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Designing the Financial Tools to Promote Universal Free Access to AIDS Care

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Abstract

Typical of the AIDS epidemics is that governments in developing countries under-invest in drugs production because of the possible appearance of a curative vaccine. We design a set of financial tools allowing to hedge against this event and achieving full risk-sharing. We show that the introduction of those assets increase social welfare in developing countries, as well as the number of treated patients and the provision of public good.

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1 Introduction

The scale of the HIV/Aids epidemics has exceeded the most pessimistic forecasts, since some 42 million people worldwide are currently estimated to be HIV-infected. Of these, 95% are living in developing countries. Amongst people living with HIV/Aids, five to six million are probably in need of antiretroviral (ARV) drugs (UNaids 2003). This life-long treatment is proven to be highly effective in drastically reducing morbidity and mortality associated with HIV infection in high-income countries. Following favorable results in terms of cost-effectiveness from pilot studies in the developing world (Moatti and Kazatchkine 2003; Cleary and Coetzee 2004), WHO and other United Nations organizations declared in the "3 by 5" initiative that 3 million people should have free access to antiretroviral treatment (ART) in developing countries by the end of 2005. To reach this goal, such international agencies will mostly subsidy local drugs production in developing countries.

Governments in developing countries are nevertheless reluctant to invest into ART production, mainly for two reasons. The first is that ARV treatment costs crowd out governments' decisions in financial, human and other health public programs. The second and most important reason is that the possible appearance of a therapeutic vaccine, whose research is done in developed countries mostly with public funds (Kremer and Glennerster 2004), will render any previous investment in drugs production nearly obsolete.[1] That is, the anticipation of future medical innovations makes current ART production relatively inefficient- which consequently leads to actual under-investment.

[1] Developed countries are currently investing in research and development of such a therapeutic vaccine, to be distributed at no cost to developing countries. This vaccine is considered as one of the most promising and innovative strategies to deal with HIV/Aids infection. This vaccine would be a first-generation vaccine, which would not prevent the infection but rather lower the viral load during the initial stage of primary infection and provide substantial individual benefit by creating a longer asymptotic period. It could therefore delay the need for ARV drugs for several years in many infected individuals (see Wei and Andrieu (2004) for the latest developments and ANRS (2004) for a review of research on lipopeptide-based strategy for HIV vaccines). By reducing the viral load in the population, the vaccine could also have substantial benefits in terms of HIV prevention by reducing the transmissibility of the virus.

In practice, even if part of the already-in-place production technologies can be turned into the production of other drugs, the specificities of ARV treatment do not allow for a complete reshuffling of the whole production process. Significant net losses are thus unavoidable if ART production decisions are made regardless of the anticipation of a vaccine appearance, and under-investment in ART appears as a natural economic consequence of the above.

Another problematic aspect of a vaccine appearance to developing countries is that international subsidies will necessarily decrease in this event. A significant amount of resources, coming from international agencies such as the Global Fund to fight AIDS, Tuberculosis and Malaria (GTFAM), will be reallocated to the production of a vaccine, thus leading to another net loss to already poor countries.

The question we thus address in this paper is which financial tools can be designed to tackle under-production of ARV treatment production, allowing hedging of actual decisions against future albeit uncertain availability of innovative treatment technologies.

At first glance, a conceptually workable tool would be an insurance contract allowing governments to cover production losses associated with a successful vaccine. This would reduce the current under-investment in ARV treatment, and would integrate future uncertainty of technological change into current decisions in an efficient manner. However, this idea has two main shortcomings: 1- there is simply too much money involved for a single insurance company to bear the risk, and 2- there is a strict risk transfer to the issuer without any equivalent risk-sharing possibility.

A more viable possibility would be to allow governments to trade derivatives to hedge themselves against the risk of a vaccine appearance, with the idea of optionizing the large insurance contract. A financial tool capable of alleviating the first shortcoming above is as follows. Consider a financial asset available at the time decisions to produce ART are made, with a fixed maturity date and small payoff if a successful vaccine is released before the maturity date. Somewhat similar types of derivatives are weather derivatives, with the common idea that the option has no underlying real asset. We call this derivative an *Arrow security*. The welfare analysis developed in the next section

shows that Arrow securities are demanded by developing countries to increase social welfare as well as the number of treated patients. Such securities also have a natural demand from pharmaceutical companies producing drugs. Indeed, the demand from such companies is motivated by two reasons: 1- ART drugs are still patented in developed countries, whereas patents are usually broken in developing countries as for instance in Brazil,[2] and 2- a commercialized therapeutic vaccine would render *de facto* current patents nearly obsolete.

