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Green accounting and sustainability of the Peruvian metal mining sector

Eugenio Figueroa B.[a,*], Carlos Orihuela R.[b], Enrique Calfucura T.[c,d]

[a] Departmento de Economía, Universidad de Chile, Diagonal Paraguay 257 Of. 1604, 8330015 Santiago, Chile
[b] Departamento de Economía y Planificación, Universidad Nacional Agraria La Molina
[c] Facultad de Economía y Empresa, Universidad Diego Portales, Santiago, Chile
[d] Department of Economics, McGill University, Montreal, Canada

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ABSTRACT

This paper estimates the true economic income of Peru's metal mining sector for the period 1992–2006, using a model of green economic income based on Hamilton (2000). The total depletion of natural capital caused by metal mining is calculated by estimating, on the one hand, the depreciation of mining resources (using the Hotelling rent approach) and, on the other, the environmental degradation provoked by metal mining activities. The results show that the total loss of natural capital represents between 31% and 51% of the metal mining GDP and between 2% and 4.9% of Peru's GDP. On the other hand, correcting the usual GDP measure produced by the traditional National Account System (NAS) for the total loss of natural capital caused by mining activities shows that the GDP traditional measure overestimated by 51–64% the true economic income generated by Peruvian's metal mining sector during the period 1992–2006. The importance of the generation, taxation, and disposition of mining economic rents for Peru's sustainable development in the future is also discussed.

Introduction

The metal mining sector has been one of the main pillars of Peru's economic growth during the last decades, attracting a large amount of foreign direct investment[1] and representing almost 50% of total exports between 1990 and 2005. In addition, the participation of the metal mining sector in Peru's GDP has risen from 4% in 1990 to 9% in 2005. However, in spite of its large contribution to the Peruvian economy, the metal mining sector has not been free from criticism. On the one hand, metal mining activities have caused significant environmental impacts. In fact, during the 1980s, the uncontrolled emissions of the Peruvian metal mining sector contaminated the air and waters in vast zones of Peru. The regulatory efforts during that time were weak, within a context of conflicting legislations, poor enforcement and a lack of regulation compliance (World Bank, 2005). Even though during the 1990s a new and more coherent and effective environmental legislation was implemented, the improvement of the metal mining sector in complying with environmental regulation has been slow, and only from 1998 a better performance has been observed.[2]

On the other hand, Peruvian metal mining generates wealth through the extraction of non-renewable natural resources using a highly specialized productive process with a large consumption of physical capital, and without clarity regarding how much of the production value is reinvested in other forms of capital. In this context, sustainable development of the metal mining sector in the future requires that both public and private agents make efforts to sustain a permanent flow of income and employment in the sector. Hartwick (1977) has proposed the so called Hartwick's rule establishing how a wise investment of the rents generated by the exploitation of non-renewable mineral resources can assure a sustainable source of employment and income along time. On the other side, due to the way income is calculated by the traditional National Account System (NAS), a country's economic income can

* Corresponding author. Tel.: +56 2 978 3419.
E-mail address: efiguero@econ.uchile.cl (E. Figueroa B.).

[1] Since 1992, Peru has attracted more than USD 10,000 million in foreign and domestic investment.

[2] La Oroya is the Peruvian city that has experienced the worst pollution problems associated to mining, such as high levels of lead, sulfur dioxide and particulate matter generated by a smelter property of Doe Run Co. In 2002, the community of La Oroya sued the Peruvian Health Ministry for failing to enforce environmental laws. As a result of this lawsuit an agreement was reached to establishing and conducting a monitoring system between the Ministry and Doe Run Co.

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be reduced as a consequence of a reduction in its natural capital caused by a careless exploitation of its non-renewable resources, jeopardizing the possibilities of future consumption, without this being reflected in the country's macroeconomic indicators (the usual measures of the NAS). Therefore, a country highly dependent on a large endowment of mineral resources and that does not take this into consideration, could see its possibilities of future development severely reduced.

During de last decades, several studies have estimated the impact of the loss of natural capital on different natural resource sectors. Such works show that the gross domestic product (GDP) and the net national product (NNP) measures of the NAS do not take into consideration the depreciation of natural resources and the environment in their costs. In this way, by disregarding the loss of natural wealth that occurs every year, the traditional measures of the NAS do not only treat asymmetrically the depreciation of man-made capital and of natural capital, but also overestimate the true national income of each year and its growth along the time. There are different works in the literature in this field (Repetto et al., 1989; Young and Seroa da Motta, 1995; Figueroa et al., 2002). In Peru there have been some attempts to include the depreciation of mineral stocks within estimations of the Peruvian metal mining income. Pascó-Font et al. (1996) calculated the depreciation of the metal mining sector to correct the sector's GDP for the 1979–1993 period using the net price and user cost methodologies.

Given the relevance of the metal mining sector in the Peruvian economy, it is indispensable that the NAS reflects in a better way the performance and evolution of this sector. For this, it is necessary to incorporate metal mining natural capital depreciation in the welfare indicators, to have a reliable measure of long-term income. This paper estimates the loss of natural capital in the metal mining sector of Peru for the period 1992–2006. These estimations are used to correct the traditional income measures of the NAS, obtaining corrected measures of Peru's net domestic product (NDP), which are conceptually more appropriate indicators of the "true" welfare generated by the economy in the period. Moreover, the loss of natural capital estimated includes two components: (1) the depreciation of mining resources caused by the reduction in country's wealth due to the extraction of non-renewable resources; and (2) the environmental degradation provoked by the pollution generated by mining activities.

The first contribution of the paper is to provide an assessment of the real economic income generated by the Peruvian metal mining sector using a methodological framework considering not only the depletion of the exhaustible resources exploited, but also the environmental degradation costs of the mining activities, on the one hand, and the value of the new mining resource discoveries, on the other. The only previous existing estimates for Peru (Pascó-Font et al., 1996) in the literature take into account only the depreciation of mining resources but do not consider these other two components of the true green income which are of key importance to asses the sustainability of the mining sector. The second contribution of the paper is extending, from 1979–1993 to 1992–2006, the period of analysis covered by the previous existing work, which is relevant for assessing the recent performance and sustainability of the Peruvian mining sector due to the highly dynamic developments this sector has gone through since the mid 1990s. A third contribution of the work is to provide new evidence on the sustainability trend of the mining industry in a Latin American country in the last decades, since recently there is a growing concern about the long-term sustainability of the economic growth of several countries in the region whose development strategies are largely dependent on the extraction of non-renewable resources. Finally, the paper also includes a comparative analysis of the contribution of the metal mining sector to the Peruvian economy by contrasting the calculated losses in natural capital with the miming tax revenues and the investment of the Canon Minero in Peru, and provides some insights on ways to improve the long-term sustainability of the industry in the future through wiser investment strategies.

The following section presents a formal model to correct the traditional NDP measure for the net loss of natural capital in the economy. "Methodological aspects" presents the approaches of valuing the depreciation of natural resources and the data used to empirically apply the model of "Sustainability and income". "Results" shows the results obtained and discusses their implications for mining taxes and economic sustainability of Peru. Finally, in the last section the main conclusions and lessons are presented.

