996	−0.218	−0.033	−0.195	−0.086	−54.321	−2.175	−0.368	−0.151	−0.275	0.004
1997	−0.153	−0.011	−0.204	−0.122	−52.370	−1.333	−0.385	−0.130	−0.268	−0.018
1998	−0.154	−0.012	−0.232	−0.124	−111.140	−1.626	−0.374	−0.172	−0.202	−0.002
1999	−0.194	−0.024	−0.218	−0.097	−158.809	−1.957	−0.239	−0.162	−0.217	0.010
2000	−0.152	−0.056	−0.225	−0.163	−196.274	−1.231	−0.351	−0.186	−0.194	0.035
2001	−0.138	−0.024	−0.224	−0.131	−79.099	−1.517	−0.390	−0.180	−0.189	0.017
2002	−0.168	−0.074	−0.238	−0.153	−78.758	−1.251	−0.335	−0.107	−0.200	0.003
2003	−0.342	−0.067	−0.416	−0.164	−68.743	−1.616	−1.154	−0.117	−0.202	0.060
2004	−0.319	−0.044	−0.331	−0.240	−63.668	−0.459	−0.715	−0.089	−0.223	0.014
2005	−0.194	−0.046	−0.258	−0.245	−61.385	−0.449	−0.319	−0.050	−0.207	0.014
2006	−0.250	−0.026	−0.266	−0.239	−64.164	−0.429	−0.268	−0.042	−0.233	−0.007
2007	−0.148	−0.025	−0.264	−0.281	−63.542	−0.151	−0.379	−0.056	−0.242	−0.005
2008	−0.288	−0.070	−0.258	−0.263	−52.086	−0.242	−0.351	−0.082	−0.261	0.004
2009	−0.294	−0.177	−0.229	−0.173	−37.368	−0.974	−0.243	−0.050	−0.235	0.042

2010	−0.299	−0.041	−0.245	−0.241	−34.976	−0.245	−0.236	−0.030	−0.262	−0.020

Table 6. Shadow price: the IWI model

Year	(1) Human capital		(2) Capital		(3) Patent stock		(4) Natural capital		(5) GHG	
Unit	USD per 1 USD of capital		USD per 1 USD of capital		Million USD per patent		USD per 1 USD of capital		Thousand USD per tonne	
	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg	Avg	Weighted avg
Entire sample										
Avg	−0.043	−0.019	−0.119	−0.050	−31.952	−0.054	−0.096	−0.007	−0.528	−0.569
1992	−0.047	−0.011	−0.114	−0.063	−38.086	−0.091	−0.075	−0.005	−0.415	−0.506
1993	−0.046	−0.013	−0.113	−0.066	−29.868	−0.078	−0.107	−0.005	−0.415	−0.501
1994	−0.039	−0.014	−0.100	−0.055	−24.312	−0.116	−0.098	−0.005	−0.411	−0.497
1995	−0.038	−0.013	−0.103	−0.056	−31.846	−0.137	−0.089	−0.005	−0.449	−0.514
1996	−0.042	−0.012	−0.097	−0.052	−9.392	−0.138	−0.109	−0.011	−0.470	−0.552
1997	−0.043	−0.012	−0.108	−0.059	−13.115	−0.113	−0.126	−0.014	−0.471	−0.508
1998	−0.040	−0.013	−0.120	−0.070	−26.811	−0.084	−0.101	−0.005	−0.480	−0.526
1999	−0.040	−0.018	−0.101	−0.054	−42.752	−0.065	−0.113	−0.011	−0.535	−0.579
2000	−0.039	−0.021	−0.124	−0.060	−60.855	−0.023	−0.087	−0.006	−0.518	−0.547
2001	−0.040	−0.024	−0.115	−0.043	−31.550	−0.036	−0.099	−0.013	−0.545	−0.576
2002	−0.042	−0.025	−0.124	−0.047	−23.046	−0.028	−0.087	−0.005	−0.528	−0.536
2003	−0.045	−0.023	−0.118	−0.045	−17.964	−0.045	−0.108	−0.009	−0.533	−0.589
2004	−0.045	−0.024	−0.130	−0.040	−28.480	−0.027	−0.082	−0.006	−0.554	−0.586
2005	−0.045	−0.020	−0.134	−0.061	−34.643	−0.031	−0.095	−0.007	−0.573	−0.555
2006	−0.046	−0.023	−0.133	−0.041	−29.136	−0.024	−0.095	−0.007	−0.617	−0.603
2007	−0.045	−0.023	−0.144	−0.048	−41.882	−0.024	−0.080	−0.007	−0.594	−0.603
2008	−0.047	−0.022	−0.138	−0.041	−41.068	−0.029	−0.091	−0.006	−0.631	−0.654
2009	−0.046	−0.021	−0.121	−0.039	−36.133	−0.026	−0.102	−0.007	−0.645	−0.650
2010	−0.047	−0.020	−0.117	−0.038	−46.143	−0.043	−0.084	−0.004	−0.656	−0.654
OECD										
Avg	−0.038	−0.015	−0.101	−0.039	−1.116	−0.032	−0.183	−0.014	−1.027	−1.209
1992	−0.026	−0.009	−0.111	−0.062	−3.398	−0.070	−0.144	−0.008	−0.778	−1.080
1993	−0.027	−0.011	−0.100	−0.056	−12.439	−0.069	−0.210	−0.010	−0.766	−1.066
1994	−0.030	−0.014	−0.100	−0.050	−0.467	−0.066	−0.181	−0.009	−0.765	−1.031
1995	−0.030	−0.012	−0.113	−0.054	−0.368	−0.061	−0.166	−0.009	−0.788	−1.059

1996	−0.033	−0.011	−0.095	−0.048	−0.454	−0.066	−0.224	−0.025	−0.857	−1.147
1997	−0.037	−0.011	−0.092	−0.046	−0.414	−0.069	−0.265	−0.034	−0.871	−1.137
1998	−0.032	−0.011	−0.114	−0.055	−0.421	−0.055	−0.189	−0.006	−0.972	−1.134
1999	−0.040	−0.017	−0.089	−0.037	−0.372	−0.040	−0.226	−0.026	−1.037	−1.179
2000	−0.036	−0.016	−0.118	−0.050	−0.242	−0.011	−0.147	−0.010	−1.023	−1.104
2001	−0.041	−0.020	−0.102	−0.035	−0.357	−0.014	−0.190	−0.029	−1.033	−1.146
2002	−0.044	−0.020	−0.104	−0.039	−0.222	−0.009	−0.167	−0.007	−1.019	−1.112
2003	−0.044	−0.017	−0.099	−0.034	−0.162	−0.039	−0.222	−0.019	−1.056	−1.245
2004	−0.045	−0.018	−0.103	−0.031	−0.195	−0.014	−0.158	−0.012	−1.091	−1.213
2005	−0.042	−0.019	−0.100	−0.031	−0.331	−0.017	−0.175	−0.013	−1.153	−1.268
2006	−0.043	−0.018	−0.101	−0.030	−0.202	−0.010	−0.171	−0.015	−1.225	−1.335
2007	−0.041	−0.018	−0.109	−0.031	−0.275	−0.014	−0.148	−0.013	−1.204	−1.337
2008	−0.041	−0.017	−0.102	−0.029	−0.247	−0.014	−0.162	−0.010	−1.288	−1.441
2009	−0.042	−0.016	−0.090	−0.029	−0.228	−0.014	−0.186	−0.012	−1.278	−1.409
2010	−0.042	−0.014	−0.080	−0.029	−0.403	−0.031	−0.151	−0.008	−1.302	−1.478
Non-OECD										
Avg	−0.047	−0.035	−0.130	−0.102	−50.886	−0.355	−0.043	−0.003	−0.223	−0.047
1992	−0.060	−0.022	−0.117	−0.069	−59.386	−0.704	−0.032	−0.003	−0.192	−0.019
1993	−0.058	−0.022	−0.121	−0.117	−40.571	−0.327	−0.043	−0.003	−0.199	0.001
1994	−0.045	−0.014	−0.099	−0.082	−38.953	−1.429	−0.047	−0.003	−0.194	−0.015
1995	−0.044	−0.018	−0.097	−0.064	−51.175	−2.033	−0.042	−0.003	−0.241	−0.015
1996	−0.048	−0.021	−0.098	−0.074	−14.881	−1.863	−0.038	−0.004	−0.232	−0.009
1997	−0.047	−0.019	−0.118	−0.123	−20.914	−1.101	−0.041	−0.004	−0.226	−0.013
1998	−0.045	−0.022	−0.123	−0.145	−43.015	−0.696	−0.047	−0.004	−0.178	−0.011
1999	−0.040	−0.023	−0.108	−0.140	−68.774	−0.574	−0.044	−0.003	−0.228	−0.004
2000	−0.041	−0.047	−0.128	−0.112	−98.074	−0.252	−0.050	−0.003	−0.209	0.001
2001	−0.040	−0.044	−0.123	−0.084	−50.704	−0.427	−0.043	−0.004	−0.245	−0.020
2002	−0.042	−0.046	−0.136	−0.086	−37.062	−0.346	−0.037	−0.004	−0.227	−0.028
2003	−0.045	−0.049	−0.129	−0.097	−28.895	−0.148	−0.038	−0.003	−0.213	−0.028
2004	−0.045	−0.049	−0.148	−0.084	−45.849	−0.209	−0.035	−0.003	−0.224	−0.052
2005	−0.046	−0.025	−0.155	−0.201	−55.712	−0.198	−0.047	−0.004	−0.216	−0.008
2006	−0.048	−0.046	−0.152	−0.095	−46.903	−0.182	−0.048	−0.003	−0.243	−0.069
2007	−0.047	−0.043	−0.166	−0.123	−67.430	−0.125	−0.038	−0.003	−0.219	−0.077
2008	−0.050	−0.044	−0.160	−0.093	−66.133	−0.168	−0.047	−0.004	−0.228	−0.113
2009	−0.048	−0.044	−0.141	−0.080	−58.180	−0.131	−0.050	−0.004	−0.257	−0.142

2010	−0.050	−0.046	−0.140	−0.073	−74.229	−0.136	−0.043	−0.002	−0.259	−0.149

Table 7. Shadow value: the base model (units: billion USD and %)

	(1) Population		(2) Capital		(3) Patent stock		(4) Energy use		(5) GHG		(6) Profit	
Year	Total	GDP%	Total	GDP%	Total	GDP%	Total	GDP%	Total	GDP%	Total	GDP%
Entire sample												
Avg	−813.2	−2.1%	−9531.4	−24.6%	−2262.1	−5.8%	−1968.4	−5.1%	−18914.5	−48.8%	5298.2	13.7%
1992	−522.9	−1.8%	−6650.1	−22.4%	−1070.8	−3.6%	−1314.2	−4.4%	−15139.0	−51.0%	4965.2	16.7%
1993	−640.4	−2.1%	−7156.4	−23.8%	−1653.6	−5.5%	−2062.3	−6.9%	−15219.6	−50.6%	3355.2	11.2%
1994	−573.1	−1.8%	−6244.8	−20.1%	−2196.0	−7.1%	−1696.7	−5.5%	−16554.5	−53.2%	3823.7	12.3%
1995	−726.8	−2.3%	−6541.9	−20.5%	−2508.8	−7.8%	−2410.4	−7.5%	−15730.3	−49.2%	4054.3	12.7%
1996	−845.0	−2.6%	−6181.8	−18.7%	−2759.0	−8.4%	−3142.4	−9.5%	−15858.3	−48.1%	4205.3	12.7%
1997	−517.2	−1.5%	−7443.3	−21.8%	−2234.6	−6.5%	−2403.3	−7.0%	−17575.6	−51.4%	4036.5	11.8%
1998	−1179.8	−3.4%	−7315.8	−20.9%	−2826.3	−8.1%	−2766.9	−7.9%	−16910.7	−48.2%	4073.2	11.6%
1999	−214.7	−0.6%	−7234.2	−19.9%	−2599.5	−7.2%	−3742.2	−10.3%	−16617.9	−45.8%	5870.8	16.2%
2000	−520.5	−1.4%	−8729.9	−23.1%	−2194.0	−5.8%	−3609.9	−9.5%	−16648.4	−44.0%	6149.7	16.2%
2001	−406.3	−1.1%	−8973.5	−23.3%	−2197.5	−5.7%	−1564.6	−4.1%	−19143.2	−49.6%	6278.8	16.3%
2002	−666.0	−1.7%	−9728.7	−24.7%	−2017.2	−5.1%	−1441.4	−3.7%	−19370.7	−49.2%	6129.4	15.6%
2003	−931.8	−2.3%	−9671.6	−23.9%	−3879.9	−9.6%	−1042.6	−2.6%	−20343.1	−50.4%	4518.1	11.2%
2004	−925.5	−2.2%	−11485.5	−27.4%	−1540.9	−3.7%	−1537.8	−3.7%	−20771.9	−49.5%	5718.2	13.6%
2005	−893.4	−2.1%	−11504.0	−26.5%	−2038.5	−4.7%	−728.8	−1.7%	−21666.9	−49.9%	6581.5	15.2%
2006	−835.4	−1.8%	−12775.1	−28.3%	−1705.1	−3.8%	−1422.0	−3.1%	−22176.5	−49.1%	6244.9	13.8%
2007	−769.1	−1.6%	−13860.7	−29.5%	−1276.3	−2.7%	−1877.7	−4.0%	−22610.7	−48.2%	6530.9	13.9%
2008	−1660.2	−3.5%	−13540.9	−28.5%	−1553.0	−3.3%	−2019.4	−4.3%	−22376.6	−47.1%	6350.7	13.4%
2009	−1532.2	−3.3%	−11667.4	−25.2%	−4685.4	−10.1%	−1442.6	−3.1%	−21431.8	−46.3%	5569.1	12.0%
2010	−1090.3	−2.3%	−14391.4	−29.9%	−2044.1	−4.2%	−1174.9	−2.4%	−23229.6	−48.3%	6210.8	12.9%
OECD												
Avg	−627.7	−1.9%	−5884.7	−18.2%	−1077.1	−3.3%	−1550.1	−4.8%	−19009.8	−58.9%	4119.6	12.8%
1992	−412.5	−1.6%	−5266.9	−20.6%	−617.9	−2.4%	−932.0	−3.6%	−14627.8	−57.2%	3708.1	14.5%
1993	−586.4	−2.3%	−4973.4	−19.2%	−1255.1	−4.8%	−1694.2	−6.5%	−15184.5	−58.6%	2206.4	8.5%
1994	−477.4	−1.8%	−5070.7	−19.0%	−1353.4	−5.1%	−1304.1	−4.9%	−16136.3	−60.4%	2363.5	8.9%
1995	−603.1	−2.2%	−5274.7	−19.3%	−1283.8	−4.7%	−1892.9	−6.9%	−15619.5	−57.0%	2707.4	9.9%
1996	−716.4	−2.5%	−4775.9	−16.9%	−1326.1	−4.7%	−2627.8	−9.3%	−15929.8	−56.5%	2808.6	10.0%