The impossibility of full risk-sharing is still present with the above option alone, thus leaving aside from commercialization any profit-seeking organization. This problem can be solved by introducing the complementary option of the Arrow security, as follows. Consider a financial asset identical to an Arrow security, with the difference that the same payment is made if a vaccine does not appear before the maturity date. This complementary asset has a natural demand from agencies in charge of developing the vaccine, since failure to achieve a successful vaccine can be financially compensated, potentially leading to more future investment in the vaccine development.

The combination of the Arrow security and its complementary naturally allows for complete risk-sharing, and thus those securities are issuable as any other existing options. Insurance companies can simply cancel out the risk by issuing an equal number of both securities, and generate profits through their intermediary function. Given relative investments in vaccine development and drugs production, the demand for Arrow securities should be greater than that of its complementary. International agencies in charge of promoting access to drugs treatment can then take the residual risk by issuing Arrow securities, and charging a risk-premium in the form of a reduction in subsidies to developing countries. Our welfare analysis also shows that security issuance is more efficient than direct subsidies. All together, our construction naturally implies that the risk of a vaccine appearance can be eliminated.

[2]For instance, Article 68 of the Brazilian patent law allows for compulsory licences, which permits a patent to be used without the consent of the patent holder. On this issue and a detailed discussion on patents and ARV generic drugs, see Dumoulin and Flori (2003).

Distribution approval of the vaccine by a health control agency such as, for instance, the Food and Drug Agency in the US carries the legal requirement for payment. Moreover, financial sanctions coming from the WTO can credibly deter default of payments. Finally, mandatory progress reports during the testing trial allows to compute the conditional success probability of the vaccine, when compared to the performances of previously tested vaccines during their respective trial periods.

In the next section, we develop a two-period model representing a typical HIV/Aids care decision setting for a developing country, to show that the demand for Arrow securities is motivated by welfare considerations. In our framework, the government allocates resources enhance national consumption, provision of a public good and production of ARV drugs for a given level of endowments (which include a given level of international subsidies). We assume that in the second period a vaccine is available with exogenous positive probability. Arrow securities are issued by a large number of risk-neutral equity companies setting prices so as to break even. This last assumption implies that the price of one Arrow security paying off one unit of consumption good equals the probability of appearance of the vaccine (fair price). We then show that, if the level of international subsidies decreases as a consequence of the availability of the vaccine, the optimal reaction of a government is to increase its security holdings. We also show that the introduction of Arrow securities strictly improves expected social welfare. Finally, holding of Arrow securities is shown to guarantee a higher number of treated patients and a higher level of public good provision.

The intuition behind our results is that, when facing the risk of a drop in contingent endowment, the need to smooth out losses from drug production becomes more and more stringent to a developing government. The Arrow security is the only way to achieve this optimal smoothing.

More generally, our work also shows that public investments in innovative treatments for current diseases is an economic disincentive to available treatment production in developing countries. That is, developing countries are expected to rationally under-invest in current treatment production, the level of under-investment depending on anticipations of future medical innovations. This issue includes the case of Aids as considered here, but also of large epidemics such as Tuberculosis and

Malaria. The availability of financial tools allowing developing governments to hedge against future innovations is shown here to foster current treatment production as well as social welfare.

Thus, we argue that an international agency's decision to invest into R&D of not-yet patented treatments[3] should go along with the creation of financial tools such as the Arrow security and its complementary security introduced here. Of course, one of the limitations of our proposition is that international agencies might be subject to moral hazard since they could provide false information about future availabilities of technologies to manipulate governments' current investment decisions and the options prices. Consequently, full transparency of scientific progress is necessary to eliminate such a moral hazard and to allow for fair pricing.

2 The formal model

We next develop a formal model to analyze the welfare implications for developing countries of our securities, in terms of national consumption, provision of public goods and number of treated patients. There are two periods, $t = 0$ and $t = 1$. There is a continuum of agents in period 0, indexed by $\mathcal{P} = [0, 1]$. Let $I = [0, i]$ be the infected population for some $0 < i \leq 1$, and let $NI = [i, 1]$ be the non-infected population.[4]

Every infected agent must receive medical treatment in period 1, or otherwise dies. Potentially, there are two forms of medical treatment that guarantee the survival of the infected patient. The first one is a pill of ARV drug,[5] with the assumption that technical knowledge exists in period 0 to start production in period 1. The alternative to this treatment is a vaccine available in period 1 with exogenous probability $\alpha > 0$.