Sustainability and income

The concept of sustainability and net national product

The most common way in which economists have analyzed the concept of sustainability is by incorporating explicitly the finite stock of a natural resource in the traditional models of economic growth, and studying the conditions under which this finite stock of the resource generates a constant per-capita consumption flow along the time. Solow (1974) studies the conditions under which the exploitation of an exhaustible natural resource permits indefinite economic growth. He derives the optimal growth path using an aggregate production function in which he explicitly incorporates a stock of a natural resource and physical capital. According to this model, even though the stock of the resource is exhaustible, an indefinite growth is still possible, because when the natural resource is exhausted the product can at least remain constant if initial generations increase the stock of reproducible capital. Solow's conclusion depends crucially on the degree of substitution between natural and physical capital. The concept of a sustainable production–consumption based on the substitution between physical (man-made) capital and natural capital (natural resources and the environment) has been denominated "weak sustainability".

Hartwick (1977) and Solow (1986) relate the saving-investment rule of growth theories with the concept of weak sustainability. In the context of a close economy, Hartwick shows that society needs to invest all current rents generated by the exploitation of the stock of its renewable resource to be able to maintain a constant per-capita consumption flow. Solow (1986) in turn, shows that the conditions for sustainability established by Hartwick (1977) do exist when the stock of total capital is kept constant.[3] This condition is sufficient for the economy to stay over a maximum sustainable consumption path along the time, and that defines total capital for each moment of time, t, as

$$\begin{aligned}(\text{Total Capital})_t = {} & (\text{Physical Capital})_t + (\text{Human Capital})_t \\ & + (\text{Natural Capital})_t \end{aligned} \tag{1}$$

The models mentioned above define sustainability as the condition in which welfare is not decreasing, which is associated with the assumption of a monotonically increasing function in consumption. Asheim (1997) proposes an alternative model in which welfare is maximized subject to the restriction that it should not decrease with time. In this case, welfare can increase initially until reaching a maximum sustainable level.

[3] This condition is obtained assuming constant population. When population grows, the Hartwick rule must be defined in per-capita terms.

The first saving-investment models in which the environment was introduced set the theoretical basis for the analysis of sustainable growth paths. Weitzman (1976) studied the determination of NNP and its welfare significance for society. In this way he answered the critic made by Samuelson (1961) that NNP of the NAS is an inappropriate welfare index since it includes investment in addition to consumption.[4] Weitzman used a model that assumes a unique composite commodity that is produced and consumed, and which is expressed as an index number with prices as weights, as a basket of goods, or simply as a cardinal utility function. In his framework, a more comprehensive concept of capital is specified than the one used in the traditional growth models, which includes not only machinery and structures as usually observed, but it also includes the stocks of natural resources.[5] The model assumes no technical progress, a population in steady state, and a constant interest rate.

Weitzman concludes that if all investment can be converted in consumption trough the existing transformation prices and the NNP path coincides with the maximum level of consumption that can be sustained indefinitely. This implies that

$$Y^{*}(t) = r\int_{t}^{\infty} C^{*}(s)e^{-r(s-t)}\,ds = C^{*}(t) + p(t)\frac{dK^{*}}{dt}(t) \tag{2}$$

where, Y is income, C is consumption, K is a vector of the stocks of different forms of capital, r is the consumption interest rate and $p(t)$ is a set of investment prices. The central term of Eq. (2) explains why the NNP of the NAS can be considered as an appropriate welfare indicator, since it represents the present value of the future flow of optimal consumption. Additionally, it corresponds to the maximum sustainable consumption along the optimal competitive path, and which satisfies the definition of economic income proposed by Hicks (1946). Weitzman explains that NNP represents economic income in the sense of a level of consumption that, if it is maintain at a constant level, would yield the same present value of consumption on the path that maximizes the present value of welfare. Moreover, in a later work, Weitzman (2000) demonstrates that, at least in principle, NDP is a proxy for money-metricised welfare, which justifies using it for green accounting in order to calculate more sustainable measures of income than the usual measures of the NAS.[6]

A model of economic income

This section presents an optimal growth model, which follows Hamilton (1994 and 2000) and extends a previous one used by Figueroa and Calfucura (2003) to calculate the economic income generated by the mining sector in Chile.[7] Let's assume a closed economy that produces a composite good, has a stock of a non-renewable natural resource and maximizes welfare within an infinite time horizon, according to

$$\text{Max} \int_{0}^{\infty} U(C)e^{-\rho t}\,dt \tag{3}$$

subject to

$$\dot{K} = F(K,E) - C - f(E,Z) - g(D,M) - \delta K - a \tag{4}$$

$$\dot{Z} = -E + D \tag{5}$$

$$\dot{M} = D \tag{6}$$

$$\dot{W} = e(E,a) - h(W) \tag{7}$$

where C is aggregate consumption, K is the stock of man-made capital, $\dot{K}$ is the net investment in man-made capital, and δ is its rate of depreciation; Z is the stock of the non-renewable natural resource (the stock of natural capital of the economy),[8] E is the extraction rate of this non-renewable resource, D represents the new discoveries of this resource, and M is the stock of discoveries economy.[9] $F(K, E)$ is the production function of the composite good of the economy. The function $f(E,Z)$ is the total cost of extracting the non-renewable resource. Finally, $g(D,M)$ is the function representing the discovery costs for this non-renewable natural resource, with $g_D > 0$, and $g_M > 0$. Moreover, it is possible to extend the model in Eqs. (3)–(6) to incorporate the country's environmental services, B. Thus the welfare of the economy, which ought to be maximized, is now a function not only of consumption but also of the flow of environmental services and amenities, B, provided by nature. This flow is assumed to be negatively affected by the cumulative stock of pollution, W, so $B=\varphi(W)$, and $\partial B/\partial W < 0$. As previously, the composite good is still consumed and invested in artificial capital, but now it can also be invested at a rate "a" to reduce pollution. It is also assumed that polluting emissions, $e=e(E,a)$, are a function of the rate of extraction of the mineral—E—and the expenditure to abate pollution—a. Moreover, $\partial e/\partial F > 0$ and $\partial e/\partial a < a$, and there is certain quantity of pollution, h, that is abated by nature itself. Therefore, the motion equation for the stock of pollution is $\dot{W} = e(E,a) - h(W)$in Eq. (7).

The current value Hamiltonian for the problem in Eqs. (3)–(7) is

$$H = U(C) + \lambda_1(\dot{K}) + \lambda_2(\dot{Z}) + \lambda_3(\dot{M}) + \lambda_4(\dot{W}) \tag{8}$$

Obtaining the first order conditions and the optimal values for the shadow prices, the λs, and replacing these optimal values in the Hamiltonian, we obtain

$$H = U + U_c\dot{K} - U_c\left(F_E - f_E + \frac{e_E}{e_a}\right)(-E+D) + U_c g_D D + \frac{1}{e_a}(e(E,a) - h(W)) \tag{9}$$

Assuming a lineal utility (welfare) function $U=U_cC$, non-decreasing in C, as the one proposed by Hartwick (1990), and dividing Eq. (9) by U_c, a monetary expression of the value of the Hamiltonian is obtained, which provides an expression for NDP according to Weitzman (1976):

$$NDP = C + \dot{K} - \left(F_E - f_E + \frac{e_E}{e_a}\right)E + g_D D + a_e(e(E,a) - h(W)) \tag{10}$$

The first two terms in the right hand side of (10) is the traditional measure of the NDP of a close economy (consumption plus net investment in man-made capital). The last three terms correspond to the necessary corrections to calculate a green NDP

[4] The model assumes no technical progress, a population in steady state, and a constant interest rate.