1997	−475.9	−1.6%	−5393.2	−18.5%	−1261.9	−4.3%	−1957.3	−6.7%	−17193.3	−58.9%	2891.5	9.9%
1998	−1131.9	−3.8%	−5151.0	−17.2%	−1514.5	−5.1%	−2179.5	−7.3%	−16867.2	−56.3%	3110.9	10.4%
1999	−119.6	−0.4%	−5504.6	−17.8%	−856.7	−2.8%	−3177.1	−10.3%	−16784.9	−54.2%	4527.3	14.6%
2000	−292.4	−0.9%	−5722.7	−17.8%	−977.7	−3.0%	−2939.8	−9.1%	−17240.2	−53.5%	5059.3	15.7%
2001	−308.4	−0.9%	−6474.4	−19.8%	−531.6	−1.6%	−902.1	−2.8%	−19443.2	−59.5%	5032.9	15.4%
2002	−360.1	−1.1%	−6699.2	−20.2%	−477.4	−1.4%	−1035.9	−3.1%	−19423.2	−58.5%	5221.5	15.7%
2003	−648.6	−1.9%	−6277.8	−18.5%	−1604.9	−4.7%	−570.3	−1.7%	−21546.9	−63.6%	3210.6	9.5%
2004	−738.2	−2.1%	−6283.4	−18.0%	−803.6	−2.3%	−1149.6	−3.3%	−21058.5	−60.3%	4875.7	14.0%
2005	−693.4	−1.9%	−5902.8	−16.5%	−1208.1	−3.4%	−499.1	−1.4%	−21990.5	−61.4%	5517.0	15.4%
2006	−721.4	−2.0%	−6987.5	−18.9%	−792.9	−2.1%	−1220.0	−3.3%	−22021.2	−59.7%	5153.2	14.0%
2007	−659.0	−1.7%	−6579.9	−17.4%	−909.2	−2.4%	−1598.1	−4.2%	−22483.7	−59.3%	5656.6	14.9%
2008	−1346.7	−3.6%	−6253.0	−16.5%	−884.0	−2.3%	−1593.8	−4.2%	−22480.3	−59.3%	5328.8	14.1%
2009	−733.9	−2.0%	−6513.5	−17.9%	−1634.0	−4.5%	−1176.8	−3.2%	−22465.1	−61.7%	3881.8	10.7%
2010	−901.3	−2.4%	−6704.3	−17.9%	−1172.1	−3.1%	−1002.6	−2.7%	−22689.6	−60.5%	5011.2	13.4%
Non-OECD												
Avg	−185.5	−2.8%	−3646.7	−55.9%	−1185.1	−18.2%	−418.3	−6.4%	95.3	1.5%	1178.6	18.1%
1992	−110.4	−2.7%	−1383.3	−33.8%	−452.9	−11.1%	−382.2	−9.3%	−511.2	−12.5%	1257.2	30.7%
1993	−54.0	−1.3%	−2183.1	−52.1%	−398.5	−9.5%	−368.2	−8.8%	−35.2	−0.8%	1148.9	27.4%
1994	−95.8	−2.2%	−1174.0	−26.8%	−842.6	−19.2%	−392.6	−9.0%	−418.2	−9.5%	1460.2	33.3%
1995	−123.6	−2.7%	−1267.2	−27.6%	−1225.0	−26.7%	−517.5	−11.3%	−110.8	−2.4%	1346.9	29.3%
1996	−128.6	−2.7%	−1405.9	−29.2%	−1432.9	−29.8%	−514.6	−10.7%	71.5	1.5%	1396.7	29.1%
1997	−41.3	−0.8%	−2050.1	−40.7%	−972.7	−19.3%	−446.1	−8.9%	−382.3	−7.6%	1145.0	22.7%
1998	−47.9	−0.9%	−2164.8	−42.3%	−1311.9	−25.6%	−587.4	−11.5%	−43.5	−0.9%	962.3	18.8%
1999	−95.1	−1.8%	−1729.6	−32.6%	−1742.9	−32.8%	−565.1	−10.6%	167.0	3.1%	1343.5	25.3%
2000	−228.1	−4.1%	−3007.2	−53.5%	−1216.4	−21.6%	−670.0	−11.9%	591.8	10.5%	1090.4	19.4%
2001	−97.9	−1.7%	−2499.1	−42.6%	−1665.9	−28.4%	−662.5	−11.3%	300.0	5.1%	1245.9	21.2%
2002	−305.9	−5.0%	−3029.5	−49.4%	−1539.8	−25.1%	−405.5	−6.6%	52.5	0.9%	907.8	14.8%
2003	−283.2	−4.3%	−3393.8	−52.0%	−2275.0	−34.9%	−472.2	−7.2%	1203.8	18.4%	1307.6	20.0%
2004	−187.3	−2.6%	−5202.1	−73.6%	−737.3	−10.4%	−388.3	−5.5%	286.6	4.1%	842.5	11.9%
2005	−200.0	−2.6%	−5601.2	−73.7%	−830.4	−10.9%	−229.7	−3.0%	323.5	4.3%	1064.5	14.0%
2006	−114.0	−1.4%	−5787.6	−70.0%	−912.2	−11.0%	−202.0	−2.4%	−155.3	−1.9%	1091.6	13.2%
2007	−110.1	−1.2%	−7280.7	−80.5%	−367.1	−4.1%	−279.6	−3.1%	−127.0	−1.4%	874.3	9.7%
2008	−313.5	−3.3%	−7288.0	−75.8%	−669.0	−7.0%	−425.6	−4.4%	103.7	1.1%	1021.8	10.6%
2009	−798.3	−8.0%	−5153.9	−51.9%	−3051.4	−30.7%	−265.8	−2.7%	1033.3	10.4%	1687.2	17.0%
2010	−189.0	−1.8%	−7687.2	−72.1%	−872.0	−8.2%	−172.3	−1.6%	−540.0	−5.1%	1199.6	11.3%

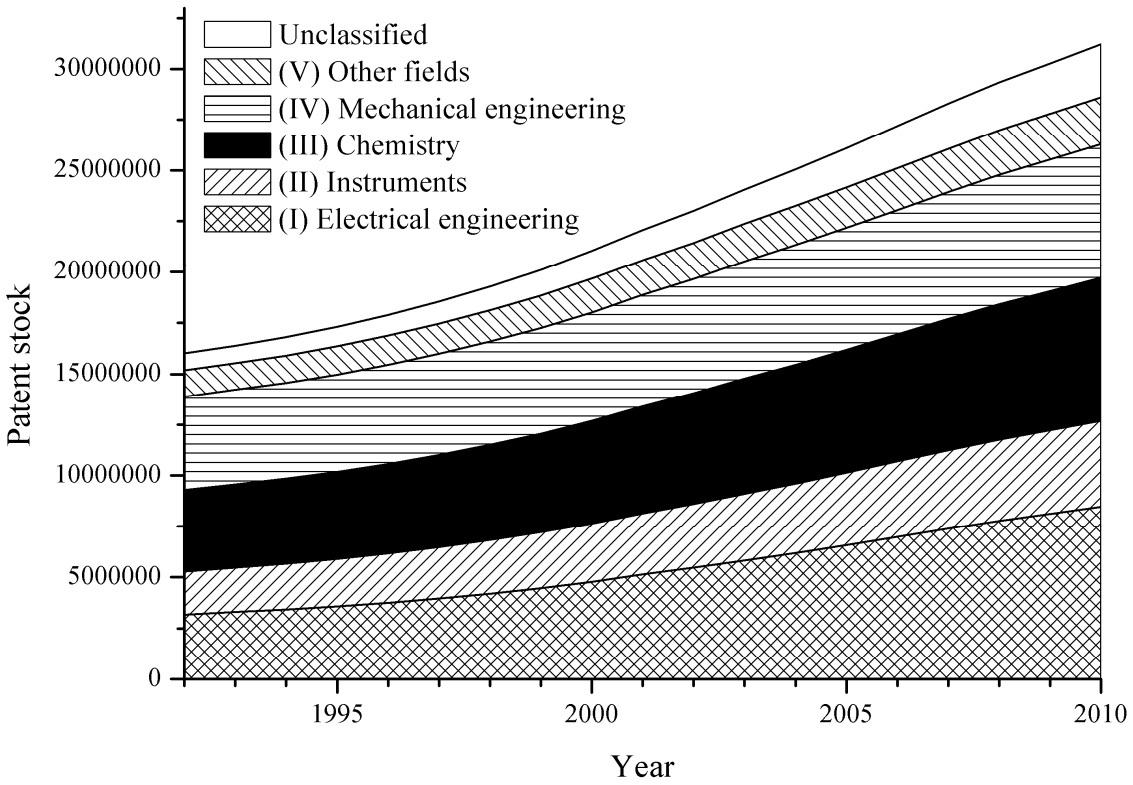
Table 8. Shadow value: the IWI model (units: billion USD and %)

Year	(1) Human capital Total	GDP%	(2) Capital Total	GDP%	(3) Patent stock Total	GDP%	(4) Natural capital Total	GDP%	(5) GHG Total	GDP%	(6) Profit Total	GDP%
Entire sample												
Avg	−5863.1	−15.1%	−5843.1	−15.1%	−1141.6	−2.9%	−465.0	−1.2%	−20930.7	−54.0%	4544.3	11.7%
1992	−3000.6	−10.1%	−5424.2	−18.3%	−1308.4	−4.4%	−305.9	−1.0%	−16565.5	−55.8%	3057.7	10.3%
1993	−3622.1	−12.0%	−5849.1	−19.4%	−1143.8	−3.8%	−362.5	−1.2%	−16140.0	−53.6%	2970.0	9.9%
1994	−4010.2	−12.9%	−5016.3	−16.1%	−1763.7	−5.7%	−357.9	−1.2%	−16299.6	−52.4%	3641.0	11.7%
1995	−3771.8	−11.8%	−5226.3	−16.3%	−2150.8	−6.7%	−356.7	−1.1%	−16868.6	−52.8%	3598.1	11.3%
1996	−3570.6	−10.8%	−5042.9	−15.3%	−2258.9	−6.8%	−724.7	−2.2%	−18441.6	−55.9%	2953.0	9.0%
1997	−3577.4	−10.5%	−5878.3	−17.2%	−1929.6	−5.6%	−940.0	−2.7%	−18991.3	−55.5%	2894.0	8.5%
1998	−3872.6	−11.0%	−7247.5	−20.7%	−1502.1	−4.3%	−311.1	−0.9%	−19330.0	−55.1%	2809.5	8.0%
1999	−5438.2	−15.0%	−5801.3	−16.0%	−1218.6	−3.4%	−709.4	−2.0%	−19797.5	−54.6%	3314.4	9.1%
2000	−6446.1	−17.0%	−6677.8	−17.6%	−458.5	−1.2%	−363.9	−1.0%	−18570.0	−49.1%	5336.1	14.1%
2001	−7490.8	−19.4%	−4923.8	−12.8%	−744.5	−1.9%	−816.6	−2.1%	−19554.7	−50.7%	5033.6	13.1%
2002	−7862.7	−20.0%	−5564.9	−14.1%	−615.8	−1.6%	−308.9	−0.8%	−19504.7	−49.6%	5496.5	14.0%
2003	−7240.5	−17.9%	−5482.8	−13.6%	−1033.4	−2.6%	−554.4	−1.4%	−21968.2	−54.4%	4107.8	10.2%
2004	−7770.1	−18.5%	−5049.6	−12.0%	−635.9	−1.5%	−403.9	−1.0%	−22484.6	−53.6%	5635.6	13.4%
2005	−6555.7	−15.1%	−7949.6	−18.3%	−760.7	−1.8%	−434.5	−1.0%	−22029.5	−50.7%	5683.0	13.1%
2006	−7702.1	−17.1%	−5565.4	−12.3%	−632.6	−1.4%	−444.6	−1.0%	−24759.1	−54.8%	6055.3	13.4%
2007	−7644.5	−16.3%	−6744.5	−14.4%	−649.8	−1.4%	−419.8	−0.9%	−25165.2	−53.6%	6301.5	13.4%
2008	−7513.8	−15.8%	−5967.6	−12.6%	−818.4	−1.7%	−352.8	−0.7%	−26736.7	−56.3%	6111.5	12.9%
2009	−7427.0	−16.0%	−5773.1	−12.5%	−765.7	−1.7%	−401.8	−0.9%	−26425.9	−57.0%	5535.0	11.9%
2010	−6881.8	−14.3%	−5833.9	−12.1%	−1299.6	−2.7%	−266.3	−0.6%	−28050.7	−58.3%	5809.0	12.1%
OECD												
Avg	−3930.4	−12.2%	−3746.7	−11.6%	−629.6	−2.0%	−330.4	−1.0%	−19987.6	−61.9%	3644.2	11.3%
1992	−2029.3	−7.9%	−4434.3	−17.3%	−973.0	−3.8%	−190.5	−0.7%	−16230.8	−63.5%	1707.3	6.7%
1993	−2613.8	−10.1%	−4118.2	−15.9%	−975.7	−3.8%	−237.9	−0.9%	−16157.5	−62.4%	1796.6	6.9%
1994	−3351.7	−12.6%	−3771.8	−14.1%	−970.6	−3.6%	−223.9	−0.8%	−16035.4	−60.0%	2352.0	8.8%
1995	−2927.5	−10.7%	−4211.6	−15.4%	−929.0	−3.4%	−218.6	−0.8%	−16606.4	−60.6%	2488.2	9.1%
1996	−2552.3	−9.1%	−3835.3	−13.6%	−1031.4	−3.7%	−575.9	−2.0%	−18278.7	−64.9%	1911.0	6.8%

