THE DISTRIBUTION OF BENEFITS FROM OWNERSHIP RIGHTS IN GENETIC RESOURCES: THE CASE OF BEANS

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ABSTRACT

With the advent of biotechnology and the emergence of property rights in genetic materials, the economic value of genetic resources is an issue of growing importance. Since neither genetic resources nor their use is equally distributed, this paper develops a model to assess the distribution of benefits from ownership and use of cultivated and wild bean (*Phaseolus vulgaris L.)* genetic resources. First, this paper quantitatively estimates the potential magnitude of royalty incomes that would accrue to countries of origin of germplasm. Second, it breaks down royalty flows by countries, thereby revealing significant intra-regional variation in the distribution of benefits. Third, a distinction is made between payment for land races versus wild germplam. Finally, an estimate of net benefit's from germplasm is presented, taking into account royalty receipts, royalty payments, and the increase in productivity due to the use of improved germplasm. The paper finds that a system of ownership rights in bean germplasm would generate income flows for countries that own major sources of diversity. High income gene-poor countries of the north, would indeed make payments to low income, gene-rich countries in the south. However, many low income countries in the south are also poorly endowed with genetic diversity, and would also be net payers for the use of germplasm. Most countries in the south would have far more to gain from increases in productivity due to utilizing germplasm, than they would from receiving royalty payments for the ownership of germplasm.

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Crop genetic resources are the foundation both of modern agriculture and the historic rise of civilization. The original farmers in Asia, Africa, Europe and Latin America first learned to cultivate wild plant food species. By domesticating these plants, they began a long process of plant improvement. Farmer selection increased the yield of crop species; changed plant architecture; and adapted crops to new growing environments (Gepts). Millennia of farmer selection has endowed today's world with a wealth of crop genetic resources commonly called farmer land races. This legacy is the basis of modern agriculture.

In the last century, by building upon the inheritance of farmer land races, the science of genetics and plant breeding has vastly accelerated the process of plant improvement, leading to huge increases in crop productivity through breakthroughs like hybrid maize and semi-dwarf rice and wheat. While the human population has exploded, massive famine has been staved off due to these productivity advances that have been made possible only by the combination of improved scientific knowledge and the utilization of the genetic resources of farmer land races.

With the advent of the new genetic techniques of biotechnology, vistas have been opened of even greater future leaps in agricultural productivity. The potential gains of harnessing biotechnology to the improvement of genetic resources is so great, that significant controversy has begun to emerge over the distribution of the benefits deriving from this work. The private sector, particularly multi-national seed corporations based in the high income countries, has been eager to establish property rights in germplasm (Mooney). It is argued that without such property rights, there will be underinvestment of private resources in germplasm improvement, and society as a whole will thus lose due to a slower pace of innovation.

This innovation is also dependent upon the availability of genetic resources, which are the "raw materials" for biotechnology as well as conventional plant breeding. Historically, land races and related wild materials have been regarded as a common heritage or public good, open for use by all. However, as property rights in germplasm have been increasingly asserted by seed companies, the issue of ownership of farmer land races and native wild materials has been reassessed. In particular, it has been agreed in the Rio Convention on Biological Diversity, that such genetic resources are the property of the nations in which they originate. This result is very much the product of pressure from low income countries which are the source of most major agricultural crops as well as the major share of the world's biodiversity (Mooney; Brush).

Thus, there is an increasing recognition of legitimacy for compensation for use of land race germplasm - "farmers' rights" - as well as for compensation to the country of origin for the use of wild germplasm. It is generally accepted that low income countries would be net beneficiaries from a system of royalties paid by users of germplasm to the country of germplasm origin. Analysis at the level of regional groupings has confirmed this tendency (Kloppenburg and Kleinman).

This paper seeks to assess the international distribution of benefits from a system of ownership rights landrace and wild in germplasm. First, it attempts to quantitatively estimate the potential magnitude of royalty incomes that would accrue to countries of origin of germplasm. Second, it breaks down royalty flows by individual countries rather than regions, thereby revealing significant intra-regional variation. Third, a distinction is made between payments for land races versus wild germplasm. Finally, an estimate of net benefits from germplasm is presented, that takes into account royalty receipts, payments, and the increase in productivity due to the use of the improved germplasm. Common beans (Phaseolus vulgaris L.) is used as a model crop for this analysis.