[3]For instance, the French National Agency for AIDS research (ANRS) has been committed for over 10 years to a research program on HIV vaccines. Around 10 millions US Dollars, *i.e* one fifth of its budget, is dedicated to this vaccine research effort (ANRS 2004).

[4]For sake of simplicity, we do not consider here demographic dynamics over the two periods.

[5]For instance, this pill can be a Fixed Dose Combination (FDA) currently produced by Indian firms. Luchini and Moatti (2003) examines the current provision of ARV drugs in developing countries.

2.1 The government

We now describe the government decision problem. The government uses an input good to produce the ARV drugs, a public good or to transform it in a consumption good. Therefore, the government faces a problem of optimal allocation of resources between national consumption, drug supply to the population and provision of a public good.

The government receives an exogenous endowment $w_0 > 0$ of input good in period 0. This endowment is the only source of revenue for the government, which can come from capital in place, direct taxation and/or international subsidies. In period 1, the government has an endowment of input good $w_1 \geq 0$ if the vaccine is not available, and $w_2 \geq 0$ otherwise.

The government can transform the input good into a consumption good in every period at no cost, using a one-to-one technology. Let c_0 denote the amount of consumption good in period 0, and let c_1 (resp. c_2) denote the amount of consumption good in period 1 if the vaccine is not available (resp. if available).

The government can also use the input good to produce a public good and ARV drugs separately. Production is realized in period 0, and is distributed to the population in period 1. For sake of simplicity, we assume that for any amount of input $d \geq 0$ (resp. $g \geq 0$), the government uses a one-to-one technology to produce a measure d of drugs (resp. g of public good). The production of the public good and drugs is distributed to the population at no cost (public good and drugs are not marketable). The government does not own any ARV drugs in period 0. If the vaccine is available, it is distributed to the population at no cost to the government. In this case, the quantity of drugs produced in period 0 becomes redundant since infected patients are already vaccinated.

With a measure $d > 0$ of drugs currently owned by the government in period 1, if $d \leq i$ the government treats a fraction $[0, di]$ of the population on a first-come first-serve basis, until drugs run out or the whole infected population is treated. If now $d > i$, the whole infected population is treated and we assume that the government redistributes the excess drugs abroad.

2.2 The financial tool

We also assume that the government trades securities to hedge against the appearance of the vaccine. The need for this hedging opportunity is motivated by the loss of prior investment in drugs production in case a successful vaccine. To simplify matters, we do not consider the complementary security to the Arrow security as described in the Introduction. This complementary security does not affect the welfare analysis developed next.

We next describe the financial tool making this insurance opportunity possible. Consider a financial asset available in period 0, paying off one unit of input good next period if the vaccine is made available and 0 unit of input good otherwise. We call this asset an *Arrow security*. This Arrow security works as an option with maturity date being one period ahead and payment contingent on the introduction of the vaccine. If the vaccine is not available in period 1, the Arrow securities become worthless.

Arrow securities are issued by a large number of identical equity companies, which set their price. Typical issuers can be international agencies in charge of promoting drugs production, as explained in the Introduction. We assume that the security price is set so that equity companies break even. We also assume that equity companies are all risk-neutral.

Let z denote the amount of Arrow securities purchased by the government, and let p be their price. The budget constraint faced by the government in period 0 is given by

$$c_0 + g + d + pz \leq w_0, \text{ and } c_0, g, d \geq 0. \tag{1}$$

In the above, we have not restrained security holdings to be positive, thus allowing for short sales. Short-saling is possible since the security can also be used as a tool to smooth out intertemporal consumption. We will later give a sufficient condition, based on contingent endowments, ensuring that the government holds a strictly positive quantity of securities.

In period 1, contingent on the availability of the vaccine, the budget constraint is given by

$$c_1 \leq w_1, \ c_1 \geq 0. \tag{2}$$

If the vaccine is not available, and with a holding z of Arrow securities, the budget constraint is given by

$$c_2 \leq w_2 + z, \ c_2 \geq 0. \tag{3}$$

The utility derived by the government from a sequence (c_0, c_1, c_2, d, g) is given by

$$U(c_0, c_1, c_2, d, g) = u(c_0) + \beta\alpha[u(c_1) + v(g) + \Gamma(d)] + \beta(1-\alpha)[u(c_2) + v(g)],$$

where $\beta > 0$ is an intertemporal discount factor, and where the functions u, v and Γ are all strictly increasing, strictly concave, twice-continuously differentiable and satisfy the Inada conditions. The function Γ measures the utility derived from treating the infected population and from redistributing the excess drugs abroad. The function u (resp. v) measures the utility derived from consumption good (resp. public good).