1997	−2607.2	−8.9%	−3808.6	−13.1%	−1126.1	−3.9%	−785.3	−2.7%	−18714.4	−64.1%	2131.5	7.3%
1998	−2738.8	−9.1%	−4733.2	−15.8%	−940.5	−3.1%	−144.4	−0.5%	−19116.7	−63.8%	2281.4	7.6%
1999	−4212.9	−13.6%	−3300.5	−10.7%	−707.6	−2.3%	−590.1	−1.9%	−19721.3	−63.7%	2437.6	7.9%
2000	−3922.8	−12.2%	−4608.6	−14.3%	−210.0	−0.7%	−237.8	−0.7%	−18595.2	−57.7%	4657.8	14.5%
2001	−5045.9	−15.4%	−3321.8	−10.2%	−275.1	−0.8%	−654.9	−2.0%	−19215.0	−58.8%	4179.7	12.8%
2002	−5281.5	−15.9%	−3861.1	−11.6%	−189.9	−0.6%	−160.2	−0.5%	−18957.4	−57.1%	4767.3	14.4%
2003	−4413.8	−13.0%	−3477.9	−10.3%	−824.5	−2.4%	−431.2	−1.3%	−21402.0	−63.2%	3309.6	9.8%
2004	−4920.4	−14.1%	−3225.4	−9.2%	−299.8	−0.9%	−279.5	−0.8%	−21414.3	−61.3%	4769.6	13.7%
2005	−5059.3	−14.1%	−3361.1	−9.4%	−394.3	−1.1%	−281.0	−0.8%	−21851.5	−61.0%	4863.6	13.6%
2006	−4917.0	−13.3%	−3263.6	−8.8%	−245.1	−0.7%	−329.8	−0.9%	−23116.8	−62.7%	5024.0	13.6%
2007	−4944.8	−13.1%	−3555.7	−9.4%	−346.5	−0.9%	−291.7	−0.8%	−23292.9	−61.5%	5454.9	14.4%
2008	−4692.2	−12.4%	−3393.9	−9.0%	−354.5	−0.9%	−211.9	−0.6%	−23992.9	−63.3%	5241.3	13.8%
2009	−4584.1	−12.6%	−3399.3	−9.3%	−355.5	−1.0%	−258.9	−0.7%	−22966.0	−63.1%	4841.4	13.3%
2010	−3863.2	−10.3%	−3505.5	−9.4%	−813.9	−2.2%	−173.9	−0.5%	−24099.2	−64.3%	5025.3	13.4%
Non-OECD												
Avg	−1932.6	−29.6%	−2096.4	−32.2%	−512.0	−7.9%	−134.7	−2.1%	−943.1	−14.5%	900.1	13.8%
1992	−971.3	−23.7%	−989.9	−24.2%	−335.4	−8.2%	−115.4	−2.8%	−334.7	−8.2%	1350.4	33.0%
1993	−1008.3	−24.1%	−1730.9	−41.3%	−168.1	−4.0%	−124.6	−3.0%	17.5	0.4%	1173.4	28.0%
1994	−658.5	−15.0%	−1244.5	−28.4%	−793.1	−18.1%	−134.0	−3.1%	−264.2	−6.0%	1288.9	29.4%
1995	−844.3	−18.4%	−1014.7	−22.1%	−1221.8	−26.6%	−138.1	−3.0%	−262.2	−5.7%	1109.9	24.2%
1996	−1018.3	−21.2%	−1207.6	−25.1%	−1227.5	−25.5%	−148.9	−3.1%	−162.9	−3.4%	1042.0	21.7%
1997	−970.2	−19.3%	−2069.7	−41.1%	−803.5	−16.0%	−154.8	−3.1%	−276.8	−5.5%	762.4	15.1%
1998	−1133.8	−22.2%	−2514.3	−49.1%	−561.6	−11.0%	−166.7	−3.3%	−213.3	−4.2%	528.1	10.3%
1999	−1225.2	−23.1%	−2500.8	−47.1%	−510.9	−9.6%	−119.3	−2.2%	−76.1	−1.4%	876.7	16.5%
2000	−2523.3	−44.9%	−2069.2	−36.8%	−248.5	−4.4%	−126.1	−2.2%	25.2	0.4%	678.4	12.1%
2001	−2444.9	−41.6%	−1602.1	−27.3%	−469.3	−8.0%	−161.7	−2.8%	−339.6	−5.8%	853.8	14.5%
2002	−2581.2	−42.1%	−1703.8	−27.8%	−425.8	−6.9%	−148.7	−2.4%	−547.3	−8.9%	729.3	11.9%
2003	−2826.7	−43.3%	−2004.8	−30.7%	−208.9	−3.2%	−123.2	−1.9%	−566.2	−8.7%	798.1	12.2%
2004	−2849.8	−40.3%	−1824.2	−25.8%	−336.1	−4.8%	−124.3	−1.8%	−1070.3	−15.1%	866.0	12.2%
2005	−1496.4	−19.7%	−4588.6	−60.4%	−366.4	−4.8%	−153.5	−2.0%	−177.9	−2.3%	819.4	10.8%
2006	−2785.0	−33.7%	−2301.8	−27.9%	−387.5	−4.7%	−114.8	−1.4%	−1642.3	−19.9%	1031.3	12.5%
2007	−2699.7	−29.9%	−3188.8	−35.3%	−303.3	−3.4%	−128.1	−1.4%	−1872.3	−20.7%	846.6	9.4%
2008	−2821.6	−29.3%	−2573.7	−26.8%	−463.9	−4.8%	−140.9	−1.5%	−2743.8	−28.5%	870.3	9.1%
2009	−2843.0	−28.6%	−2373.9	−23.9%	−410.2	−4.1%	−142.9	−1.4%	−3459.9	−34.9%	693.6	7.0%
2010	−3018.5	−28.3%	−2328.4	−21.8%	−485.7	−4.6%	−92.4	−0.9%	−3951.5	−37.1%	783.7	7.4%

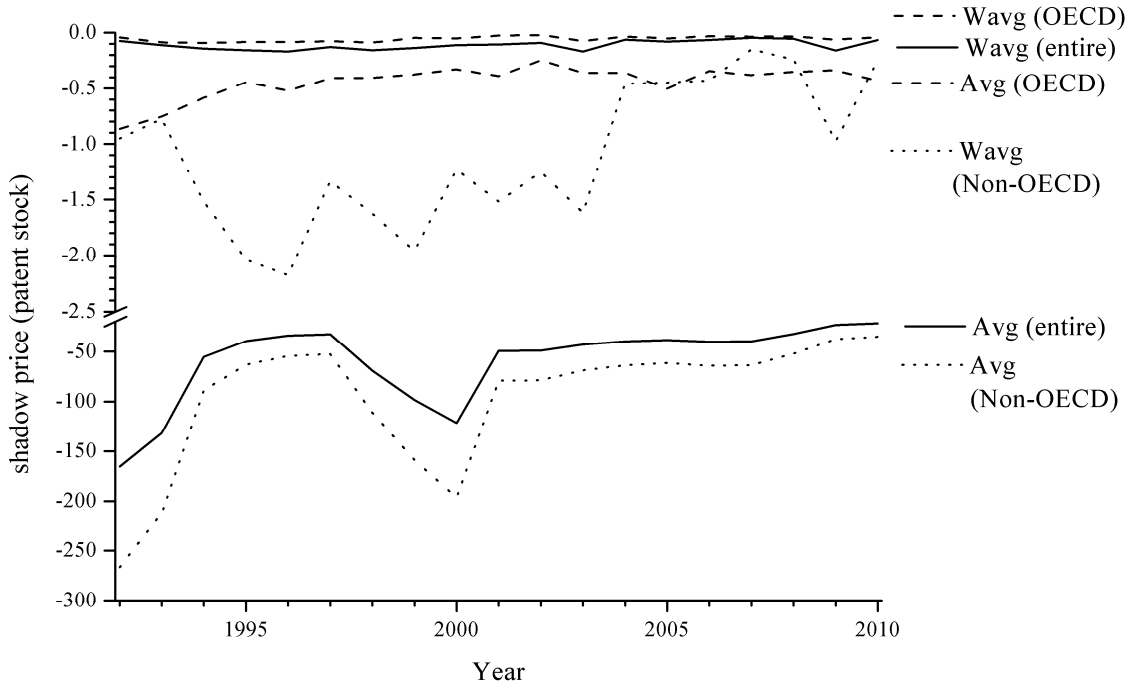
Supplementary material

Note: The supplementary material contains additional tables and figures for the data and estimated results.



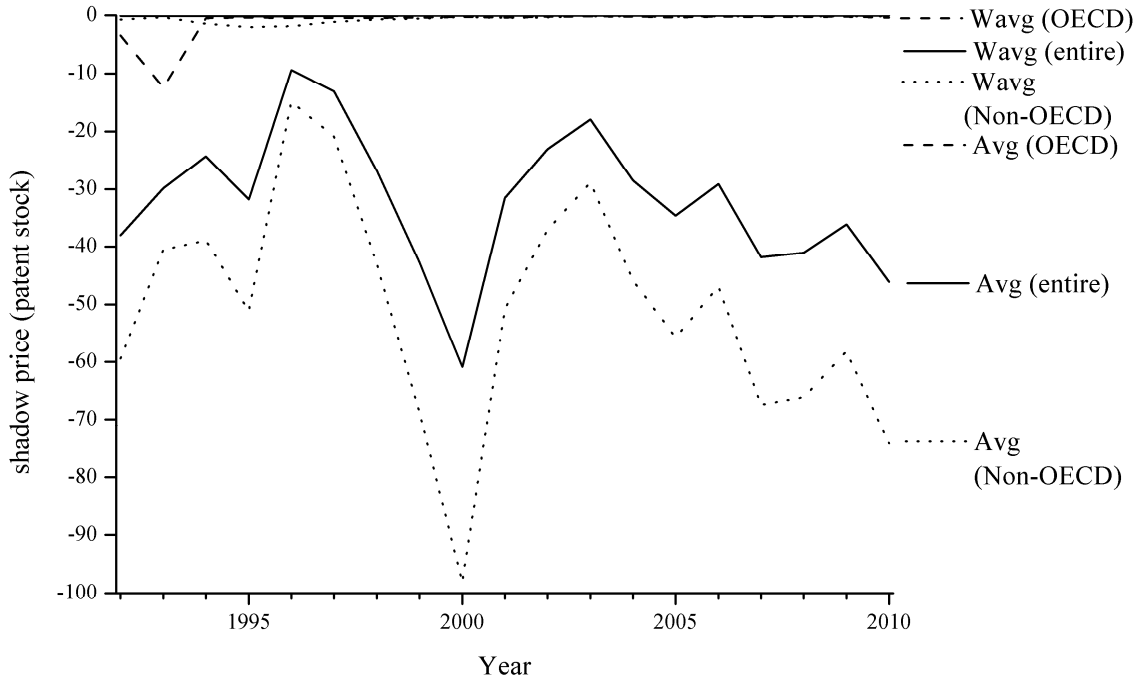
Supplementary Information Figure S1. Total patent stock from 1992 to 2010

Notes: Retrieved from EPO PATSTAT (2016a version), including out of sample. The entire sample consists of 92 sample countries (35 OECD members and 57 non-OECD members). See Table 1.