A Model System of Landrace and Wild Germplasm Royalties

To estimate the royalty flows associated with ownership rights in landrace and wild germplasm, this paper develops a conceptual model of how such a system would operate. This model assumes that payments for the use of germplasm are ultimately collected at the point of sale of seed. These payments are levied as a per cent of the value of the seed price. Thus, income generated by the use of germplasm is the product of the quantity of seed sold that is based on the germplasm; the price of the seed; and the proportion of the seed price that is paid as royalties.

Royalty payments made by countries for their use of germplasm, are calculated based on area planted to beans in the period 1990-92. To simulate the maximum possible total of royalty payments, these are estimated as if all area sown to beans had to pay royalties.

In actual practice, royalties could accrue both to both owners of the germplasm that is used to generate the genotypes sold as seed, and also to those who performed the research that produced the new genotypes. It is likely that the relative shares of these two classes of royalties would be the subject of negotiation among the involved parties. As such, final royalty share could to a significant degree reflect the relative bargaining power between, roughly speaking, the country that owns the germplasm and the seed company that develops the new variety.

If there were asymmetry in the bargaining strength of the negotiating parties, for example, due to cost of enforcement or the superior market access of the seed companies, royalty shares could be biased in favor of the stronger party which might well be the seed company. This paper abstracts from any such bargaining process, and assumes that the countries of origin of germplasm receive royalties equal to ten per cent of the value of seed sold. This may be an overestimate of what might actually be earned by the countries.

Royalty receipts garnered by the countries for their ownership rights in germplasm, would be proportional to the degree that their germplasm would be used in genotypes sown by farmers. Again in actual practice, negotiations on this point could be complicated because modern varieties have increasingly complex pedigrees, with ancestors typically coming from several countries. Although payments could be calculated relatively straightforward based on the per cent of ancestry coming from each country, this might not be fully acceptable. For example, germplasm from a given country might constitute only one of 16 ancestors, but contribute genes of particularly high value. In contrast, genes from another country might overcome only an occasional minor constraint, making it illogical that both countries receive the same royalty.

The procedure used here is to abstract from any negotiating problem and conduct a simulation as if countries received royalties proportional to the amount of genetic diversity they have. This in turn is based on the assumption that useful alleles are randomly distributed. In this conceptual model for common beans, then, a country's royalty receipts are equal to its share of useful diversity which is equal to its share in total diversity, both of land races and wild ancestors.

Historically, most gains in crop improvement have come from land races. However, there are recent examples of introgression of useful traits from wild ancestors into cultivated materials (Cardona et al). It is also known that genetic variability in wild materials is often greater than that present in domesticated germplasm (Gepts). Consequently over time, particularly with improved techniques for gene transfer, the contribution of currently undomesticated germplasm to agricultural productivity, could be as greater or greater in importance as further use of land races. Thus, in this paper these two sources of variability are treated as of equal importance.

It must also be noted, that while wild materials are only found in the centers of origin of crop species, land races have a much wider dispersion. In the case of common beans, it is known that it has two centers of origin, Mexico and the Andes (Singh). However, since the encounter of 1492, beans have spread throughout Africa, Asia and Europe, giving rise to the emergence there of unique diversity in the land races in the secondary centers of origin.

Thus, the approach of this paper is to include diversity from the land races of both the primary and secondary centers of diversity, as well as from the wild ancestors. The issue then becomes, how to measure the relative amounts of diversity by region. This is done by relying on prior work to select a core collection for common beans (Tohme et al). The core collection was devised to represent the distribution of diversity in common bean germplasm based on knowledge of variability in morphological, agronomic, and molecular characters as well as geographical data on the origin of accession. For this paper, then, the amount of variability in a country or region, is taken to be equal to its per cent participation in the common bean core collections, one for cultivated land races, the other for wild ancestors.