We can now define an equilibrium for this economy.

Definition 1 *A financial equilibrium is a sequence* $(\overline{c}_0, \overline{c}_1, \overline{c}_2, \overline{d}, \overline{g}, \overline{z})$ *with an asset price* $\overline{p}$ *such that*

1. *given* $\overline{p}$*, the sequence* $(\overline{c}_0, \overline{c}_1, \overline{c}_2, \overline{d}, \overline{g}, \overline{z})$ *is a solution to the program of maximizing* (4) *subject to* (1)*,* (2) *and* (3)*, and*

2. *the equity companies break even; i.e., we have that* $\overline{p} * \overline{z} - \alpha * \overline{z} = 0$.

Thus at the equilibrium, the government seeks to maximize its utility function taking the asset price as given, and equity companies set the asset price so as to break even. One can notice that, as long as the asset is traded in equilibrium (i.e., $\bar{z} \neq 0$), it must be true from Definition 1 part 2) that

$$\bar{p} = \alpha. \tag{4}$$

3 Welfare analysis

We now study some welfare properties of a financial equilibrium. We first carry out some comparative statics on the fundamentals of the economy. In particular, we are interested in analyzing the effect of a drop in international subsidies on Arrow securities holding if a vaccine is available. Such a decrease in international subsidies can be justified by a reallocation of resources at an international level to the production and distribution of the vaccine.

Proposition 2 *In equilibrium, if w_2 decreases and all else remains equal, then the equilibrium holding of Arrow securities increases.*

Proof. See Appendix. ■

Proposition 2 states that a drop in international subsidies, as a consequence of the availability of the vaccine appearance, leads the government to increase its security holdings. The intuition is that, when facing the risk of a drop in contingent endowment, the need to smooth out loss of drug production becomes more and more stringent to the government. The Arrow security is the only way in our economy to achieve this optimal smoothing.

At this point, the government still has the opportunity to short-sale the security, depending on the level of contingent endowments. The possibility of short-sales shows an additional property of the Arrow security: the government can also use the asset to smooth out contingent consumption of various goods even if the vaccine does not appear. If contingent endowment in this last event is anticipated to be high, the government can thus short-sale the security to increase contingent consumption in case of non-appearance. The optimal level of security holdings in Proposition 2, which includes the possibility of short-sales, depends on various fundamentals of the economy such as government preferences and contingent endowments.

Our next result gives a sufficient condition on contingent endowments ensuring no short-sale of Arrow securities in equilibrium.

Proposition 3 *There exists $e > 0$ such that, for every $w_2 \leq e$, we have that $\overline{z} > 0$ in equilibrium .*

Proof. See Appendix. ■

Propositions 2 and 3 together show that, if a significant drop of contingent endowment occurs in case a successful vaccine, the government finds it optimal to hold a positive amount of Arrow securities. One can also notice that, by equation (4), the price of the Arrow security is not affected by a decrease in w_2. Thus, a possible moral hazard based on manipulation of international subsidies is ruled out in our setting. The hedging decisions are then not driven by speculative considerations, but rather by consumption smoothing and welfare issues.

We next study the influence of the Arrow security on equilibrium supply of drugs and public good. We first define a notion of equilibrium without financial assets. We call a sequence $(\tilde{c}_0, \tilde{c}_1, \tilde{c}_2, \tilde{d}, \tilde{g})$ a *production equilibrium* if $(\tilde{c}_0, \tilde{c}_1, \tilde{c}_2, \tilde{d}, \tilde{g})$ is solution to the program of maximizing (4) subject to (1)-(3) with the additional constraint that $z = 0$. Thus, a production equilibrium is simply an optimal allocation of resources towards various productions without any available financial tool. Our next result compares some properties of the financial and the production equilibriums.

Proposition 4 *Assume that $w_2 \leq e$, where e is given by Proposition 3. The equilibrium supply of the public good and the ARV drugs is strictly higher in a financial equilibrium than in a production equilibrium.*

Proof. See Appendix. ■

Proposition 4 compares equilibrium supplies of various goods, when contingent endowment is significantly low in case of a successful vaccine. This case is the most relevant one, as explained in the Introduction. Proposition 4 states that the introduction of the Arrow security increases drug production and public good delivery to the population.

Thus, availability of the security allows the government to increase the number of treated patients while being efficient. Since this increase was impossible without the security, we have thus establish the importance of our financial tool.

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A Appendix

We now prove the technical results stated earlier.

A.1 Proof of Propositions 2

The proof of Proposition 2 starts by analyzing the program faced by the government in equilibrium.