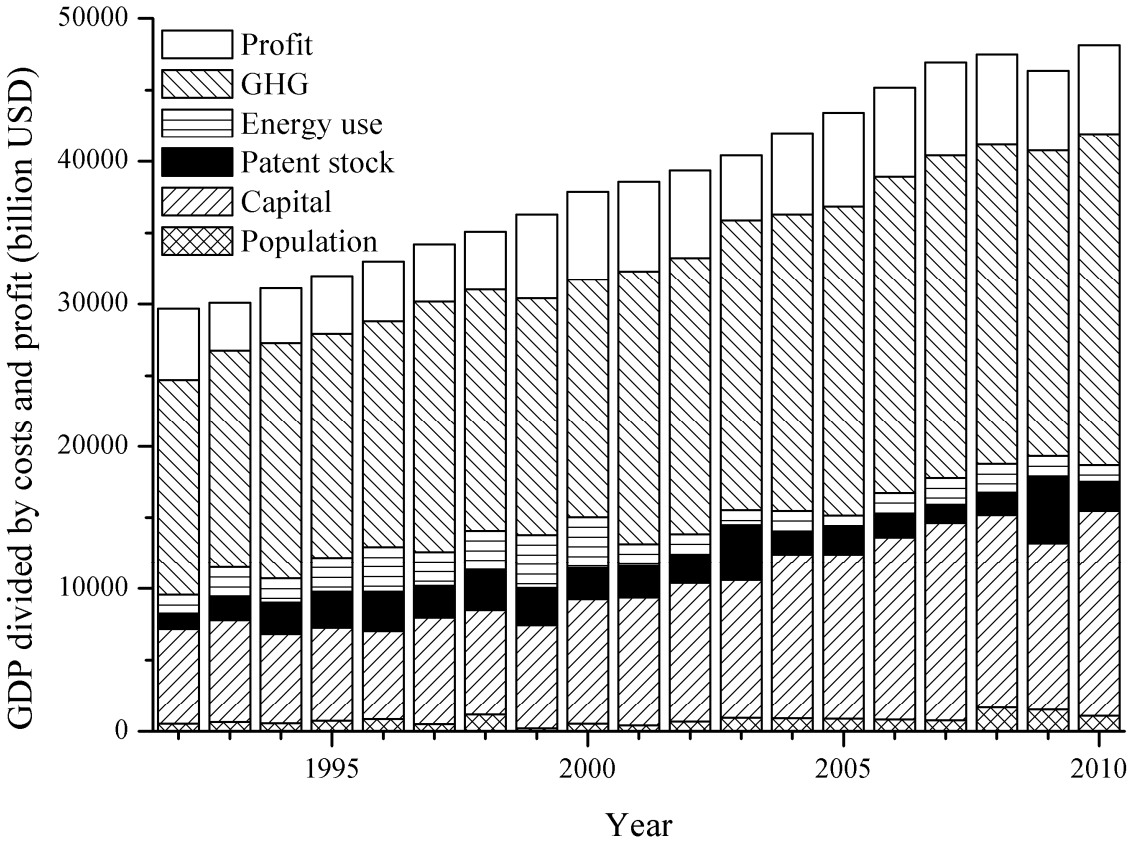
Supplementary Information Figure S2. Shadow price of patent stock: the base model

Notes: Unit is million USD per patent. “Entire”, “OECD”, and “non-OECD” in parentheses denote the entire sample, OECD members, and non-OECD members, respectively. “Avg” and “wavg” denote simple average and weighted average (by GDP), respectively. Note that vertical axis is broken once between −2.5 and −50. See Table 5.



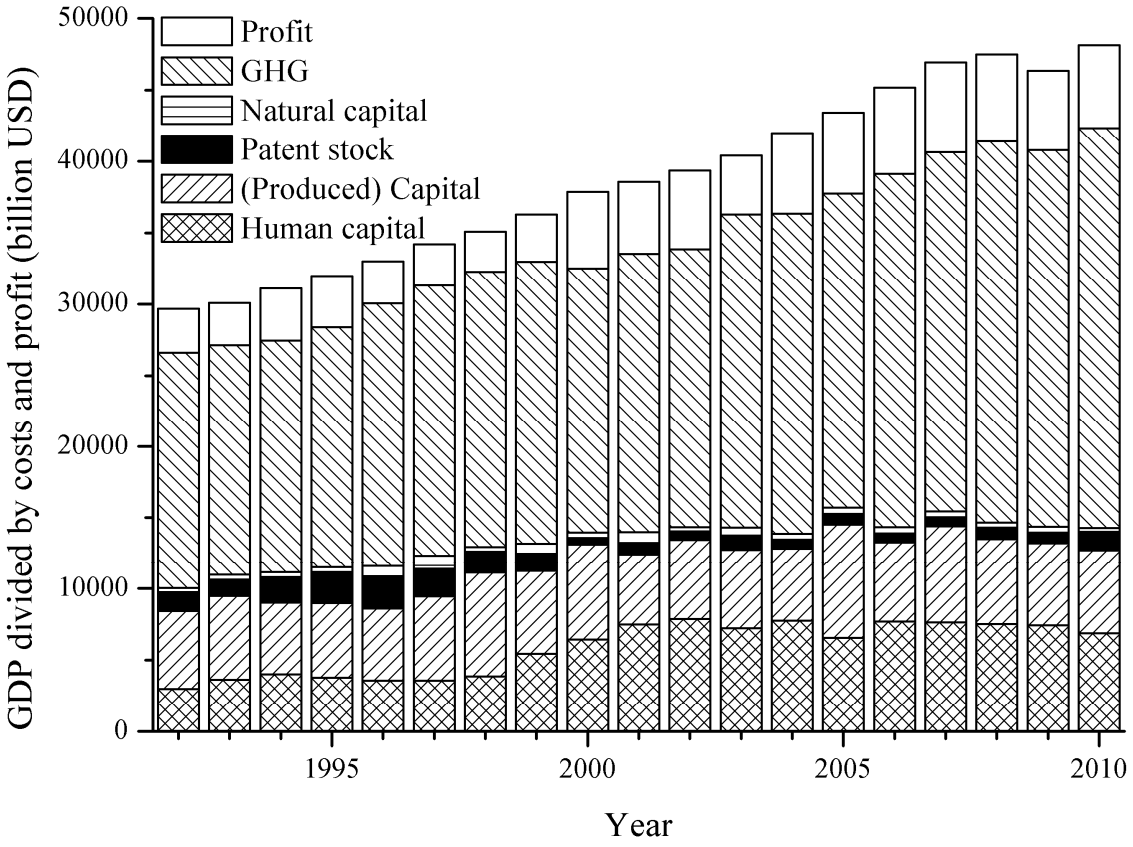
Supplementary Information Figure S3. Shadow price of patent stock: the IWI model

Notes: Unit is million USD per patent. “Entire”, “OECD”, and “non-OECD” in parentheses denote the entire sample, OECD members, and non-OECD members, respectively. “Avg” and “wavg” denote simple average and weighted average (by GDP), respectively. See Table 6.



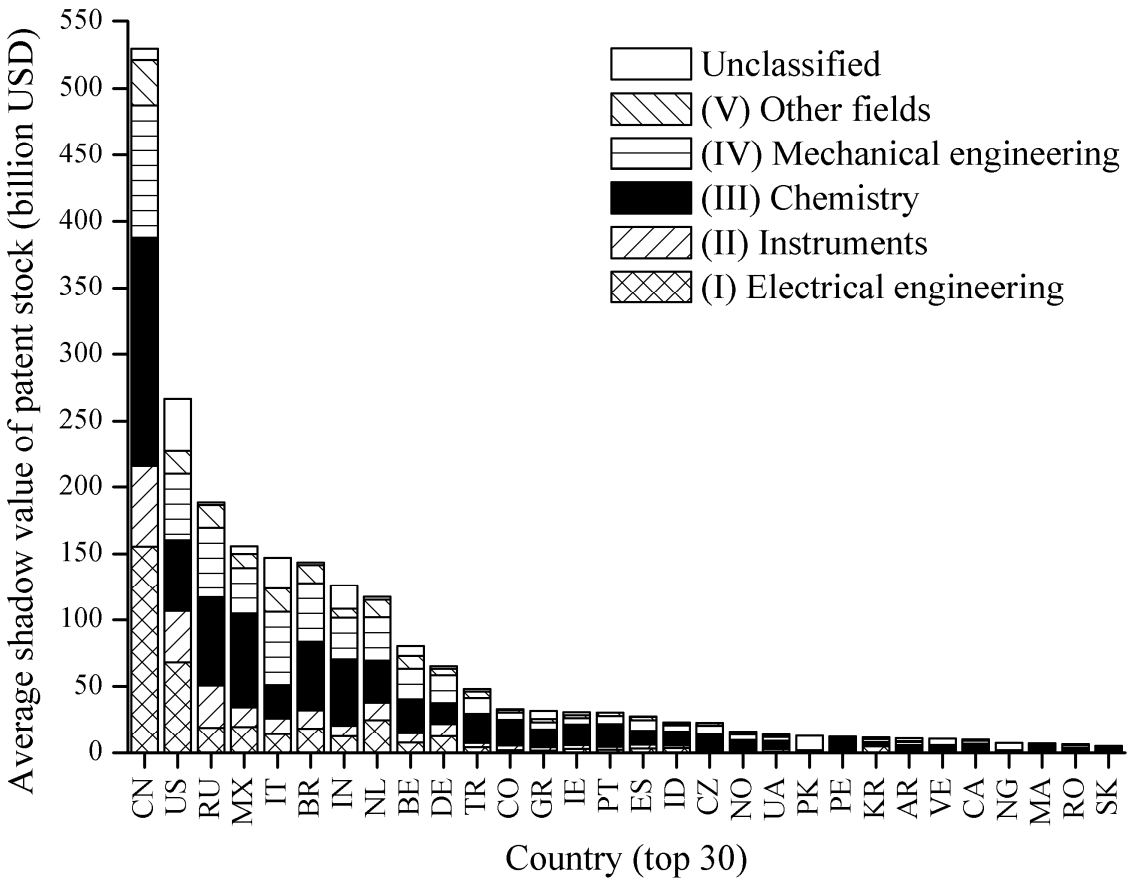
Supplementary Information Figure S4. GDP divided by costs and profit in the entire sample: the base model

Note: See Table 7.



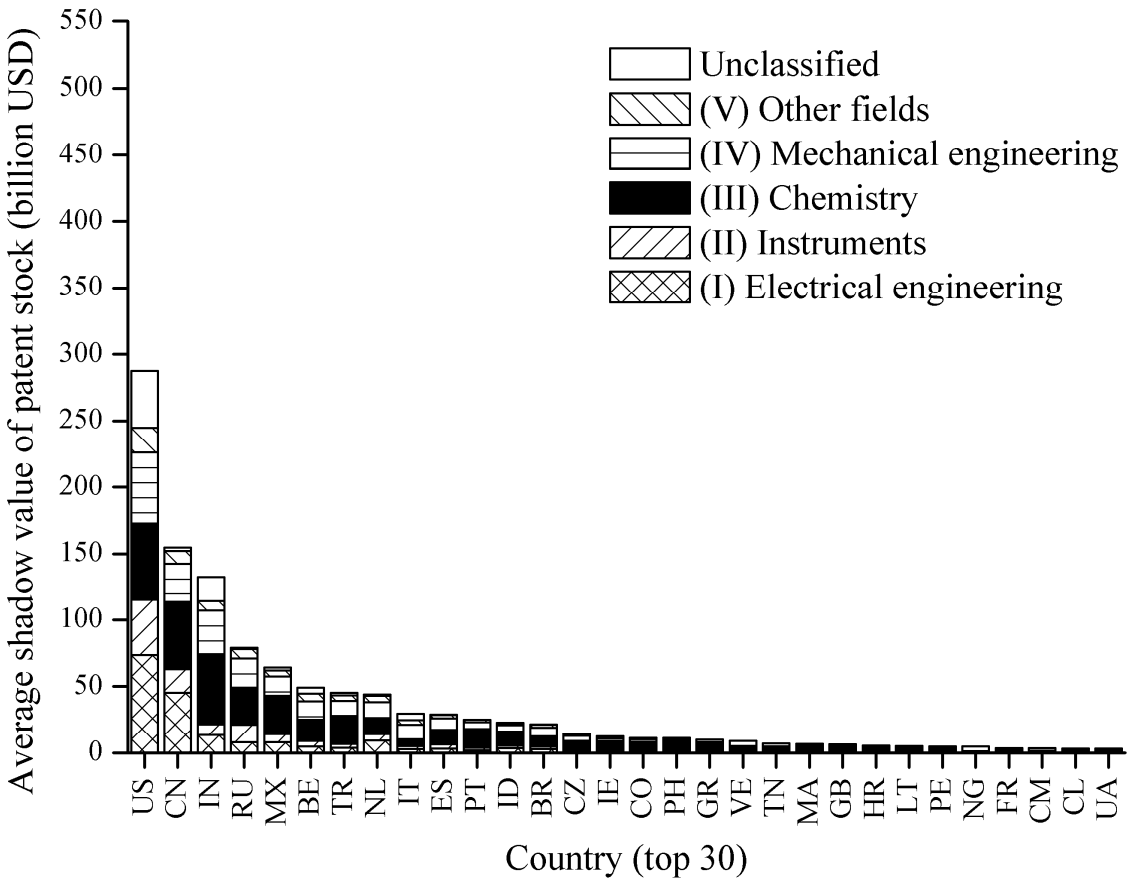
Supplementary Information Figure S5. GDP divided by costs and profit in the entire sample: the IWI model

Note: See Table 8.



Supplementary Information Figure S6. Average shadow value of patent stock in top 30 countries: the base model

Notes: This figure shows the average shadow value (in absolute value) of patent stock from 1992 to 2010, respectively, in the base model. The shadow value is simply divided by the ratio of technical classification (exogenously). See Supplementary Information Table S5.



Supplementary Information Figure S7. Average shadow value of patent stock in top 30 countries: the IWI model

Notes: This figure shows the average shadow value (in absolute value) of patent stock from 1992 to 2010, respectively, in the IWI model. The shadow value is simply divided by the ratio of technical classification (exogenously). See Supplementary Information Table S6.