Projected Flow of Landrace and Wild Germplasm Royalties

Based on the proceeding model system for ownership rights, the estimated flow of annual royalties for common beans by major continental groupings was calculated. The situation modeled here is one in which all bean producing regions in the world would sow seeds using improved germplasm on which royalty payments were due. As such it is a model of the maximum possible royalty flows. Actual royalty flows would likely be considerably smaller, but this represents the ideal case in which all growers had access to the best germplasm.

This model does not obligate farmers to pay royalties on their own land race germplasm. It does assume, though, that their native germplasm is improved through the introduction of new genes that are covered by ownership rights property protection. The model simulates a pattern of payments for these new genes that is proportional to the share of diversity in land races and wild ancestors by country or region of origin.

On this basis, Tropical America would owe the largest royalty payments since it has the largest area sown in beans, while sub-saharan Africa would owe the second largest amount (Table 1). However, as the major source of variability in land races and as the sole origin of wild ancestors, Tropical America would earn the vast bulk of royalties, so on balance would receive a positive net income of $19.6 million from royalties on common bean seed.

In contrast, the high income countries of North America and Europe would have to make net payments under a royalty system for bean seed. Even taking into account receipts accruing from useful genes found in the diversity of their secondary center land race germplasm, the USA/Canada would pay $2.6 million annually, and Europe $1.3 million. This confirms the expected view that the wealthy industrialized countries would end up paying in a system of ownership rights for wild and landrace germplasm.

The biggest net payments under this system, through, would come from sub-saharan Africa. As the most important of the secondary centers of land race diversity, it would receive 7.2% of total royalties from land race genes, that being the region's estimated share of land race diversity. These royalty receipts of $2.0 million are considerably overshadowed by projected payments $14.1 million, leaving Africa with a net bill of $12.1 million. The other two groupings of low income countries - East/South Asia and West Asia/North Africa, would also make net payments under a system of royalties for ownership rights in germplasm for common beans.

Thus, this analysis is consistent with the conventional view that in the aggregate, the high income countries would pay out, while low income countries would earn net positive receipts. However, not all developing regions would gain. Only in center of highest biodiversity will there be net gains. Further disaggregation by country illustrates that this pattern also repeats itself at the regional level. Table 2 shows estimated annual royalty flows for selected countries and sub-regions of Tropical America. These data portray remarkable disparities in net royalty income even within Tropical America.

At the positive extreme, is Mexico which is the world's greatest source of bean genetic diversity, both in land races and wild ancestors. Consequently, Mexico would earn a net of $13.2 million annually, even though as the world's second greatest bean producer, it would be paying royalties of $7 million for germplasm that is brought into Mexico. This is likely a real rather than an artificial result. Despite its wealth of bean genetic resources, self sufficiency would be unattractive. It has been found, for example, that the anthracnose pathogen (one of the most important bean pathogens in Mexico) has co-evolved separately with its host in the two major centers of primary diversity. Mexican strains of anthracnose can attack Mexican bean germplasm, but Andean germplasm is highly resistent to Mexican anthracnose. Hence, Mexico's best strategy for dealing with several of its most important pathogens, is to import novel resistance alleles from the Andean center of diversity (Pastor-Corrales et al).

Peru, as the second most important home of common bean genetic diversity, reaps the second highest level of royalty earnings. Since it would make very minor royalty payments due to the relatively small area sown to beans in Peru today, it emerges as gaining overall from royalties even more than Mexico. Ecuador, Colombia, Central America, and Chile/Argentina would also be net winners from royalty payments.

Brazil, and to a lesser extent the Caribbean, represent the opposite extreme. Brazil is the world's largest producer of beans, but it has no known native wild ancestors and quite a narrow genetic base in its land races. As a major grower of beans, and thereby a major user of bean seed and bean genetic resources, projected royalty payments from Brazil reach $18.3 million, with a net outflow of $17.5 million.