[5] Human capital should also be included, if it possible to measure it. In the same way, natural assets such as the air, water and the environment are generally considered as a form of capital. For a review of these topics see Mäler (1991).

[6] This time Weitzman derives his conclusion from a standard welfare maximization problem with a money-metric utility function and using a linearized Hamiltonian.

[7] Figueroa and Calfucura (2010) use a different approach to incorporate the environmental degradation by including the value of the environmental services in the utility function rather than relating pollution to the extraction of resources as in the model presented here.

[8] The total capital stock of the economy is therefore constituted by the stock of man-made capital, K, plus the stock of the natural resource, Z.

[9] Dasgupta et al. (1997) conclude that NDP should not include the value of new discoveries and exploration costs since this would imply double counting due to the fact that exploration costs are considered as part of investment in the NAS figures of NDP. However, as we are going to discuss later, more disaggregated measures of NDP—mining NDP, for example—do not include exploration costs due to the way they are calculated by the NAS. Therefore, if this is the case, a complete measure of mining NDP should add exploration costs.

measure that incorporates the depreciation of the natural resources and the degradation of the environment. The term $(F_E - f_E + (e_E/e_a))$ corresponds to the marginal unit rent of the non-renewable resource corrected by an optimal Pigouvian tax reflecting the fact that resource extraction also generates an externality. Therefore, the third term on the right hand side of (10) subtracts the net depreciation of the non-renewable natural resource valued at its marginal rents. Moreover, g_D, is the marginal cost of new discoveries of the non-renewable resource, and $g_D D$ represents the value of new reserves of this resource valued at the marginal discovery cost. Then, and following Hamilton (1994), $g_D D$, can be seen as investment for new discoveries of the non-renewable resource, also known as exploration investment. Finally, the fifth term on the right hand side of (10) subtracts the depreciation of environmental services, $(e-h)$, valued at the social marginal pollution abatement cost, a_e. To avoid the empirically complex problem of estimating the Pigouvian tax, e_E/e_a, empirical applications of Eq. (8) usually assume that this term is zero, which we also assume here. Therefore, a definite measure for the NDP would be

$$NDP = C + \dot{K} - (F_E - f_E)E + g_D D + a_e(e(E,a) - h(W)) \tag{11}$$

Eq. (11) can be used to obtain a corrected measure of NDP, which now incorporates not only the depreciation of the non-renewable resource due to extraction of the non-renewable resource but also the additional depreciation of natural capital corresponding to the degradation of environmental resources due to pollution.

Methodological aspects

Valuation of mineral resources

The most used methodologies to value mineral resource depreciation have been the methods of net price (NP), user cost (UC) and net present value (NPV) (Repetto et al., 1989; El Serafy, 1989). However other authors have used mixed methodologies; like Figueroa et al. (2002) who estimated the natural depreciation of the Chilean mining sector using Hartwick (1990) model and incorporating a variant proposed by Hamilton (1994).

The NPV method calculates the change in an asset value during its life, assuming that it is optimally exploited; its rationale is that theoretically the depreciation corresponds to the loss in the value of the natural asset. In general, and from a theoretical point of view, this is the correct method to valuing an asset. However, it has the disadvantage of requiring the estimation (prediction) of future prices, rents and interest rates. As a result, NPV estimations generally have large uncertainty.

The Hotelling rent (HR) method is based on optimal exploitation models of natural resources (Hotelling, 1931), and assumes that the value of a natural resource corresponds to the difference between the market price and the *marginal* extraction cost:

$$[P(t) - MagC(E)]E(t) \tag{12}$$

where $P(t)$ is the market price of the asset or exhaustible natural resource, $MagC(E)$ is the marginal extraction cost of the resource, and $E(t)$ is its level of extraction; every variable evaluated at time t. This expression corresponds to the economic depreciation of an exhaustible natural resource (Hartwick, 1989; Hartwick and Lindsey, 1989). Under certain conditions,[10] the HR method uses a particular NPV, the one estimated by the market agents. The reason is that the Hotelling rent of the current period results from an inter-temporal optimization process based on future price and cost expectations optimized by the economic agent (Gómez-Lobo, 1991). The HR method requires information on the marginal exploitation cost which is rarely available. For this reason, empirically it is common to use the average exploitation cost as a proxy for the marginal cost. Under such circumstances, $[P - AvgC(E)]E$ will measure the total resource rent (RR) rather than the HR. Nevertheless, assuming that firms maximize profit, $AvgC(E)$ would be smaller than $MagC(E)$, which implies that the expression $[P - AvgC(E)]E$ would be larger than $[P - MagC(E)]E$, overestimating the HR (Figueroa et al. 2002). Fortunately, Davis and Moore (2000) estimated correcting factors to eliminate the difference between marginal and average cost and therefore, to eliminate the resulting overestimation when using average cost instead of marginal cost. As it will be shown later, here we use one of the correcting factors calculated by these authors.

El Serafy (1989) proposes valuing the natural asset depreciation as the part of its net income which needs to be saved in the present to assure a permanent future income after the asset's depletion. Therefore, this method has two components: a capital component, called User Cost (RR-X), which is the part to be invested to generate a constant income flow, and income (X), the portion that can be consumed without decreasing wealth.

To obtain the user cost, initially the NPV of a finite flow of net current incomes RR_t is made equal to the NPV of an infinite flow of sustainable (permanent) incomes X_t in the following fashion:

$$\int_0^\infty X_t e^{rt}\,dt = \int_0^T RR_t e^{rt}\,dt \tag{13}$$

where r is the interest rate, and T represents the expected life of the resource. Assuming RR_t constant and solving, the user cost would be

$$RR - X = RR\left[\frac{1}{(1+r)^{s/q}}\right] \tag{14}$$

where s/q is the reserve rate which is equal to the number of years remaining for stock depletion; s is the stock of total reserves and q is the current level of production.

The user cost method initially employs the resource rent, and not only has the same disadvantages of the net price method but also has some additional ones. One of them is to infer a constant extraction rate which depends of each mining firm and the metal prices that are volatile. Another problem is the lack of realism of the assumed constant discount rate. Finally, due to the fact that it is not inferred from an optimal extraction model for the resource and having and endogenous interest rate, the method is not useful for a small open economy with an exogenously determined interest rate, which makes it advisable not to use it (Gómez-Lobo, 2001).

To estimate the natural resource depreciation, here we choose to use the HR method due to some advantages it offers. On one hand, given that the NPV and the HR methods are equivalent under long-run equilibrium conditions there would be no differences in using any of them. However, given the above mentioned disadvantages of the NPV method it is preferable to estimate the depreciation of the natural resource using the HR method. On the other hand, the HR method is theoretically based on an inter-temporal optimization model, and there is more information available to apply it. Finally, using the HR method has the advantage of using extraction prices and costs which are observable from the market and therefore it needs not to project future rents arbitrarily.