Supplementary Information Table S1. Average patent stock in each country

#	Avg patent stock	Technology field					
		I	II	III	IV	V	unclassified
OECD (35)							
AU	874030.1	14.7%	13.1%	33.8%	19.8%	8.6%	10.1%
AT	396485.8	13.5%	12.3%	34.1%	27.5%	10.7%	1.9%
BE	69733.2	9.4%	8.9%	32.2%	28.3%	12.0%	9.2%
CA	635600.8	16.9%	13.8%	36.1%	23.2%	9.1%	0.8%
CH	134176.8	9.5%	13.6%	24.3%	27.2%	10.6%	14.7%
CL	1269.9	3.8%	4.8%	56.7%	11.6%	4.5%	18.5%
CZ	32138.7	6.9%	7.2%	49.6%	27.4%	8.5%	0.5%
DE	2333555.8	19.3%	13.9%	24.1%	32.0%	7.8%	2.9%
DK	164226.2	8.3%	10.7%	44.7%	23.4%	8.8%	4.2%
ES	325712.1	11.1%	10.9%	38.5%	30.0%	8.5%	1.0%
EE	3525.9	14.8%	6.9%	59.5%	12.4%	6.3%	0.2%
FI	116242.5	16.9%	9.0%	31.3%	31.1%	9.7%	2.0%
FR	492253.7	18.0%	12.8%	20.6%	35.1%	12.8%	0.6%
GB	726568.6	13.8%	10.6%	15.8%	22.2%	9.5%	28.1%
GR	47512.6	5.1%	7.4%	42.3%	17.7%	7.5%	19.9%
HU	81350.9	7.4%	7.2%	51.6%	16.8%	7.5%	9.5%
IE	44505.9	8.8%	9.6%	51.6%	15.8%	7.3%	6.8%
IS	3621.7	3.8%	7.2%	60.0%	15.7%	3.8%	9.5%
IL	101895.9	13.5%	14.5%	46.0%	14.6%	6.0%	5.4%
IT	277941.4	9.5%	8.3%	17.1%	37.4%	12.1%	15.7%
JP	7331432.3	31.9%	15.1%	17.7%	24.4%	7.0%	3.9%
KR	810425.6	40.3%	9.8%	18.5%	19.6%	6.8%	5.1%
LU	11145.6	7.0%	8.4%	47.2%	25.5%	10.1%	1.7%
LV	3575.7	6.4%	8.3%	52.7%	18.7%	8.6%	5.4%
MX	97326.0	12.6%	9.4%	44.9%	22.6%	6.9%	3.6%
NL	133613.4	21.0%	11.4%	26.8%	27.8%	11.1%	1.9%
NO	115302.5	9.9%	10.3%	40.0%	25.0%	14.3%	0.6%
NZ	74122.7	7.1%	8.2%	51.1%	18.2%	7.4%	7.9%
PL	121642.3	9.9%	10.8%	38.6%	27.3%	11.1%	2.3%
PT	60453.0	6.9%	7.9%	57.0%	20.4%	7.6%	0.2%
SK	17135.4	5.2%	6.4%	59.4%	20.8%	7.9%	0.3%
SI	14118.7	6.7%	6.6%	55.1%	19.5%	11.7%	0.4%
SE	155965.8	15.4%	11.8%	17.4%	33.2%	10.2%	12.0%
TR	21670.0	8.6%	6.5%	46.5%	24.7%	9.5%	4.3%
US	3978538.5	25.6%	14.5%	20.1%	18.6%	6.4%	14.9%
Non-OECD (57)							
AL	4.3	0.0%	0.0%	13.6%	66.7%	0.0%	19.8%
AE	56.5	20.0%	4.9%	11.0%	25.3%	12.7%	26.1%
AR	52711.8	7.6%	7.1%	39.3%	20.5%	6.9%	18.6%
AM	61.0	6.3%	4.8%	10.6%	4.0%	4.2%	70.1%
BG	29363.5	10.4%	10.2%	43.3%	22.4%	5.7%	8.0%
BO	8.9	4.1%	0.0%	5.9%	24.9%	5.3%	59.8%
BR	226558.5	12.8%	9.6%	35.8%	30.6%	9.8%	1.3%
CN	724094.4	29.3%	11.4%	32.6%	18.7%	6.4%	1.6%
CI	2.9	0.0%	0.0%	20.0%	52.7%	27.3%	0.0%
CM	4.0	0.0%	7.9%	18.4%	0.0%	21.1%	52.6%
CO	7632.1	5.3%	11.2%	58.6%	16.7%	5.5%	2.7%
CR	1069.7	4.5%	6.1%	65.9%	13.2%	6.3%	4.0%
CU	1850.9	6.1%	10.7%	55.2%	13.9%	4.8%	9.2%

DO	536.9	0.7%	1.0%	28.7%	2.3%	2.5%	64.9%
DZ	1142.2	5.4%	4.5%	64.1%	9.4%	6.5%	10.1%
EC	3228.8	2.8%	6.0%	73.4%	9.4%	5.4%	3.1%
EG	6790.2	6.3%	10.3%	51.6%	19.7%	9.1%	3.0%
GT	2539.6	2.4%	4.0%	73.5%	9.6%	6.1%	4.3%
HN	645.7	0.6%	1.7%	49.4%	3.2%	2.2%	42.9%
HR	6712.5	6.1%	6.0%	52.8%	21.9%	11.9%	1.4%
HT	6.3	0.0%	15.1%	0.0%	0.0%	11.8%	73.1%
ID	10073.7	15.5%	7.5%	47.1%	20.4%	6.9%	2.6%
IN	41332.0	10.0%	6.2%	39.7%	24.7%	5.4%	14.0%
IQ	12.6	14.2%	6.7%	0.0%	1.3%	6.3%	71.5%
JM	3.9	0.0%	0.0%	9.5%	32.4%	0.0%	58.1%
JO	1176.6	1.9%	1.8%	25.6%	5.2%	3.2%	62.4%
KZ	267.2	2.5%	1.8%	6.6%	4.6%	3.4%	81.0%
KE	794.1	3.8%	2.8%	73.5%	11.2%	4.7%	4.0%
LK	64.6	2.9%	0.8%	3.1%	15.5%	9.4%	68.3%
LT	2787.9	5.9%	10.2%	51.5%	21.1%	10.5%	0.7%
MA	7110.3	5.8%	5.1%	51.2%	15.5%	8.1%	14.3%
MD	2449.9	6.3%	16.9%	44.3%	21.8%	6.2%	4.6%
MN	115.3	7.1%	12.3%	38.5%	18.9%	9.9%	13.3%
MY	21012.5	23.8%	7.6%	38.4%	17.4%	7.8%	5.0%
NA	9.1	12.7%	20.8%	38.0%	2.9%	20.3%	5.2%
NG	11.7	2.4%	0.3%	10.3%	0.0%	12.6%	74.4%
PK	15.2	0.0%	5.9%	3.2%	0.9%	4.2%	85.8%
PA	1206.7	5.1%	6.5%	67.0%	9.9%	10.7%	0.8%
PE	6219.4	4.8%	8.8%	70.6%	10.8%	4.5%	0.6%
PH	11442.7	4.3%	5.3%	68.3%	13.5%	5.4%	3.2%
PY	4.7	0.0%	0.0%	3.3%	0.0%	12.2%	84.4%
RO	36049.1	8.6%	11.1%	41.3%	28.5%	7.2%	3.3%
RU	212351.3	10.0%	17.0%	35.1%	27.8%	9.2%	0.9%
SD	18.2	2.9%	0.0%	18.4%	14.8%	3.5%	60.4%
SN	2.4	20.3%	23.9%	37.0%	0.0%	3.6%	15.2%
SV	649.9	3.2%	9.3%	66.7%	9.2%	3.8%	7.8%
SY	25.8	1.4%	13.2%	3.7%	27.9%	2.2%	51.6%
TH	156.7	3.0%	2.7%	8.8%	14.4%	9.1%	62.0%
TJ	253.2	2.2%	16.9%	50.7%	13.3%	7.1%	9.8%
TN	2432.3	4.3%	7.8%	42.3%	9.7%	5.8%	30.1%
UA	14839.8	7.5%	14.1%	42.4%	22.6%	6.7%	6.7%
UY	2314.3	1.5%	3.0%	67.8%	4.2%	2.0%	21.6%
VE	87.8	2.1%	5.0%	37.9%	3.3%	6.7%	44.9%
VN	128.6	13.5%	6.8%	31.0%	21.5%	6.9%	20.3%
YE	1.7	0.0%	0.0%	48.5%	0.0%	0.0%	51.5%
ZM	917.8	2.3%	3.0%	62.6%	19.3%	8.1%	4.7%
ZW	2061.5	2.4%	3.5%	60.1%	19.6%	9.1%	5.3%

Supplementary Information Table S2. DEA score in each country

		(1) Base model		(2) IWI model	
Country	#	Avg	SD	Avg	SD
OECD members (35)					
Australia	AU	0.000	0.000	0.011	0.003
Austria	AT	0.206	0.014	0.002	0.000
Belgium	BE	0.039	0.044	0.001	0.001
Canada	CA	0.109	0.054	0.005	0.001
Switzerland	CH	0.000	0.000	0.000	0.000
Chile	CL	0.000	0.001	0.000	0.000
Czech Republic	CZ	0.501	0.102	0.010	0.002
Germany	DE	0.028	0.025	0.000	0.000
Denmark	DK	0.007	0.011	0.000	0.000
Spain	ES	0.150	0.029	0.001	0.000
Estonia	EE	0.342	0.162	0.016	0.010
Finland	FI	0.271	0.056	0.003	0.001
France	FR	0.000	0.000	0.000	0.000
United Kingdom	GB	0.000	0.000	0.000	0.000
Greece	GR	0.140	0.032	0.003	0.001
Hungary	HU	0.448	0.040	0.007	0.001
Ireland	IE	0.023	0.054	0.001	0.002
Iceland	IS	0.000	0.000	0.000	0.000
Israel	IL	0.114	0.060	0.002	0.001
Italy	IT	0.000	0.000	0.000	0.000
Japan	JP	0.000	0.000	0.000	0.000
Republic of Korea	KR	0.321	0.081	0.005	0.001
Luxembourg	LU	0.000	0.000	0.000	0.000
Latvia	LV	0.342	0.149	0.010	0.006
Mexico	MX	0.013	0.028	0.001	0.002
Netherlands	NL	0.012	0.022	0.000	0.001
Norway	NO	0.000	0.000	0.000	0.000
New Zealand	NZ	0.235	0.024	0.005	0.001
Poland	PL	0.107	0.073	0.012	0.005
Portugal	PT	0.197	0.101	0.002	0.001
Slovakia	SK	0.577	0.077	0.011	0.003
Slovenia	SI	0.248	0.134	0.003	0.002
Sweden	SE	0.019	0.027	0.000	0.000
Turkey	TR	0.000	0.000	0.000	0.000
United States of America	US	0.000	0.000	0.000	0.000
Non-OECD members (57)					
Albania	AL	0.016	0.037	0.000	0.001
United Arab Emirates	AE	0.000	0.000	0.000	0.000
Argentina	AR	0.474	0.121	0.017	0.002
Armenia	AM	0.104	0.185	0.006	0.012
Bulgaria	BG	0.669	0.107	0.027	0.006
Bolivia	BO	0.017	0.041	0.020	0.047
Brazil	BR	0.051	0.088	0.019	0.005
China	CN	0.000	0.000	0.025	0.015
Côte d'Ivoire	CI	0.000	0.000	0.016	0.033
Cameroon	CM	0.254	0.311	0.049	0.034
Colombia	CO	0.063	0.048	0.005	0.002
Costa Rica	CR	0.000	0.000	0.000	0.000
Cuba	CU	0.246	0.165	0.006	0.004

Dominican Republic	DO	0.001	0.005	0.000	0.000
Algeria	DZ	0.312	0.030	0.008	0.001
Ecuador	EC	0.345	0.061	0.008	0.001
Egypt	EG	0.024	0.021	0.008	0.007
Guatemala	GT	0.212	0.042	0.009	0.008
Honduras	HN	0.417	0.065	0.013	0.004
Croatia	HR	0.188	0.079	0.003	0.001
Haiti	HT	0.000	0.000	0.000	0.000
Indonesia	ID	0.037	0.068	0.022	0.021
India	IN	0.023	0.048	0.009	0.014
Iraq	IQ	0.291	0.384	0.047	0.059
Jamaica	JM	0.000	0.000	0.000	0.000
Jordan	JO	0.489	0.066	0.012	0.002
Kazakhstan	KZ	0.709	0.179	0.054	0.015
Kenya	KE	0.351	0.112	0.021	0.006
Sri Lanka	LK	0.112	0.088	0.003	0.002
Lithuania	LT	0.397	0.106	0.009	0.004
Morocco	MA	0.301	0.039	0.006	0.001
Republic of Moldova	MD	0.734	0.145	0.045	0.017
Mongolia	MN	0.000	0.000	0.000	0.000
Malaysia	MY	0.260	0.118	0.017	0.006
Namibia	NA	0.000	0.000	0.000	0.000
Nigeria	NG	0.083	0.112	0.013	0.015
Pakistan	PK	0.000	0.000	0.001	0.005
Panama	PA	0.000	0.000	0.000	0.000
Peru	PE	0.073	0.063	0.002	0.002
Philippines	PH	0.372	0.116	0.012	0.004
Paraguay	PY	0.051	0.126	0.074	0.043
Romania	RO	0.547	0.118	0.016	0.005
Russian Federation	RU	0.389	0.362	0.036	0.016
Sudan	SD	0.000	0.000	0.000	0.000
Senegal	SN	0.000	0.000	0.000	0.000
El Salvador	SV	0.003	0.006	0.000	0.000
Syrian Arab Republic	SY	0.251	0.103	0.018	0.005
Thailand	TH	0.000	0.000	0.006	0.006
Tajikistan	TJ	0.416	0.342	0.039	0.034
Tunisia	TN	0.297	0.036	0.006	0.001
Ukraine	UA	0.775	0.220	0.061	0.015
Uruguay	UY	0.082	0.088	0.007	0.006
Venezuela	VE	0.064	0.125	0.006	0.005
Viet Nam	VN	0.249	0.069	0.032	0.004
Yemen	YE	0.000	0.000	0.000	0.000
Zambia	ZM	0.747	0.085	0.419	0.130
Zimbabwe	ZW	0.000	0.000	0.000	0.000