At first glance, then, developing countries of Asia and Africa as well as Brazil and the Caribbean islands, would emerge as losers from a royalty payment system. Such a view overlooks the gains from increased productivity that would accrue to these countries due to improved germplasm. Several studies have shown that improved bean varieties can increase yields 30-40% (Janssen et al; Pachico and Borbon). Here, the conservative assumption is made that improved germplasm results in a 10% increase in production.

The benefits of increased productivity due to new germplasm are far greater than royalty payments. For example, although Brazil would pay $17.5 million in royalties, improved germplasm would lead to production gains conservatively worth $116.8 million, 6.7 times the amount of the royalty payments. Total net benefits to Brazil would be $99.3 million. Similarly, Africa would gain ten times as much from improved productivity as it would have to pay in royalties.

For countries that are net recipients of royalties as well as bean growers, the two classes of benefits are additive (Table 3). Even for most of these countries, the benefits from improved productivity in beans considerably outweigh those from royalties. Only in Peru and Ecuador would royalty receipts exceed projected productivity gains. These countries have the unusual features of a wealth of bean genetic diversity combined with fairly small bean production. Since bean production is modest in these countries, productivity gains are slight. At the same time royalty revenues are high due to substantial genetic diversity.

Conclusions and Implications

A system of ownership rights in common bean land race and wild germplasm would generate income flows for those countries that are major sources of diversity in bean land races and wild relatives. The high income, gene-poor countries of the north, would indeed have to make payments to low income, gene-rich countries in the south. However, many countries in the south are poorly endowed in bean genetic diversity. In particular, Africa and Asia would be net payers for germplasm, as also would be Brazil and the Caribbean.

Notwithstanding the royalty payments, the north would very much emerge as gaining from access to germplasm. Even on conservative assumptions for productivity gains, and liberal assumptions for royalty payments, the projected gains in productivity in the north would far exceed royalty payments. This implies that economically it would be worthwhile for the north to pay for germplasm. If agreements about enforcement of ownership rights could be made workable, the system would be viable economically.

A system of ownership rights in bean landrace and wild germplasm would impose royalty costs on low income countries that are poor in bean diversity and are major bean growers. This might seem disadvantageous to Africa, Asia, Brazil and the Caribbean. Nonetheless these countries would gain substantially from improved productivity, and these gains would be 6 to 27 times greater than projected royalty payments. It would, in principle, be worthwide for gene poor low income countries to pay for access to genes.

Alternatively, rather than a uniform system of ownership rights, the system could be discriminatory and offer preferential access to germplasm among low income countries while charging full prices for germplasm to those who can afford it. In practice, germplasm exchange may be negotiated bilaterally and such a system could evolve. It might, though, raise complicated issues of enforcement of rights with respect to subsequent transfer of germplasm to third countries.

Preferential germplasm access for low income countries, however, would do away with the bulk of the potential royalty flows in the case of beans. If bean germplasm were exchanged freely in the south without any royalty charges, total royalty payments from Europe and North America would amount to only $4 million. This is such a small amount as to make the system hardly worthwhile.

In any case, most countries in the south have far more to gain from increasing the productivity of their bean crop than from a royalty system in bean germplasm. This suggests that they have most to gain from investing in agricultural research to develop improved germplasm. Not only is this generally true for almost all countries, but it is likely to be a good strategy even for the most gene rich countries. As noted above, royalties on property rights in improved germplasm include both compensation for genetic resources as raw materials, and compensation for the knowledge needed to identify and use these genetic resources. Typically raw material prices are a fraction of final product prices, with most income going to value added in processing. Therefore, it would be highly advantageous for countries which are origins of genes, to also develop them. This would not only contribute to their earning a larger share of royalties, but also could enable them to insure the development of their genes. Some valuable alleles may not be unique to a single country, and sometimes different alleles may produce a similar expression of a desired trait. Thus, it is in the interests of gene possessing countries to be able to expedite development of their genes. In addition, this would also contribute to their production agriculture, and in many if not most cases, this may yield benefits much larger than those from ownership rights in germplasm.