[10] An important assumption is that the marginal rent increases with the interest rate.

Estimation of the mining resource rent and the corrected NDP for the Peruvian metal mining sector

The traditional National Account System offers one way of estimating a resource rent, by subtracting production costs from the value of production. Production costs include inputs values, workers compensations, fixed capital consumption and a normal rate of return on fixed capital investments (United Nations, 1993). In this way, calculating the Hotelling rent has the advantage of using the macroeconomic data of the metal mining sector, which is generally available. Applying this to the Peruvian metal mining sector, the following expression is obtained:

$$\sum_{i=1}^{7}[P_{it}-AvgC_i(E_{it})]E_{it}=VA_t-REM_t-CKF_t-r_tK_t \quad (15)$$

where $\sum_{i=1}^{7}[P_{it}-AvgC_{it}(E_{it})]E_{it}$ is the total Hotelling rent of the metal mining in period t; P_{it} the price of resource i in period t; $AvgC_i$ the average cost of metal mining resource i; E_{it} the extraction level of resource i in period t; I the type of mining resource, where: 1=Gold; 2=Copper; 3=Silver; 4=Led; 5=Zinc; 6=Pewter; and 7=Iron; VA_t the metal mining value added (GDP) in period t; REM_t the total labor payments of metal mining in period t; CKF_t the metal mining fixed capital consumption in period t; r_tK_t the metal mining capital cost in period t.

The right hand side of Eq. (15) shows the way of calculating the resource rent for the whole Peruvian metal mining sector. All data, except the resource price, average cost and capital cost, was obtained from the National Accounts managed by the National Institute of Statistics and Information (INEI, 2003; INEI, 2005; INEI, 2006a; INEI, 2006b).[11] Indirect taxes are not deducted from value added, since they have to be considered as a rent transfer between institutional agents (firms and government). Subsidies of the value added are not considered either, since conceptually they are not part of the value generated by mining resource production.

To estimate capital costs a rate of return (r_t) on the aggregate mining net fixed assets ($AMNFA_t=K_t$) is used, which corresponds to the average annual foreign exchage active rate (USD) for loans of more than one year. Regarding the normal return rate on capital (r_t), Otto (2002) proposes that any mining project should have a rate of at least 12%. He calculated a 14.7% profit rate for the hypothetical case of a cooper mine in Peru. Given that copper represents an important proportion of the Peruvian metal mining sector income, here it is assumed, in a conservative way, a normal annual rate of return on capital of 15% for the entire period under analysis. In some industrialized countries (USA, Korea and Australia) the normal rate of return in the metal mining sector varies between 5% and 10% (United Nations, 2002). It is possible to assume that the favorable legal and tax framework implemented by Peru at the beginning of the last decade generated attractive normal rates of return for investors, which suggests normal return rates above the average of the industrialized countries. For this reason, it sounds reasonable to use here a normal rate of return of 15%

The data on $AMNFA_t$ correspond to a sample of firms that concentrates – depending on the mineral and the year – between 88% and 100% of the sector's production, which includes firms melting and refining the minerals under analysis. This data was obtained mainly from the National Commission of Stocks Superintendence (CONASEV), the Mining, Oil and Energy National Society (SNMPE) and the Mining Annual Reports published by the Ministry of Energy and Mining (MEM) of Peru (ANUAMIN, 1995–2006).

Using this data, we estimate here three corrected (or adjusted) NDP measures, which correct, first, for the traditional NDP measure of the NAS for the depreciation of the mining natural resource; second, for this depreciation plus the environmental degradation provoked by the mining sector; and, third, for the mentioned deprecition and the environmental degration plus new discoveries of the mining resource. The first one of these three corrected measures, which we call NDP-1, is equal to the traditional GDP measure minus the value of the depreciation of metal mining resources (third term on the right hand side of Eq. (11)); formally,

$$NDP-1_t=GDP_t-\sum_{i=1}^{7}[P_{it}-AvgC_i(E_{it})]E_{it} \quad (16)$$

Data on GDP was obtained from INEI.

As it was already mentioned, in an industry in which firms maximize profits, $AvgC(E)$ would be smaller than $MagC(E)$, which implies that the $[P-Cavg(E)]E$ is greater than $[P-MagC(E)]E$, and using average cost instead of marginal cost will overestimate the rent of the metal mining resources. Based on Davis and Moore (2000) estimation for the USA mining sector, Figueroa et al. (2002) and Figueroa and Calfucura (2003) propose to used a parameter φ=0.7, to transform the estimated average rent into marginal rent. There are three reasons to use this correcting factor. On the one hand, there are no empirical results in developing countries which could be used to correct the average rent. On the other hand, according to Davis and Moore (2000) their calculated value of φ=0.7 is robust to many different econometric specifications. Finally, even when the value of the parameter depends on the extraction technology, metal mining activity in Peru is technologically highly efficient, and the extraction technology has little differences with the one used in the USA or other developed countries.

Therefore, correcting Eq. (16) using the Davis and Moore parameter, we obtain the following final expression for our NDP-1 corrected measure of net domestic product (NDP):

$$NDP-1_t=GDP_t-\varphi\sum_{i=1}^{7}[P_{it}-AvgC_i(E_{it})]E_{it} \quad (17)$$

In addition to this measure, and according to the model presented in "Sustainability and income", we calculate the costs of environmental degradation and the value of new metal mining discoveries to obtaining the other two corrected NDP measures that satisfy Eq. (9), which expressions are

$$NDP-2_t=GDP_t-\varphi\sum_{i=1}^{7}[P_{it}-AvgC_i(E_{it})]E_{it}-w_t(e_t-h_t) \quad (18)$$

$$NDP-3_t=GDP_t-\varphi\sum_{i=1}^{7}[P_{it}-AvgC_i(E_{it})]E_{it}-w_t(e_t-h_t)+g_DD \quad (19)$$

Eq. (18) shows a corrected NDP measure (called NDP-2), which corrects the traditional GDP measure not only for the depreciation of metal mining resources but also for the environmental cost (degradation) of the metal mining sector; and therefore, NDP-2 is a GDP measure net of total degradation of natural capital.

On the other hand, Eq. (19) shows the third corrected NDP measure calculated here (named NDP-3), which corrects traditional GDP for the net loss of natural capital, and therefore reduces GDP by the total loss of natural capital but also it increases it by the value of the new discoveries of the metal resource (the last term in Eq. (19)).

[11] All the dataset used in the estimations presented here is available from www.econ.uchile.cl or can be requested to efiguero@econ.uchile.cl

Table 1
Peru: estimation of the metal mining sector's Hotelling rent (USD million of 2006).