Supplementary Information Table S3. shadow price of each country: the base model

	(1) Population		(2) Capital		(3) Patent stock		(4) Energy use		(5) GHG	
Unit	Thousand USD per person		USD per 1 USD of capital		Million USD per patent		Thousand USD per TOE		Thousand USD per tonne	
#	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
OECD (35)										
AU	−10.984	6.891	−0.242	0.116	0.000	0.000	−1.565	0.839	0.314	0.126
AT	−1.357	1.994	−0.202	0.022	0.000	0.000	−0.228	0.313	−0.662	0.144
BE	−2.611	4.559	−0.090	0.099	−1.590	1.041	0.000	0.000	−1.118	0.812
CA	−5.158	7.205	−0.340	0.049	−0.018	0.077	0.000	0.000	0.093	0.271
CH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−6.434	0.600
CL	−0.052	0.130	−0.140	0.108	−2.110	0.983	0.000	0.000	−0.736	0.299
CZ	−0.218	0.334	−0.101	0.063	−1.409	2.167	0.000	0.000	−0.227	0.122
DE	−0.053	0.230	−0.085	0.034	−0.032	0.040	−2.048	2.525	−0.439	0.800
DK	−1.410	3.637	−0.229	0.037	0.000	0.000	−1.687	1.603	−0.677	0.336
ES	0.000	0.000	−0.069	0.079	−0.099	0.151	−1.444	0.917	−1.253	0.577
EE	−1.500	0.802	−0.301	0.084	−0.963	2.445	0.000	0.000	−0.009	0.063
FI	−2.801	2.733	−0.197	0.010	−0.009	0.039	0.000	0.000	−0.495	0.171
FR	−0.040	0.174	0.000	0.000	−0.006	0.015	0.000	0.000	−3.228	0.406
GB	0.000	0.000	−0.103	0.074	0.000	0.000	−0.507	0.867	−1.652	0.885
GR	−0.284	0.450	−0.178	0.009	−0.686	0.291	−0.941	0.911	−0.246	0.219
HU	0.000	0.000	−0.192	0.025	−0.002	0.008	0.000	0.000	−0.370	0.103
IE	−2.281	5.223	−0.116	0.079	−0.809	0.802	−2.807	1.930	−0.564	0.824
IS	−0.887	1.423	−0.163	0.028	−0.191	0.296	−0.115	0.354	−2.566	1.571
IL	−0.358	0.521	−0.323	0.034	0.000	0.000	−0.082	0.181	−0.226	0.219
IT	0.000	0.000	0.000	0.000	−0.559	0.588	−1.220	1.438	−2.267	0.366
JP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−2.782	0.098
KR	−0.101	0.222	−0.247	0.042	−0.059	0.105	0.000	0.000	−0.246	0.188
LU	−0.160	0.454	−0.206	0.047	−0.135	0.261	−0.560	1.403	−1.718	0.674
LV	−0.939	0.684	−0.284	0.113	−0.110	0.209	−0.233	0.697	−0.168	0.205
MX	−0.127	0.205	−0.144	0.090	−1.839	1.035	0.000	0.000	−0.229	0.306
NL	−6.320	5.960	−0.138	0.072	−0.911	0.360	−0.880	0.890	−0.257	0.356
NO	−3.963	3.343	−0.202	0.074	−0.164	0.352	−0.344	0.467	−0.957	0.279

NZ	−1.127	0.394	−0.301	0.041	−0.023	0.071	−0.367	0.297	0.015	0.058
PL	−0.333	0.331	−0.391	0.024	0.000	0.000	0.000	0.000	0.023	0.038
PT	−0.162	0.311	−0.166	0.030	−0.488	0.126	−0.215	0.255	−0.550	0.108
SK	−0.139	0.179	−0.120	0.076	−0.491	0.605	0.000	0.000	−0.270	0.089
SI	−1.572	2.743	−0.175	0.089	−0.478	0.616	−0.002	0.009	−0.489	0.281
SE	−0.005	0.022	−0.229	0.033	0.000	0.000	0.000	0.000	−1.429	0.663
TR	0.000	0.000	−0.119	0.096	−2.207	1.621	0.000	0.000	−0.703	0.188
US	0.000	0.000	0.000	0.000	−0.092	0.117	0.000	0.000	−1.311	0.186
Non- OECD (57)										
AL	−0.012	0.054	−0.037	0.046	−32.187	35.412	−0.567	0.658	−0.915	0.197
AE	−0.018	0.077	−0.009	0.041	−4.833	1.413	0.000	0.000	−1.072	0.143
AR	−0.080	0.196	−0.201	0.072	−0.243	0.233	0.000	0.000	−0.118	0.087
AM	−0.546	0.415	−0.293	0.140	−448.632	1209.993	0.000	0.001	−0.447	0.140
BG	−0.071	0.128	−0.213	0.038	0.000	0.000	0.000	0.000	−0.072	0.028
BO	−0.626	0.155	−0.509	0.092	−69.105	160.366	−0.021	0.090	0.006	0.012
BR	−0.035	0.079	−0.238	0.076	−0.668	0.450	−1.225	0.905	0.163	0.135
CN	−0.033	0.083	−0.226	0.163	−1.578	1.454	0.000	0.000	0.058	0.040
CI	0.000	0.000	−0.338	0.105	−77.690	120.880	−0.587	0.889	−0.120	0.145
CM	−0.237	0.264	−0.207	0.072	−764.592	801.528	−0.449	0.602	0.006	0.022
CO	0.000	0.000	−0.005	0.020	−6.064	3.603	−3.451	0.941	0.028	0.067
CR	−0.172	0.302	−0.131	0.129	−1.769	1.789	−0.172	0.639	−1.230	0.414
CU	−0.091	0.257	−0.167	0.156	−1.195	0.863	−0.023	0.092	−0.323	0.153
DO	−0.003	0.014	−0.176	0.091	−45.766	67.115	−0.663	0.787	−0.561	0.399
DZ	0.000	0.000	0.000	0.000	−3.909	0.884	−0.307	0.678	−0.514	0.164
EC	0.000	0.000	−0.100	0.076	−1.674	1.444	−0.372	0.848	−0.321	0.117
EG	−0.048	0.078	−0.451	0.044	−0.007	0.032	−0.003	0.013	−0.006	0.021
GT	0.000	0.000	−0.272	0.058	−0.106	0.144	−0.158	0.347	−0.272	0.189
HN	−0.138	0.186	−0.278	0.068	−12.598	47.197	0.000	0.000	−0.181	0.168
HR	−0.313	0.486	−0.148	0.084	−1.106	0.861	−0.051	0.223	−0.471	0.202
HT	−0.035	0.082	−0.270	0.064	−5.375	4.643	−0.252	0.338	−0.536	0.063
ID	−0.089	0.094	−0.284	0.121	−2.594	2.688	0.000	0.000	0.071	0.054
IN	0.000	0.000	−0.133	0.120	−3.080	1.970	0.000	0.000	−0.067	0.103
IQ	−0.003	0.015	−0.388	0.209	−71.157	96.705	0.000	0.000	−0.033	0.020
JM	−1.872	1.761	−0.141	0.091	−29.627	40.242	−0.105	0.261	−0.700	0.269
JO	−0.246	0.288	−0.111	0.082	−1.486	1.062	0.000	0.000	−0.402	0.155

KZ	−0.016	0.051	−0.012	0.046	−450.028	1898.950	0.000	0.000	−0.147	0.062
KE	0.000	0.000	−0.327	0.048	−1.069	1.890	0.000	0.000	−0.080	0.041
LK	0.000	0.000	−0.072	0.052	−20.458	16.222	0.000	0.000	−0.761	0.107
LT	−0.546	0.525	−0.102	0.074	−1.468	0.630	0.000	0.000	−0.329	0.085
MA	0.000	0.000	−0.123	0.066	−1.063	0.669	−0.011	0.032	−0.403	0.138
MD	−0.279	0.278	−0.207	0.164	−2.454	7.753	−0.151	0.359	−0.205	0.061
MN	−1.746	0.531	−0.987	0.213	−2.610	5.487	0.000	0.000	−0.051	0.030
MY	−0.478	0.648	−0.312	0.054	−0.249	0.495	0.000	0.000	0.015	0.107
NA	−0.719	0.499	−0.310	0.118	−14.862	12.102	−0.522	0.747	−0.330	0.248
NG	0.000	0.000	−0.254	0.097	−664.634	1528.384	0.000	0.000	−0.043	0.097
PK	0.000	0.000	−0.163	0.085	−913.545	713.122	−0.148	0.255	0.000	0.103
PA	−0.374	0.288	−0.275	0.155	−0.887	1.044	−0.699	1.503	−0.858	0.416
PE	0.000	0.000	−0.059	0.088	−3.317	1.890	−2.661	1.379	−0.159	0.183
PH	0.000	0.000	−0.188	0.050	−0.664	0.659	−0.030	0.089	−0.216	0.088
PY	−1.002	0.344	−0.371	0.108	−1126.191	893.994	0.000	0.000	0.026	0.022
RO	0.000	0.000	−0.194	0.050	−0.215	0.279	0.000	0.000	−0.141	0.061
RU	−0.240	0.453	−0.112	0.120	−1.762	1.496	0.000	0.000	0.037	0.096
SD	0.000	0.000	−0.476	0.085	−1.876	2.816	−0.154	0.239	−0.064	0.049
SN	0.000	0.000	−0.319	0.044	−222.096	75.667	−1.632	0.410	−0.014	0.028
SV	0.000	0.000	−0.213	0.150	−1.468	1.524	−0.015	0.066	−0.938	0.546
SY	−0.110	0.132	−0.285	0.074	−141.191	158.099	0.000	0.000	−0.027	0.014
TH	−0.072	0.151	−0.013	0.034	−24.919	31.621	0.000	0.000	0.010	0.102
TJ	−1.208	2.763	−1.118	2.523	−5.077	16.453	−4.535	11.735	−0.155	0.038
TN	0.000	0.000	−0.076	0.061	−1.852	0.784	0.000	0.000	−0.503	0.140
UA	−0.063	0.277	−0.030	0.043	−7.943	21.580	0.000	0.000	−0.065	0.048
UY	−0.859	0.787	−0.178	0.123	−1.384	1.485	−2.064	1.105	−0.005	0.063
VE	−0.109	0.151	0.000	0.000	−93.718	130.119	−0.050	0.113	0.067	0.217
VN	0.000	0.000	−0.372	0.087	−4.922	9.778	−0.092	0.126	−0.034	0.027
YE	0.000	0.000	−0.365	0.059	−123.561	147.607	−0.729	0.664	−0.068	0.071
ZM	−0.270	0.048	−0.287	0.012	−0.670	0.593	−0.065	0.117	−0.001	0.002
ZW	−0.009	0.022	−0.493	0.025	0.000	0.000	0.000	0.000	−0.129	0.070

Notes: Values are rounded off.

Supplementary Information Table S4. shadow price of each country: the IWI model

	(1) Human capital		(2) (Produced) capital		(3) Patent stock		(4) Natural capital		(5) GHG	
Unit	USD per 1 USD of capital		USD per 1 USD of capital		Million USD per patent		USD per 1 USD of capital		Thousand USD per tonne	
#	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
OECD (35)										
AU	−0.093	0.055	−0.094	0.096	0.000	0.000	0.000	0.000	−0.056	0.117
AT	−0.089	0.005	0.000	0.000	0.000	0.000	−0.105	0.128	−0.768	0.054
BE	0.000	0.000	0.000	0.000	−1.118	1.125	−1.376	1.185	−2.050	0.176
CA	−0.044	0.010	−0.215	0.045	0.000	0.000	0.000	0.000	−0.081	0.096
CH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−6.434	0.600
CL	−0.002	0.008	−0.081	0.113	−3.159	1.459	−0.007	0.011	−0.821	0.273
CZ	−0.104	0.060	−0.008	0.016	−1.073	1.597	−0.900	0.536	0.232	0.261
DE	−0.025	0.025	−0.090	0.022	0.000	0.001	0.000	0.000	−0.808	0.328
DK	−0.046	0.032	−0.126	0.106	0.000	0.000	−0.328	0.363	−0.916	0.229
ES	−0.032	0.025	−0.086	0.077	−0.113	0.170	0.000	0.001	−0.912	0.244
EE	−0.034	0.028	−0.137	0.114	−27.773	97.757	−0.044	0.121	−0.105	0.140
FI	−0.045	0.011	−0.135	0.047	0.000	0.000	−0.019	0.026	−0.263	0.084
FR	0.000	0.000	0.000	0.000	−0.006	0.015	−0.003	0.012	−3.231	0.402
GB	0.000	0.000	−0.072	0.088	−0.009	0.034	−0.922	0.999	−2.102	1.106
GR	−0.118	0.019	−0.007	0.019	−0.233	0.390	−0.012	0.020	−0.263	0.104
HU	−0.038	0.007	−0.126	0.029	0.000	0.000	−0.024	0.024	−0.139	0.066
IE	−0.057	0.026	−0.097	0.065	−0.363	0.579	−0.085	0.069	−0.620	0.632
IS	−0.026	0.031	−0.114	0.063	−0.118	0.360	0.000	0.000	−2.477	1.701
IL	−0.017	0.018	−0.362	0.056	0.000	0.000	−1.402	0.527	0.395	0.436
IT	−0.036	0.024	0.000	0.000	−0.109	0.372	0.000	0.000	−2.096	0.389
JP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−2.782	0.098
KR	−0.085	0.024	−0.103	0.051	0.000	0.000	−0.173	0.152	0.081	0.341
LU	−0.048	0.037	−0.071	0.097	−0.029	0.127	−0.063	0.056	−2.485	0.798
LV	−0.006	0.009	−0.224	0.082	−0.074	0.207	−0.010	0.022	−0.372	0.224
MX	−0.055	0.046	−0.075	0.077	−1.043	1.232	0.000	0.000	−0.374	0.178
NL	−0.053	0.022	−0.112	0.076	−0.345	0.349	−0.321	0.305	−0.473	0.608
NO	−0.085	0.018	−0.019	0.046	−0.005	0.021	0.000	0.000	−1.492	0.344