Since this paper deals specifically with the case of beans, it is useful to assess the degree to which this case is likely to be representative of other major crops. Royalty incomes from beans are modest in comparison to potential increases in productivity in low income countries due to improved bean germplasm. To a significant degree, this is due to the fact that 79.6% of beans are produced in low income countries. Obviously, the higher the share of production of a crop that occurs in low income countries the relatively less important royalty revenues become compared to productivity increases. Many other major crops, like beans, are grown principally in low income countries. Such crops include rice, sugar cane, cassava, banana sweet potatoes, yam, millet, coconut and sesame. Significant revenues from ownership rights to this germplasm could only come about through horizontal transfers among low income countries, but not to any important degree as revenues from the north to the south.

In contrast, some major crops are grown mainly in developed countries: wheat (64%), maize (64%), potato (78%), barley (86%) and soybean (66%). Revenues from germplasm rights to these commodities, would be relatively more important compared to productivity gains than in the case of beans. It is likely, though, that as in the case of beans, royalties would accrue principally to a few countries in the south that are particularly rich in genetic variability. Thus, ownership rights in germplasm may be a significant benefit to some selected countries, for example, Mexico and Peru in the Americas, and Ethiopia in Africa. The rest of Africa and Latin America could expect little income from ownership rights royalties in agricultural crops.

Nonetheless, a system of ownership rights in germplasm could be in the common interest if it serves to provide improved incentives for the conservation of genetic diversity. Moreover, ownership rights do reflect a concern for fairness in the distribution of benefits as property rights are increasingly asserted in germplasm. Such a system could produce important income flows for some poor countries. Finally, though, most low income countries, even the few with a wealth of genes, have far more to gain from a research capacity that enables them to more effectively utilize genetic diversity.

Table 1. **Estimated Flows of Annual Royalties under a System of Ownership Rights in Landrace and Wild Common Beans ($US million).**

	Royalty Payments	Royalty Receipts from Land Races	Royalty Receipts from Wild Ancestors	Net Income from Royalties
Tropical America	30.6	22.7	27.5	19.6
Sub-Saharan Africa	14.1	2.0	0	- 12.1
USA/Canada	3.2	0.6	0	- 2.6
East and S. Asia	3.1	0.3	0	- 2.8
Europe	2.6	1.3	0	- 1.3
W. Asia/N. Africa	1.3	0.5	0	- 0.8

Table 2. **Estimated Flows of Annual Royalties under a System of Ownership Rights in Landrace and Wild Common Beans in Selected Countries and Sub-regions of Tropical America ($US million).**

	Royalty Payments	Royalty Receipts from Land Races	Royalty Receipts from Wild Ancestors	Net Income from Royalties
Brazil	18.3	0.8	0	- 17.5
Mexico	7.0	8.0	12.2	13.2
Central America	2.0	1.9	3.3	3.1
Chile/Argentina	1.0	0.5	2.3	1.8
Caribbean	0.7	0.3	0	- 0.4
Colombia	0.6	1.5	1.3	2.2
Ecuador	0.2	1.2	1.3	2.3
Peru	0.2	7.9	5.7	13.4

Table 3. Comparison of Net Gains From Royalty Flows with Gains From Increased Productivity Due to Improved Germplasm.

	Net Payments or Income from Royalties ($ US million)	Benefits from Improved Germplasm (US$ million)	Total Benefits (US$ million)	Ratio of Productivity Benefits to Royalties
Countries or Regions with Net Royalty Payments				
W. Asia/N. Africa	- 0.8	20.9	20.1	27.9
USA/Canada	- 2.6	71.8	69.2	27.6
Caribbean	- 0.4	9.4	9.0	22.9
Europe	- 1.3	28.6	27.3	21.7
Sub Saharan Africa	- 12.1	121.0	108.9	10.0
East S. Asia	- 2.8	27.2	24.4	9.7
Brazil	- 17.5	116.8	99.3	6.7
Countries or Regions with Net Royalty Income				
Southern Cone	1.8	13.6	15.4	7.4
Central America	3.1	17.4	20.5	5.6
Colombia	2.2	6.0	8.2	2.7
Ecuador	2.3	1.3	3.6	0.6
Peru	13.4	2.2	15.6	0.2

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