Year	Value added (VA)	Total labor payments (TLP)	Physical capital depreciation (PCD)	Economic surplus (ES)	Capital stock (K)	Capital cost (rK)	Resorce rent (RR)	Resource depreciation (RD)
1992	3086	1111	216	1759	3706	556	1203	842
1993	3447	1241	241	1965	2639	396	1569	1098
1994	3574	1274	266	2034	2926	439	1595	1117
1995	3803	1377	285	2141	3254	488	1653	1157
1996	4139	1417	358	2364	3668	550	1813	1269
1997	4603	1470	347	2786	3924	589	2197	1538
1998	4676	1595	392	2689	5026	754	1935	1354
1999	5533	1626	365	3542	5314	797	2745	1921
2000	5677	1719	343	3615	6229	934	2681	1876
2001	6337	2090	383	3864	7989	1198	2666	1866
2002	7354	2134	387	4833	10,254	1538	3295	2306
2003	7638	1978	343	5316	9196	1379	3937	2756
2004	8162	1867	449	5847	7334	1100	4747	3323
2005	8758	1546	477	6736	7083	1062	5673	3971
2006	8848	1264	505	7079	5250	787	6291	4404

Estimation of environmental degradation costs and of discoveries value (exploration costs)

The measure of environmental degradation used here corresponds to the value of the environmental degradation provoked by the atmospheric pollution caused by metal mining activities in Peru. Atmospheric pollution has been considered as the main externality associated to Peruvian metal mining during the last 20 years (World Bank, 2005). The other environmental problems, such as soil degradation and superficial and underground water contamination are also relevant. However, the available information to analyze their environmental cost is too limited.

In 1991, the Natural Resource Evaluation National Office (ONERN) of Peru established that the metal mining sector was one of the main activities responsible of soil, air and water degradation in the country. The two most conspicuous cases have been the ones associated to the La Oroya Metallurgic Complex and the Ilo Smelter which have demanded almost USD 1 billion to implement environmental plans (PAMAs) to recuperate the environmental quality of the affected areas (World Bank, 2005).

Even though the PAMAs originally considered finishing their implementation in 2004 (Ilo) and 2007 (La Oroya), only the Ilo Smelter fulfilled partially the commitment with a 33% and a 92% reduction in emissions of SO_2 at 1998 and 2006. La Oroya Metallurgic Complex postponed to the end of 2011 the date for complying with its commitment. Therefore, the 1992–2006 period of analysis covers a partial reduction of pollution with respect to the environmental norms. According to Eq. (18), the environmental degradation costs include the value of emissions in excess of the norm valued at their average abatement cost. The NDP measure corrected by mineral resources depreciation and the cost of environmental degradation is called NDP-2 (see Eq. (18) above).

Data on average daily SO_2 emission for La Oroya is provided by Doe Run in their annual reports for the period 1997–2011. Information for previous years comes from Doe Run (1998). In the case of Ilo Smelter, the yearly SO_2 emissions are estimated using information about copper production and an emission–production factor estimated from the information in Gesta (2006). Emissions in excess of the norm are defined by the difference between the current SO_2 emissions and the emission target associated with the fulfillment of the PAMA. In the case of La Oroya, there is daily based limit of 175 ton SO_2 per day whereas Ilo Smelter is required to achieve a reduction of 92% of emissions for the year 2007 when the PAMA is fully implemented. We convert these requirements into annual emission limits: 45 thousand and 31 thousand tons of SO_2 for La Oroya and Ilo smelters, respectively.

The annual cost of emission in excess is calculated as the annualized investment cost per ton of SO_2 reduction in the same way as calculated by Lagos et al. (2002) using a discount rate of 15% and 10 years of amortization. The average cost of the SO_2 was estimated to be US$ 189 per ton for the Ilo Smelter and US$ 76 per ton for La Oroya. The higher cost of SO_2 in the Ilo Smelter results from a major modernization in the smelter with an investment of almost US$ 500 million between 1997 and 2006. On the other hand, the air pollution program in La Oroya only considers the implementation of sulphur acid plants with an investment of US$ 152 million mostly between 2007 and 2011 according to MEM (2006).

It is worth mentioning that it has been assumed that the emission limits imposed in the PAMAs by the environmental Peruvian authorities are enough to fulfill the air quality standard for SO_2. However it is not sure those standards are set at the efficient levels where marginal cost and marginal benefits of pollution are equal. There is no information about the cost-benefit of the air quality standards in Peru but studies for the same kind of facilities in Chile (Sanchez et al., 2005; Calfucura, 2007) show that the marginal abatement cost is higher than the marginal abatement benefit in the case of SO_2 control programs in copper smelters. Chile follows the directives of the World Health Organization like Peru. If that is case, the efficient tax or price of SO_2 would be smaller than the marginal or average abatement cost estimated for the Peruvian facilities and the environmental degradation costs would be overestimated.

Finally, to correct the metal mining sector NDP for discoveries it is necessary to add the exploration costs, as it is shown by the fourth term on the right hand side of Eq. (19). Unfortunately, the lack of data in Peru makes it impossible to calculate marginal exploration costs. In fact, the existing data on exploration expenditures is incomplete, and it was only possible to obtained reliable data for the exploration of the Metals Economic Group for the period 1997–2006. However, as it is demonstrated below, exploration costs have a relatively insignificant effect when correcting for green NDP and, therefore, the possible bias would be even more insignificant in terms of that correction.

All estimations of the environmental degradation cost and of exploration costs were converted to USD of 2006, using each year implicit deflator of the metal mining sector and average exchange rate.

Table 2
Peru: estimation of the metal mining sector's environmental degradation and mining resource discoveries, total ... (USD million of 2006)

Year	Resource depreciation (RD)	Environmental degradation (ED)	Resource discoveries (EE)	Total gross natural capital loss (RD+ED)	Total net natural capital loss (RD+ED−EE)
1992	842	114		956	
1993	1098	114		1212	
1994	1117	112		1229	
1995	1157	118		1275	
1996	1269	119		1389	
1997	1538	122	380	1660	1280
1998	1354	125	400	1480	1080
1999	1921	107	397	2028	1631
2000	1876	103	368	1979	1612
2001	1866	105	384	1971	1587
2002	2306	102	297	2408	2111
2003	2756	101	285	2856	2571
2004	3323	102	364	3425	3060
2005	3971	101	389	4072	3683
2006	4404	100	328	4504	4176

Results

Depreciation of mineral resources

Table 1 shows the relevant variables for estimating the depreciation of the mineral resources of Peru for the period 1992–2006 through the calculation of the Hotelling rent of such resources for that period. Columns 2–4 show the value added, the total labor payments and the fix capital consumption (usual man-made capital depreciation), respectively, while column 6 presents the value of the net fix physical capital stock (K) of the Peruvian metal mining sector. The figures show that the capital/product (K/GDP) ratio within the metal mining sector is low, with a value between 0.77 in 1993 and 1.39 in 2002, and an average of 1.0 for the 1992–2006 period. These values imply that the Peruvian metal mining is relatively less capital intense than other countries' mining sectors of the Latin American region. For example, Perez (2003) and Henriquez (2008) found a K/GDP ratio of 2.0 and 2.71 for the mining sector in Chile. On the other hand, Pinto and Candia (1986) found an average K/GDP ratio of 1.15 for the Bolivian mining during the 1974–1986 period, a figure more similar to the Peruvian one.

Using the figures of fix physical capital stock (K), we estimated the capital cost or the normal profitability of fix assets (rK), which is shown in column 7 of Table 1. Column 5 presents the economic surplus of the mining activity (ES=AV–TLP–PCD); column 8 shows the total rent of the resource (RR=ES–rK); and column 9 shows the value of resource depreciation (RD) which corresponds to the Hotelling rent of the resource corrected by the factor proposed by Davis and Moore (2000).