NZ	−0.127	0.018	−0.020	0.030	−0.001	0.006	0.000	0.000	−0.124	0.101
PL	0.000	0.000	−0.433	0.032	0.000	0.000	−0.315	0.248	0.255	0.198
PT	0.000	0.000	−0.178	0.027	−0.469	0.322	−0.205	0.238	−0.509	0.339
SK	−0.051	0.022	−0.038	0.052	−0.350	0.676	−0.088	0.105	−0.144	0.112
SI	0.000	0.000	−0.159	0.075	−0.521	0.872	−0.007	0.012	−0.570	0.164
SE	−0.002	0.005	−0.224	0.031	0.000	0.000	0.000	0.000	−1.405	0.681
TR	0.000	0.000	−0.136	0.099	−2.020	1.673	−0.004	0.010	−0.693	0.171
US	0.000	0.000	0.000	0.000	−0.112	0.126	0.000	0.000	−1.325	0.159
Non-OECD (57)										
AL	−0.048	0.031	−0.006	0.020	−46.376	109.265	−0.002	0.005	−0.915	0.197
AE	−0.008	0.023	0.000	0.001	−4.228	1.396	0.000	0.000	−1.077	0.193
AR	−0.045	0.016	−0.157	0.022	0.000	0.000	0.000	0.000	−0.039	0.039
AM	−0.038	0.038	−0.005	0.017	−150.809	333.291	−0.175	0.149	−0.396	0.144
BG	−0.070	0.033	−0.099	0.071	0.000	0.000	−0.002	0.004	−0.008	0.012
BO	−0.068	0.072	−0.215	0.190	−109.964	197.861	0.000	0.000	0.000	0.019
BR	−0.024	0.027	−0.260	0.102	−0.097	0.150	0.000	0.000	0.036	0.022
CN	−0.064	0.060	−0.103	0.157	−0.955	1.520	0.000	0.000	−0.020	0.080
CI	−0.019	0.031	−0.339	0.136	−12.716	15.429	−0.009	0.014	−0.107	0.136
CM	−0.065	0.044	−0.148	0.173	−1039.077	945.618	−0.004	0.007	0.029	0.059
CO	−0.006	0.016	−0.131	0.038	−3.823	5.237	0.000	0.000	−0.297	0.166
CR	−0.001	0.003	−0.102	0.126	−9.008	16.192	−0.022	0.027	−1.400	0.352
CU	−0.059	0.028	−0.086	0.110	−1.609	0.753	−0.173	0.138	−0.064	0.208
DO	−0.001	0.003	−0.081	0.115	−6.651	4.986	−0.079	0.057	−0.618	0.279
DZ	−0.101	0.027	0.000	0.000	−2.756	1.489	−0.013	0.014	−0.190	0.111
EC	−0.142	0.033	−0.012	0.023	−0.937	0.747	−0.002	0.006	−0.116	0.130
EG	−0.025	0.021	−0.311	0.063	−0.171	0.266	−0.067	0.098	−0.042	0.025
GT	−0.001	0.006	−0.256	0.057	−0.235	0.276	−0.058	0.093	−0.267	0.202
HN	−0.016	0.012	−0.152	0.082	−15.418	45.641	0.000	0.000	−0.267	0.172
HR	0.000	0.000	−0.145	0.092	−1.274	1.134	−0.076	0.156	−0.412	0.190
HT	−0.053	0.026	−0.070	0.056	−5.097	3.717	−0.012	0.027	−0.536	0.063
ID	−0.045	0.034	−0.162	0.121	−2.599	2.239	0.000	0.000	0.048	0.033
IN	0.000	0.000	−0.136	0.145	−3.275	2.121	0.000	0.000	−0.070	0.113
IQ	−0.020	0.029	−0.324	0.227	−59.271	100.852	0.000	0.000	−0.025	0.017
JM	−0.032	0.034	−0.005	0.014	−94.707	114.085	−0.084	0.057	−0.441	0.294
JO	−0.035	0.018	−0.026	0.056	−1.407	0.899	−0.142	0.160	−0.347	0.208

KZ	−0.120	0.026	0.000	0.000	−23.735	51.496	−0.001	0.003	0.000	0.025
KE	−0.003	0.008	−0.322	0.038	−1.684	2.536	−0.049	0.029	−0.013	0.018
LK	0.000	0.000	−0.001	0.005	−16.129	12.345	−0.358	0.368	−0.427	0.571
LT	−0.037	0.026	−0.020	0.036	−1.864	0.828	−0.030	0.042	−0.321	0.255
MA	−0.001	0.002	−0.132	0.060	−1.005	0.611	−0.014	0.020	−0.361	0.127
MD	−0.168	0.048	−0.002	0.007	−0.113	0.413	−0.270	0.248	−0.172	0.108
MN	−0.234	0.178	−0.272	0.459	−4.518	3.905	0.000	0.000	−0.043	0.040
MY	−0.027	0.016	−0.241	0.055	−0.009	0.039	−0.001	0.003	−0.034	0.042
NA	−0.007	0.007	−0.182	0.051	−144.854	196.742	0.000	0.000	−0.278	0.283
NG	−0.018	0.019	−0.183	0.082	−421.556	668.798	−0.013	0.025	−0.011	0.078
PK	0.000	0.001	−0.125	0.023	−11.554	4.836	−0.152	0.073	−0.028	0.082
PA	−0.018	0.025	−0.280	0.094	−0.236	0.432	−0.003	0.007	−0.570	0.321
PE	−0.034	0.025	−0.084	0.065	−4.304	13.293	0.000	0.000	−0.408	0.217
PH	−0.053	0.023	−0.097	0.040	−1.811	2.355	−0.112	0.062	−0.001	0.124
PY	−0.100	0.047	−0.055	0.040	−88.448	153.900	−0.003	0.005	0.004	0.036
RO	−0.046	0.025	−0.137	0.039	−0.036	0.103	−0.003	0.008	−0.038	0.030
RU	−0.044	0.034	−0.039	0.067	−1.396	2.046	0.000	0.000	−0.014	0.028
SD	−0.077	0.017	−0.163	0.058	−1.151	0.922	−0.001	0.005	−0.034	0.026
SN	−0.123	0.017	−0.065	0.031	−209.555	332.022	−0.001	0.002	−0.008	0.019
SV	−0.003	0.009	−0.128	0.123	−1.616	1.121	−0.062	0.054	−1.282	0.356
SY	−0.042	0.018	−0.137	0.063	−55.655	60.684	−0.073	0.055	0.000	0.040
TH	−0.020	0.030	0.000	0.000	−10.058	4.586	−0.072	0.047	−0.249	0.077
TJ	−0.144	0.033	−0.055	0.074	−0.617	0.697	−0.019	0.042	−0.155	0.038
TN	−0.015	0.022	−0.024	0.057	−2.802	0.813	−0.132	0.157	−0.367	0.188
UA	−0.068	0.041	0.000	0.000	−1.488	1.809	−0.004	0.006	−0.029	0.038
UY	−0.029	0.027	−0.208	0.102	−3.177	5.038	−0.023	0.031	−0.043	0.063
VE	−0.010	0.021	−0.016	0.037	−79.353	106.700	0.000	0.000	−0.007	0.156
VN	−0.022	0.023	−0.305	0.170	−4.314	3.428	−0.090	0.043	0.026	0.041
YE	0.000	0.000	−0.345	0.088	−234.875	328.008	−0.022	0.028	−0.188	0.127
ZM	−0.198	0.054	−0.041	0.042	−0.142	0.404	0.000	0.000	0.002	0.006
ZW	−0.022	0.020	−0.393	0.097	0.000	0.000	0.000	0.000	−0.102	0.052

Note: Values are rounded off.

Supplementary Information Table S5. Shadow value (simple average) (1992 to 2010): the base model (unit: billion USD)

#	(1) GDP	(SD)	(2) Population	(3) Capital	(4) Patent stock	(5) Energy use	(6) GHG	(7) Profit
OECD								
AU	672.8	129.5	−216.1	−515.0	0.0	−162.7	253.3	32.3
AT	280.5	35.5	−11.3	−202.9	0.0	−7.6	−58.5	0.1
BE	347.6	39.7	−26.6	−86.6	−80.3	0.0	−154.7	−0.6
CA	997.3	161.5	−161.9	−922.8	−9.8	0.0	106.1	8.8
CH	353.5	34.8	0.0	0.0	0.0	0.0	−353.5	0.0
CL	101.6	23.3	−0.9	−34.6	−1.8	0.0	−61.1	3.2
CZ	115.8	21.4	−2.3	−51.9	−22.7	0.0	−34.3	4.7
DE	2668.5	204.1	−4.3	−713.3	−65.3	−694.6	−423.3	767.7
DK	237.1	24.5	−7.8	−147.2	0.0	−32.7	−50.3	−0.9
ES	986.2	172.1	0.0	−191.6	−27.4	−186.3	−478.5	102.4
EE	10.9	3.3	−2.1	−12.2	−0.2	0.0	−0.2	−3.8
FI	172.0	30.7	−14.8	−115.8	−0.9	0.0	−40.2	0.5
FR	1965.8	208.7	−2.3	0.0	−3.6	0.0	−1785.1	174.7
GB	2003.6	310.2	0.0	−442.0	0.0	−106.5	−1090.1	364.9
GR	208.0	37.0	−3.0	−117.6	−31.9	−23.0	−28.7	3.9
HU	94.2	15.4	0.0	−67.0	−0.1	0.0	−27.8	−0.8
IE	159.8	47.5	−8.4	−46.8	−30.7	−34.7	−38.8	0.4
IS	13.7	2.8	−0.2	−6.3	−0.4	−0.3	−12.7	−6.2
IL	119.8	25.6	−2.5	−103.8	0.0	−1.6	−12.5	−0.6
IT	1674.9	117.5	0.0	0.0	−146.9	−211.6	−1188.8	127.6
JP	4313.9	248.7	0.0	0.0	0.0	0.0	−3878.6	435.3
KR	713.1	188.3	−4.6	−571.3	−11.4	0.0	−121.9	3.9
LU	31.9	7.4	−0.1	−15.6	−0.9	−2.3	−20.4	−7.3
LV	12.5	3.8	−2.3	−11.7	−0.2	−1.0	−2.7	−5.4
MX	759.1	118.8	−14.0	−311.2	−155.5	0.0	−118.8	159.6
NL	586.4	80.4	−101.6	−230.9	−117.3	−65.0	−54.2	17.3
NO	270.5	39.1	−17.9	−160.7	−16.1	−9.4	−68.0	−1.6
NZ	98.1	16.9	−4.4	−88.4	−1.1	−5.8	1.3	−0.3
PL	269.4	65.5	−12.8	−253.1	0.0	0.0	10.3	13.9
PT	176.3	20.5	−1.6	−95.9	−30.5	−5.0	−43.1	0.2
SK	42.2	10.9	−0.7	−23.3	−5.2	0.0	−13.9	−0.9
SI	31.1	6.5	−3.1	−19.6	−2.1	0.0	−10.0	−3.8
SE	328.2	51.1	0.0	−212.5	0.0	0.0	−108.1	7.5
TR	410.8	90.9	0.0	−113.1	−48.2	0.0	−221.5	28.0
US	11041.9	1700.5	0.0	0.0	−266.7	0.0	−8880.4	1894.8
Non- OECD								
AL	6.7	2.2	0.0	−1.6	−0.1	−0.8	−6.7	−2.5
AE	147.6	44.8	0.0	−4.2	−0.3	0.0	−138.0	5.1
AR	175.6	34.7	−3.2	−120.5	−10.8	0.0	−35.8	5.4
AM	3.7	1.7	−1.7	−4.9	−1.1	0.0	−3.7	−7.7
BG	25.6	5.0	−0.5	−20.3	0.0	0.0	−5.2	−0.4
BO	8.6	1.7	−5.3	−9.5	−0.5	−0.1	1.4	−5.3
BR	812.1	139.6	−6.5	−578.8	−143.5	−217.8	260.0	125.5
CN	1840.8	978.8	−42.7	−1397.6	−529.5	0.0	413.2	284.2
CI	15.8	1.6	0.0	−10.6	−0.2	−3.1	−2.3	−0.5
CM	14.5	2.9	−4.2	−8.1	−2.5	−2.8	1.0	−2.2
CO	135.4	24.8	0.0	−1.5	−33.2	−94.7	4.6	10.6