Since the utility functions are strictly increasing, the budget constraints in (1), (2) and (3) must be binding. This implies that the program faced by the government can be rewritten as

$$\text{Max}_{d,g\geq 0,z}\ u(w_0 - pz - d - g) + \beta\alpha(\Gamma(d) + u(w_1)) + \beta(1-\alpha)(u(w_2 + z) + v(g). \tag{5}$$

We can now notice that, by the Inada conditions, the solution variables $(\overline{d}, \overline{g})$ to the above program must be strictly positive. Since also we have placed no restriction on the security holding, the Lagrangian to the above program can be written as

$$\mathcal{L} = u(w_0 - pz - d - g) + \beta\alpha(\Gamma(d) + u(w_1)) + \beta(1-\alpha)(u(w_2 + z) + v(g). \tag{6}$$

Taking the first order conditions give the following relations:

$$u'(w_0 - pz - d - g) = \frac{\beta(1-\alpha)}{p}u'(w_2 + z), \tag{7}$$

$$u'(w_0 - pz - d - g) = \beta\alpha v'(g), \text{ and} \tag{8}$$

$$u'(w_0 - pz - d - g) = \beta\alpha\Gamma'(g). \tag{9}$$

Rearranging the above equations and using the price relation (4), we obtain that

$$u'(w_2 + z) = \delta v'(g), \text{ and} \tag{10}$$

$$u'(w_2 + z) = \delta\Gamma'(d), \tag{11}$$

where $\delta = \frac{\alpha^2}{(1-\alpha)}$.

To prove our result, we now proceed by way of contradiction. Assume that there exists two endowments w_2^1 and w_2^2 such that $w_2^1 > w_2^2$ and $\overline{z}^1 \geq \overline{z}^2$. By (7), we must have that

$$w_0 - p\overline{z}^1 - \overline{d}^1 - \overline{g}^1 > w_0 - p\overline{z}^2 - \overline{d}^2 - \overline{g}^2. \tag{12}$$

Rearranging and using the fact that $\overline{z}^1 \geq \overline{z}^2$, we get that

$$\overline{d}^2 - \overline{g}^2 > \overline{d}^1 - \overline{g}^1. \tag{13}$$

Moreover, by equations (10) and (11), we also have that $\overline{d}^1 > \overline{d}^2$ and $\overline{g}^1 > \overline{g}^2$. This contradicts equation (13), and the proof of Proposition 2 is now complete.

A.2 Proof of Proposition 3

To prove our result, we now proceed by way of contradiction. Assume that there exists a sequence $(w_2^n)_{n\geq 0}$ and corresponding solutions $(\overline{z}^n)_{n\geq 0}$ such that $w_2^n \to 0$ and $\overline{z}^n \leq 0$.

By Proposition 2, the sequence $(\overline{z}^n)_n$ is increasing and thus bounded from below. It follows that $(\overline{z}^n)_n$ converges to some $\tilde{z} \leq 0$. By equation (7), the expression $w_0^n - p\overline{z}^n - \overline{d}^n - \overline{g}^n$ converges to 0.

Moreover, it must be true that $\overline{g}^n$ and $\overline{d}^n$ converge to 0 for (10) and (11) to hold.

Thus, it follows from the above that $p\overline{z}^n$ converges to w_0. Since w_0 is strictly positive, and since the price p depends only on α, we have established that $\tilde{z} > 0$, which is a contradiction. The proof is now complete.

A.3 Proof of Proposition 4

In a financial equilibrium, it follows from (10) and (11) that the equilibrium quantities of public good and drugs must satisfy the following relations

$$u'(w_2 + \overline{z}) = \delta v'(\overline{g}) \text{ and} \tag{14}$$

$$u'(w_2 + \overline{z}) = \delta \Gamma'(\overline{d}), \tag{15}$$

where $\overline{z}$ is the optimal holding of Arrow securities. Since $w_2 \leq e$, it follows from Proposition 2 that $\overline{z} > 0$.

In absence of tradable securities, it must be true that $z = 0$ is solution to the program faced by

the government, and thus we must have that

$$u'(w_2) = \delta v'(\tilde{g}) \text{ and} \tag{16}$$

$$u'(w_2) = \delta \Gamma'(\tilde{d}), \tag{17}$$

where $\tilde{g}$ and $\tilde{d}$ are optimal variables in the production equilibrium. Since u', v' and Γ' are monotonic functions, and since $\overline{z} > 0$, it follows that $\overline{g} > \tilde{d}$ and $\overline{d} > \tilde{d}$. The proof is now complete.