Last column in Table 1 shows that the annual depreciation of the Peruvian metal mining resources fluctuated between USD 842 millions and USD 4,404 millions,[12] showing an increasing trend within the 1992–2006 period. These depreciation figures represent a large proportion of the Peruvian metal mining value added (second column in Table 1). While in 1992 the depreciation of mineral resources was 31% of the metal mining sector's GDP, this figure increased to 51% in 2006. However, for most of the years of the period considered here, the proportion is between 31% and 37%. These results are larger than the ones obtained by Pascó-Font et al. (1996) for the Peruvian mining for 1993, who found that the depreciation of metal resources over the GDP of the sector was between 13% and 30%. This large difference reflects the fact that Pascó-Font et al. (1996) applied the user cost method, which in general yields lower values compared to the net price method. However, the figures in Table 1 are not very much larger than the ones calculated by Figueroa et al. (2002) for the Chilean mining sector for the period 1977–1996, estimating only the copper depreciation and using a methodology similar to the one employed here.[13]

Environmental degradation and mining resource discoveries

Columns 2–4 of Table 2 present the estimations of mining resource depreciation (RD) (the same figures of column 9 of Table 1), the environmental degradation costs (ED) due to the atmospheric pollution generated by Peru's metal mining sector, and the metal resource discoveries (EE) (calculated through the exploration expenditures) for the 1992–2006 period, respectively. Moreover, columns 5 and 6, show the total gross natural capital loss, which corresponds to RD+ED, and the total net natural capital loss, which corresponds to RD+ED−EE.

Column 2 of Table 2 shows a small non-monotonic increase, from 1992 to 1998, of the environmental degradation costs caused by the atmospheric pollution generated by the Peruvian metal mining operations. After 1998, however, the figures decrease between 1999 and 2006; a reduction in the value of environmental degradation that is explained by the successful air decontamination policies implemented in the Ilo smelter during the 1990s (Gesta, 2006). Fig. 1, shows that, on average, the environmental degradation (the loss of environmental services) caused by the metal mining sector represented 2.2% of the metal mining GDP, and 6.4% of the sector's total gross natural capital loss. The increase in the depreciation of the metal mining resources during the 1992–2006 period, together with a slight reduction in the costs of the environmental degradation, implied that the relative importance of the environmental degradation as a proportion of mining GDP decreased with the years. This way, in 1992, the cost of environmental degradation represented 3.7% of the sector's GDP and 11.9% of the total gross loss of natural capital provoked by the sector; however, in the year 2006, these percentages reached only 1.1% and 2.2%, respectively.

The third column of Table 2 shows the new resource discoveries, valued at the sector's average exploration costs, which according to Eq. (13), represent a natural capital gain. The estimations cover only the 1997–2006 period, and depict an irregular pattern with a peak of US$ 400 million in 1998. This

[12] USD of 2006.

[13] Figueroa and Calfucura (2003) found a value of 24% of GDP for the gold mining in Chile, a figure closer to the values calculated here.

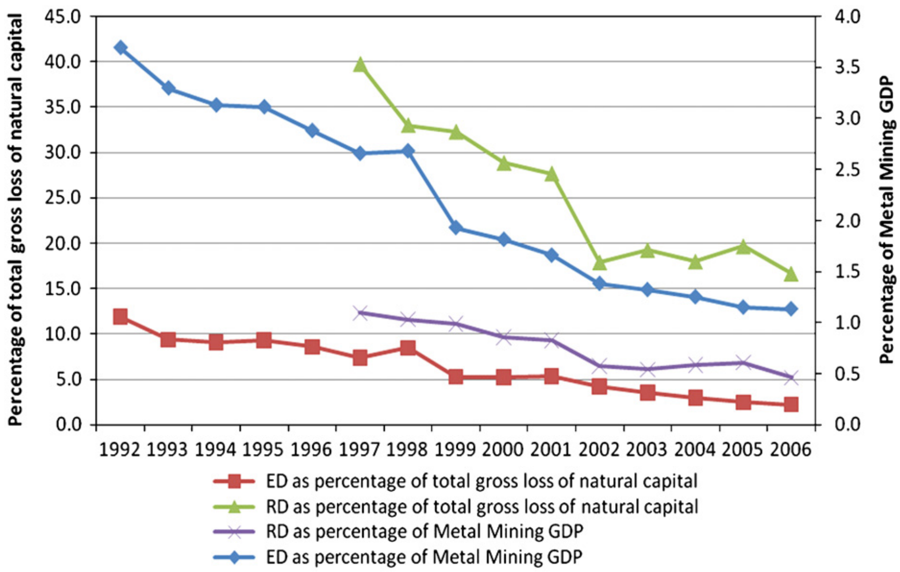

Fig. 1. Peru: environmental degradation (ED) and resource discoveries (RD) as percentage of metal mining GDP and total gross loss of natural capital; 1992–2006.

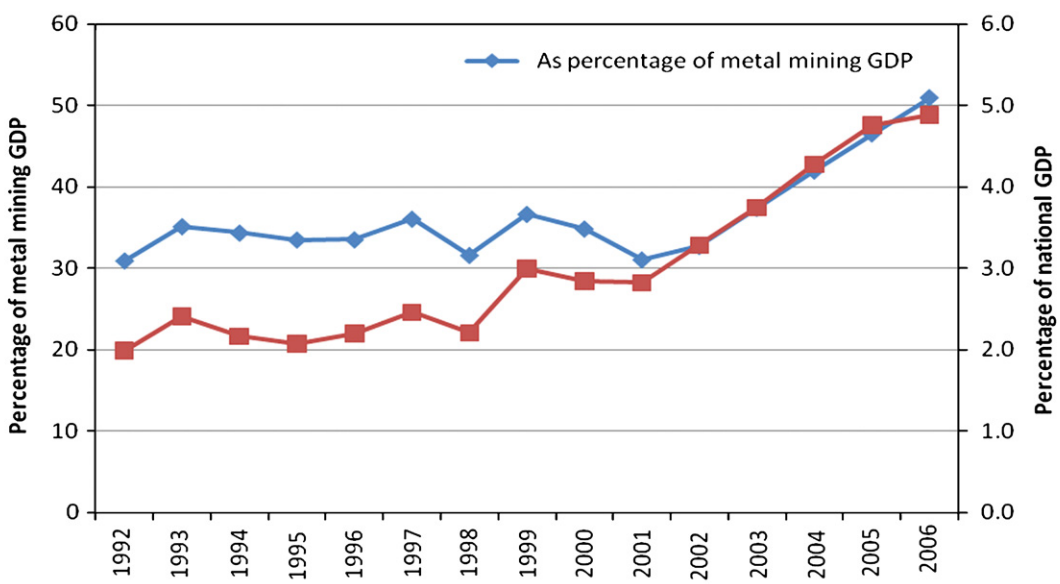

Fig. 2. Peru: gross natural capital loss in metal mining as a percentage of metal mining GDP and total-GDP; 1992–2006.

increasing tendency has continued in the last years. The figures of the Metal Group Economics show that Peru is the developing country in which exploration efforts have increased most significantly in the recent years, until reaching USD 450 million[14] in 2008.