CR	17.4	4.5	−0.6	−6.0	−0.7	−0.7	−12.8	−3.5
CU	37.4	10.2	−1.0	−16.8	−2.2	−0.2	−15.2	2.0
DO	29.7	9.0	0.0	−10.5	−1.8	−4.3	−15.1	−2.0
DZ	88.4	17.3	0.0	0.0	−4.4	−8.0	−72.3	3.7
EC	32.4	6.3	0.0	−11.6	−2.9	−2.5	−13.6	1.8
EG	84.1	22.5	−3.8	−66.9	0.0	−0.2	−1.9	11.3
GT	24.4	5.0	0.0	−17.3	−0.2	−1.1	−6.3	−0.5
HN	8.5	1.9	−0.8	−7.2	−0.5	0.0	−3.0	−2.9
HR	38.7	7.5	−1.4	−18.9	−4.8	−0.3	−12.8	0.4
HT	3.8	0.2	−0.3	−2.0	0.0	−0.6	−3.8	−3.0
ID	258.9	57.7	−20.0	−199.5	−22.9	0.0	77.2	93.7
IN	699.9	267.1	0.0	−193.5	−126.0	0.0	−164.4	216.1
IQ	15.2	6.1	−0.1	−11.7	−0.6	0.0	−3.8	−0.9
JM	10.7	0.5	−4.9	−6.4	−0.1	−0.3	−8.5	−9.5
JO	10.8	3.3	−1.3	−4.7	−1.8	0.0	−7.3	−4.4
KZ	47.2	16.1	−0.3	−3.9	−3.8	0.0	−39.8	−0.6
KE	17.0	3.3	0.0	−13.4	−0.2	0.0	−3.7	−0.3
LK	21.4	6.0	0.0	−4.4	−1.2	0.0	−18.3	−2.5
LT	21.3	5.8	−1.9	−8.3	−4.1	0.0	−8.6	−1.5
MA	52.8	12.2	0.0	−22.4	−7.0	−0.1	−21.1	2.2
MD	2.8	0.5	−1.1	−5.7	−1.0	−0.5	−2.8	−8.2
MN	2.2	0.7	−4.3	−13.6	−0.1	0.0	−2.1	−17.9
MY	116.8	32.1	−10.8	−96.2	−2.7	0.0	5.2	12.4
NA	6.3	1.5	−1.3	−6.1	−0.1	−0.7	−5.2	−7.2
NG	85.0	28.4	0.0	−50.6	−7.2	0.0	−12.1	15.1
PK	93.9	22.4	0.0	−40.3	−12.9	−11.6	0.0	29.3
PA	14.0	4.3	−1.1	−9.1	−0.6	−2.1	−8.9	−7.8
PE	71.9	19.3	0.0	−15.5	−12.2	−31.0	−10.1	3.0
PH	90.1	21.4	0.0	−51.7	−5.0	−1.2	−29.7	2.5
PY	7.2	1.0	−5.5	−9.7	−4.6	0.0	1.9	−10.7
RO	88.1	17.8	0.0	−60.5	−6.3	0.0	−20.5	0.8
RU	667.6	155.3	−34.7	−362.2	−188.4	0.0	106.6	189.1
SD	29.5	11.5	0.0	−11.3	−0.1	−1.9	−15.3	1.0
SN	7.4	1.7	0.0	−6.4	−0.6	−4.2	−0.3	−4.0
SV	15.4	2.4	0.0	−7.8	−1.1	−0.1	−9.7	−3.3
SY	24.7	6.2	−2.0	−18.6	−1.4	0.0	−1.7	0.9
TH	154.1	31.5	−4.8	−5.4	−3.4	0.0	6.7	147.3
TJ	2.0	0.6	−7.6	−12.2	−0.3	−10.2	−2.0	−30.2
TN	27.9	7.2	0.0	−7.6	−4.3	0.0	−15.0	0.9
UA	78.3	17.8	−3.3	−15.3	−13.7	0.0	−29.5	16.6
UY	17.4	2.5	−2.8	−8.9	−0.6	−5.8	−0.1	−0.8
VE	138.4	22.4	−2.7	0.0	−10.6	−3.1	19.9	141.9
VN	42.9	16.8	0.0	−31.3	−0.7	−4.4	−5.4	1.1
YE	14.7	4.6	0.0	−11.1	−0.2	−3.6	−1.7	−1.9
ZM	6.6	1.5	−2.8	−5.1	−0.3	−0.4	−0.4	−2.5
ZW	7.2	1.0	−0.1	−2.2	0.0	0.0	−5.7	−0.8

Notes: Values are rounded off. See Supplementary Information Figure S6.

Supplementary Information Table S6. Shadow value (simple average) (1992 to 2010): the IWI model

(unit: billion USD)

#	(1) GDP	(SD)	(2) Human capital	(3) (Produced) capital	(4) Patent stock	(5) Natural capital	(6) GHG	(7) Profit
OECD								
AU	672.8	129.5	−445.9	−171.0	0.0	0.0	−23.1	32.9
AT	280.5	35.5	−198.5	0.0	0.0	−6.6	−67.6	7.8
BE	347.6	39.7	0.0	0.0	−49.3	−5.7	−290.4	2.2
CA	997.3	161.5	−348.1	−568.7	0.0	0.0	−56.8	23.7
CH	353.5	34.8	0.0	0.0	0.0	0.0	−353.5	0.0
CL	101.6	23.3	−1.9	−21.4	−3.1	−1.9	−69.5	3.7
CZ	115.8	21.4	−100.4	−4.4	−14.2	−18.3	34.7	13.2
DE	2668.5	204.1	−501.3	−755.0	−0.3	0.0	−825.8	586.1
DK	237.1	24.5	−85.7	−72.7	0.0	−8.4	−65.8	4.5
ES	986.2	172.1	−314.3	−250.2	−28.8	−0.1	−344.3	48.6
EE	10.9	3.3	−3.6	−5.9	−0.4	−0.8	−2.1	−1.9
FI	172.0	30.7	−62.3	−81.5	0.0	−3.2	−21.2	3.8
FR	1965.8	208.7	0.0	0.0	−3.5	−0.7	−1786.9	174.6
GB	2003.6	310.2	0.0	−294.3	−6.4	−117.6	−1389.4	195.8
GR	208.0	37.0	−148.3	−5.7	−9.7	−2.7	−29.1	12.5
HU	94.2	15.4	−34.7	−44.2	0.0	−1.1	−10.6	3.7
IE	159.8	47.5	−59.0	−37.6	−12.6	−2.6	−42.7	5.3
IS	13.7	2.8	−2.8	−4.2	−0.5	0.0	−10.9	−4.6
IL	119.8	25.6	−18.9	−116.0	0.0	−8.8	27.3	3.3
IT	1674.9	117.5	−430.2	0.0	−29.4	0.0	−1096.7	118.6
JP	4313.9	248.7	0.0	0.0	0.0	0.0	−3878.6	435.3
KR	713.1	188.3	−429.0	−201.2	0.0	−62.8	30.3	50.4
LU	31.9	7.4	−7.7	−5.2	−0.2	−0.1	−29.2	−10.5
LV	12.5	3.8	−0.7	−9.3	−0.2	−0.2	−5.5	−3.5
MX	759.1	118.8	−263.6	−152.7	−64.2	0.0	−210.6	67.9
NL	586.4	80.4	−222.3	−178.5	−43.9	−27.0	−99.5	15.3
NO	270.5	39.1	−148.3	−16.9	−0.5	0.0	−106.0	−1.2
NZ	98.1	16.9	−76.7	−7.3	−0.1	0.0	−8.9	5.1
PL	269.4	65.5	0.0	−280.9	0.0	−52.7	105.0	40.9
PT	176.3	20.5	0.0	−103.8	−25.0	−6.3	−41.4	−0.1
SK	42.2	10.9	−20.4	−7.8	−2.5	−1.4	−7.3	2.7
SI	31.1	6.5	0.0	−17.8	−2.0	−0.1	−11.9	−0.7
SE	328.2	51.1	−5.6	−208.0	0.0	0.0	−106.2	8.3
TR	410.8	90.9	0.0	−124.4	−45.4	−1.4	−219.9	19.6
US	11041.9	1700.5	0.0	0.0	−287.4	0.0	−8973.7	1780.8
Non-OECD								
AL	6.7	2.2	−2.1	−0.2	−0.1	−0.1	−6.7	−2.5
AE	147.6	44.8	−4.5	−0.1	−0.3	0.0	−140.4	2.3
AR	175.6	34.7	−68.6	−90.7	0.0	0.0	−12.4	3.9
AM	3.7	1.7	−1.8	−0.1	−1.0	−0.4	−3.2	−2.8
BG	25.6	5.0	−14.2	−9.3	0.0	−0.1	−0.6	1.4
BO	8.6	1.7	−5.1	−4.6	−1.0	0.0	0.6	−1.5
BR	812.1	139.6	−159.8	−636.9	−21.4	0.0	66.2	60.2
CN	1840.8	978.8	−803.7	−386.8	−154.6	0.0	−283.6	212.1
CI	15.8	1.6	−2.7	−10.7	0.0	−0.6	−2.0	−0.3
CM	14.5	2.9	−9.7	−5.8	−3.5	−0.9	3.6	−1.8
CO	135.4	24.8	−7.1	−53.7	−11.2	0.0	−48.8	14.6

CR	17.4	4.5	−0.1	−5.1	−0.9	−0.7	−14.6	−4.1
CU	37.4	10.2	−15.3	−8.7	−2.9	−5.1	−3.1	2.3
DO	29.7	9.0	−0.3	−5.9	−1.5	−2.4	−17.1	2.5
DZ	88.4	17.3	−48.6	0.0	−3.0	−6.3	−27.4	3.1
EC	32.4	6.3	−24.0	−1.3	−2.5	−0.4	−4.5	−0.2
EG	84.1	22.5	−16.1	−48.2	−1.2	−6.7	−8.7	3.2
GT	24.4	5.0	−0.4	−16.3	−0.5	−1.8	−5.7	−0.3
HN	8.5	1.9	−1.5	−4.4	−0.7	0.0	−4.3	−2.4
HR	38.7	7.5	0.0	−18.7	−5.3	−1.6	−11.3	1.8
HT	3.8	0.2	−1.9	−0.6	0.0	0.0	−3.8	−2.5
ID	258.9	57.7	−110.0	−101.5	−22.9	0.0	54.6	79.1
IN	699.9	267.1	0.0	−185.8	−132.5	0.0	−173.1	208.5
IQ	15.2	6.1	−2.6	−10.1	−0.4	0.0	−2.8	−0.7
JM	10.7	0.5	−2.8	−0.2	−0.5	−2.4	−5.4	−0.7
JO	10.8	3.3	−3.8	−1.3	−1.7	−1.0	−6.1	−3.2
KZ	47.2	16.1	−44.1	0.0	−2.2	−0.8	0.4	0.5
KE	17.0	3.3	−0.4	−13.4	−0.4	−2.0	−0.6	0.4
LK	21.4	6.0	0.0	−0.1	−0.9	−7.2	−11.5	1.6
LT	21.3	5.8	−7.2	−1.7	−5.1	−0.5	−7.7	−0.9
MA	52.8	12.2	−0.6	−23.4	−6.7	−0.8	−19.2	2.1
MD	2.8	0.5	−4.5	0.0	0.0	−1.1	−2.1	−5.0
MN	2.2	0.7	−3.6	−3.4	−0.2	0.0	−1.6	−6.7
MY	116.8	32.1	−27.8	−75.3	−0.2	−0.5	−7.4	5.6
NA	6.3	1.5	−0.7	−3.6	−0.7	0.0	−3.5	−2.2
NG	85.0	28.4	−14.4	−36.4	−4.6	−9.1	−3.4	17.2
PK	93.9	22.4	−0.2	−31.9	−0.2	−28.3	−10.8	22.6
PA	14.0	4.3	−1.8	−8.9	−0.3	−0.1	−6.1	−3.3
PE	71.9	19.3	−19.3	−19.9	−4.8	0.0	−24.8	3.0
PH	90.1	21.4	−37.1	−25.0	−11.1	−12.2	−0.7	3.9
PY	7.2	1.0	−6.8	−1.5	−0.3	−0.4	0.3	−1.6
RO	88.1	17.8	−35.4	−41.6	−0.8	−0.6	−5.8	4.0
RU	667.6	155.3	−275.4	−128.1	−79.0	0.0	−40.8	144.3
SD	29.5	11.5	−12.1	−4.0	0.0	−0.6	−9.4	3.4
SN	7.4	1.7	−6.5	−1.4	−0.8	0.0	−0.3	−1.6
SV	15.4	2.4	−0.3	−4.9	−1.0	−0.5	−13.4	−4.8
SY	24.7	6.2	−11.2	−8.8	−0.7	−3.3	0.0	0.8
TH	154.1	31.5	−18.8	0.0	−1.5	−17.6	−82.5	33.8
TJ	2.0	0.6	−1.9	−0.6	−0.2	−0.1	−2.0	−2.8
TN	27.9	7.2	−4.4	−2.7	−6.9	−2.1	−10.4	1.3
UA	78.3	17.8	−51.4	0.0	−3.1	−2.6	−13.8	7.4
UY	17.4	2.5	−4.9	−10.1	−0.4	−0.8	−1.4	−0.2
VE	138.4	22.4	−15.0	−8.3	−8.9	0.0	0.1	106.1
VN	42.9	16.8	−10.4	−21.8	−0.6	−11.6	4.5	2.9
YE	14.7	4.6	0.0	−10.3	−0.4	−1.3	−4.6	−1.8
ZM	6.6	1.5	−8.0	−0.6	−0.1	0.0	0.8	−1.2
ZW	7.2	1.0	−1.4	−1.8	0.0	0.0	−4.7	−0.7

Notes: Value are rounded off. See Supplementary Information Figure S7.