For the metal mining sector, the value of discoveries is larger than the cost of environmental degradation for the whole period of 1997–2006; in fact, the value of new discoveries is 3.3 times the value of environmental degradation. However, as it was already mentioned, the value of the depreciation of metal mining resources is much larger than the value of discoveries, being the latter only 27.7% of the former. The total value of discoveries reached only 25.3% of the total gross loss of natural capital.

[14] USD of 2006.

Fig. 2 shows the total gross loss of natural capital expressed as a percentage of total-GDP and of metal mining-GDP. It can be seen that for the 1992–2006 period, the total gross loss of natural capital was between almost 2.0% and more than 4.9% of total-GDP and between 31% and almost 51% of metal mining-GDP, which represent considerable magnitudes. Moreover, there are other non-renewable resources (oil) and environmental services (soil, water, etc.) that, due to the lack of data, we have not included in our estimates of the value of total (resource plus environmental) natural capital loss (degradation) calculated here. Thus, it should be expected that incorporating the depreciation suffered by these other natural resources and environmental services would increase those percentages. On the other hand, the values of discoveries are not included in Fig. 2 due to the lack of data for the 1992–1996 period. Considering new resource discoveries for the shorter period of 1997–2006 for which data is available, the loss

Table 3
Peru: GDP and NDP-corrected measures. (USD million of 2006)

Year	GDP	NDP-1	NDP-2	NDP-3
1992	3086	2244	2130	
1993	3447	2349	2235	
1994	3574	2457	2345	
1995	3803	2646	2528	
1996	4139	2870	2751	
1997	4603	3065	2943	3323
1998	4676	3321	3196	3596
1999	5533	3611	3504	3901
2000	5677	3800	3698	4065
2001	6337	4471	4366	4751
2002	7354	5047	4946	5243
2003	7638	4882	4781	5066
2004	8162	4840	4738	5102
2005	8758	4787	4686	5076
2006	8848	4444	4343	4671
GDP/NDP-1 (1992–2006)		1.56		
GDP/NDP-2 (1992–2006)			1.61	
GDP/NDP-1 (1997–2006)		1.60		
GDP/NDP-2 (1997–2006)			1.64	
GDP/NDP-3 (1997–2006)				1.51
Growth rates (1992–2006)	7.8	5.0	5.2	
Growth rates (1997–2006)	7.5	4.2	4.4	3.9

of natural capital as a proportion of the national GDP is reduced in 0.5%. With respect to the sector's GDP, the incorporation of the value of discoveries implies that the net loss of natural capital represents between 23% and 47% of metal mining-GDP, compared with a range of 32–51% for the case of the total gross natural capital loss to metal mining-GDP ratio.

Corrected macroeconomics figures

Table 3 presents the different estimations of the corrected measures of the economic income generated by the metal mining sector of Peru calculated here. Following "Sustainability and income", the figures calculated and presented in Table 3 are the traditional gross domestic product (GDP); GDP minus the depreciation of mineral resources (NDP-1); GDP minus the depreciation of mineral resources and the cost of environmental degradation (NDP-2); and, GDP minus the depreciation of mineral resources and the cost of environmental degradation, plus the value of new discoveries (NDP-3).

Column 2 of Table 3 shows the usual measure of the country's gross domestic product (GDP) reported by the traditional NAS. In the lower part of the table it is possible to observe that for the period 1992–2006, the GDP measure was on average 56% higher than the NDP-1 measure and 61% higher than the NDP-2 measure. Given the availability of information on exploration costs, comparison with NDP-3 variable only can be made for the period 1997–2006. It is worth noting that GDP-NPD-1 and GDP-NDP-2 gap increases, as GDP is 60% higher than NDP-1 and 64% higher than NDP-2. However, when the additions of new discoveries through explorations costs are considered, GDP was on average 51% higher than NDP-3. Higher ratios for GDP/NDP-1 and GDP/NDP-2 during the period 1997–2006 reflect higher levels of total loss of natural capital than those for the period 1992–2006. Note that even when we do not have estimations for explorations costs for the period 1992–1996, there is some evidence that these were substantially lower given that most of the metal mining companies were owned by the State. The privatization of metal mining State-owned companies after 1996 increased the level of explorations costs and discoveries during the period 1997–2006.

The results discussed above imply that the traditional miming GDP measure of the NAS overestimates the corrected measures calculated here—NDP-1, NDP-2 and NDP-3. This is an important conclusion since as it was shown above the corrected measures are more accurate indicators of the economic income generated by the economy in a given year and of its associated welfare level.

Regarding the growth rate of macroeconomic variables, the GDP shows a systematic larger growth rate compared with the corrected NDP measures calculated here, which would indicate that the loss of natural capital in the metal mining sector have been larger during the last years of the 1992–2006 period. This is confirmed for the sub-period of 1997–2006, in which GDP growth rate is 7.5% while NDP-1 and NDP-2 growths rates are 4.2% and 4.4%, respectively (see bottom row of the Table 3). The larger gap between these rates during this sub-period confirms a larger relative loss of natural capital.[15]

These estimates indicate that the overestimation of the true economic income implied by the traditional measures of the NAS is significant and cannot be disregarded to appropriately assess the sustainability of the growth of the Peruvian economy.

Natural capital loss and taxes on mining

The figures presented in the previous sub-sections show that for the period under analysis there was a significant depreciation of the natural capital of the Peruvian metal mining sector. The larger part of it is explained by the depreciation of metal mining resources, which increased in the last years of the period due to the increase in the relative price of mining commodities. On the other hand, the metal mining activity represented around 45% of total exports during the 1992–2004 period, figure that rose to 65% in 2007. However, due to the sector's scarce productive linkages and low labor intensity, the mining sector represents only between 2% and 3% of direct employment in Peru (Glave and Kuramoto, 2003).

In this context, and given the political and economic relevance and the public exposure that the discussion about royalties and other mining taxes have reached in several Latin American countries (Chile, Ecuador, Peru, etc.) during the recent years, it is interesting to analyze the direct contribution of Peru's metal mining to tax revenues and how they are used by the central government and the local governments.[16] Within the period under analysis, 1992–2006, several taxes were in effect in Peru for the metal mining sector: income tax, the general sales tax and the selective tax on consumption, among others.[17] All these together constitute what is called the internal taxes (tributos internos in Spanish): the revenues of the public treasury and the taxes allocated to other organisms. Within the internal taxes the main tax being collected is the income tax on the profits of the mining companies which charges 15% of profits, and considers a series of

[15] The lower growth rate of the corrected NDP measures is explained by the increase, on average, of the extraction level of all minerals studied here, with the exception of iron.

[16] Worldwide the different states use different ways to charge royalties to their extractive sectors. In the USA, a progressive federal tax rate on profits is charged, which goes from 15% to 35%. At the federal level, no royalties or specific rates are charged to mining, which nevertheless are charged by the individual States who are the owners of the minerals. The States generally charge a royalty calculated over the gross production value, and which fluctuates between 2% and 10%, in addition to a 4% to 7% property tax which is calculated on a third of the total value of the property (Eggert, 1998).

[17] Only in 2004, the Law 28258 is enacted and charges a royalty equivalent to 1% to 3% of gross revenues of the mining sector. In this way the mining sector will pay directly to local governments, independently of the general income taxes charged to the mining sector. However, mining firms obtaining concessions with legal stability contracts are not required to pay royalties under Law 28258.

Table 4
Peru: natural capital loss and metal mining taxes, 1998–2006.

Year	Total gross natural capital loss (TGNCL)	Internal mining tax (IMT)	Distributed Canon Minero (CM)	As a proportion of TGNCL	
				Canon Minero	Internal mining tax
	(USD millions of 2006)			(%)	
1998	1480	513	147	10	35
1999	2028	393	69	3	19
2000	1979	530	42	2	27
2001	1971	524	70	4	27
2002	2408	565	95	4	23
2003	2856	806	211	7	28
2004	3425	949	246	7	28
2005	4072	1509	434	11	37
2006	4504	2357	532	12	52
Average	2747	905	205	7.4	33

tax deductions and shelters similar to those existing in other metal mining developing countries (Otto et al., 2006). Since 1992, a part of the mining income taxes are kept in an ad hoc fund called "Canon Minero", which was conceived mainly for the investments in the communities where the minerals are extracted and a smaller fraction is devoted to financing research in the universities. The "Canon Minero" is generated as a proportion of the annual income tax[18] generated by the mining sector and was distributed in twelve deferred payments from the middle of the next calendar year during the whole period of analysis. This way, while most part of the income tax finances directly the expenditure of the central government and indirectly the expenditure of the local governments, the so called "Canon Minero" goes directly to local governments, being them regional, provincial, or municipal. Nevertheless, accessing this fund is a burdensome administrative process. Investing those resources is just as difficult. What must also be taken into consideration is the lack of management skills in public institutions that are charged with administering the "Canon Minero", an issue faced by every other public fund in Peru.[19]

Kaspoli (2006) indicates that regional and local governments use these resources to finance or co-finance public investment projects to generate public services of universal access and that provide benefits to the community at large, which are within the competencies of the local governments and are compatible with the guidelines of the sector policies. The current legislation does not restrict the use of the "Canon Minero" resources to infrastructure projects only, but according to population's necessities and priorities, it also allows their use in all kinds of public investment projects.

Table 4 provides a comparison between the total loss on natural capital caused by the metal mining sector calculated here, the tax paid (internal taxes) by the sector and the "Canon Minero" distributed to the local authorities in Peru (SUNAT, 2009).

Table 4 shows that during the 1998–2006, the "Canon Minero" represented between 2% and 12% of the value of the gross loss of natural capital, while internal taxes represented between 19% and 52%. Finally, considering the average for the period, the "Canon Minero" was only 7.4% of the value of the gross loss of natural capital, while all taxes were 33% of it.

It is supposed that the "Canon Minero" must be allocated to investment but it has been common that local authorities have used part of the "Canon Minero" to finance current expenditures instead of investments (PNUD, 2002). Though the royalty to the mining sector was established in the year 2004, its destiny seems not to be very different from the "Canon Minero". It is not new in Peru that investment in research and development (R&D) is very limited, being one of the lowest of Latin America; for the year 2002 the national investment (State and private) in R&D reached scarcely US$ 58 millions (CONCYTEC, 2004). R&D expenditures have fallen from 0.36% of GDP in 1975 to approximately 0.12% of GDP in 2006.

There is room for the metal mining sector to foster human capital formation in Peru, particularly by means of direct learning. Nevertheless, this is discarded by Luit et al. (2004), who on the basis of a study made for the last 30 years, conclude that the Peruvian metal mining industry (unlike other mining countries as Canada, Australia and Chile) has not contributed to the development of technologies. All these arguments suggest that the metal mining sector has not been re-investing appropriately the income from mining royalties perceived by the "Canon Minero" recently. This implies that the Peruvian metal mining industry was not in a sustainable path during the period of study, at least from the point of view of a wise investment of the rents generated by the country's natural resource endowment as recommended by the Hartwick's rule.

Conclusions

This paper estimates the loss of natural capital and corrects the measure of economic income generated by the metal mining of Peru during the period 1992–2006. The estimates show that the economic income corrected for the depreciation of mineral resources and the environmental degradation has been significantly overestimated by the usual GDP measure for the period. Also the growth rate of GDP is persistently higher than the growth rate of the corrected measures of economic income estimated—NDP-1, NDP-2 and NDP-3—which shows that the overestimation of economic income has been larger during the last years of the period 1992–2006. On the other hand, the internal taxes provided by the Peruvian metal mining sector to the State and local communities represent approximately 33% of the sector's natural capital depreciation.

The estimations made allow discussing a series of relevant ideas concerning Peru's future development. First, it seems necessary an additional contribution of the metal mining sector to make the country's economic growth sustainable in the future. However, the royalty issue is more complex and controversial of what it might appear at the first sight. On the one hand it is argued that the State has the duty of collecting and adequate

[18] The proportion of the mining income tax revenue allocated to the "Canon Minero" increased from a 20% for the 1992–2002 period to a 50% since 2003.

[19] This has meant that a part of the "Canon Minero" that is distributed is not being implemented.

retribution for the use of country's natural resources. On the other hand, some people question the legality of taxing the metal mining sector with a royalty, the proper magnitude of such a royalty and/or the way the revenues collected from the royalty are expended or invested. Therefore, the controversy extends from the rightness of imposing and calculating a royalty up to the appropriateness of the different eventual ways of disposing of the revenues collected from it. This is perhaps one of the most relevant issues regarding Peru's future development due to its high dependency on its metal mining sector. Currently only metal exports account for approximately half of the value of total exports, making metal mining the economic sector that by far contributes the most to the country's provision of foreign currency.

Second, even if increasing the tax load to the Peruvian metal mining sector was possible, this could be counterproductive for the sustainable development of Peru if the collected revenues were inefficiently expended by the central and local governments of the country. As it is mentioned by Kaspoli (2006), the legal framework of the ''Canon Minero'' does not restrict the use of its funds to infrastructure investment, but it allows for its use in public projects in general.

Third, it is worth noticing that in contrast to other sectors, metal mining is an activity that generates and attracts very specific human capital and, therefore, the technological spillover to other sectors of the economy is low. Thus, to contribute in the long-run growth of the Peruvian economy the metal mining sector's rents should be invested in human capital associated to other sectors with larger externalities or spillover capacity. In this way the metal mining activity of the country could contribute to reach a path of truly sustainable growth in the future. An alternative option would be the development of metal mining clusters, as it has been the case in the metal mining areas of Chile. For example, around the mining facilities of Minera Escondida, which represented 24% of the Antofagasta Region's GDP, a large number of synergic and complementary economic activities have been developed, most of them related to the provision of services and training to the mining company. In contrast, the recent Peruvian experience shows a much more disperse mining expansion; a lower potential for taking advantage of synergies and complementarities due to low levels of human capital; and an increasing redistribution of resources through the government.

Finally, it would be relevant and useful for the National Account System of Peru incorporating the depreciation of the country's natural resources and the degradation of its environment to the conventional measures of economic income and activity, which would be possible with the availability of more statistical data needed for valuing natural resources and making environmental policy decisions.

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