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Designing the Financial Tool 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 financial tool allowing to hedge against this event. We show that the introduction of this asset increases social welfare, as well as the number of patients treated 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 has been 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 feasibility and cost-effectiveness from pilot studies in the developing world (Moatti et al. 2003; Cleary et al. 2004), WHO and other United Nations organizations have declared in the "3 by 5" initiative that 3 million people should access antiretroviral treatment (ART) in developing countries by the end of 2005.

However, governments in developing countries seem to be reluctant to invest into ART production. Economists explain this reluctance because of governments' constraints in financial, human and other health system resources as well as concerns about the crowding out of other public programs through the ARV treatment costs. One solution to alleviate these treatment production constraints is to invest in research and development of a more cost-effective treatment, such as a therapeutic vaccine, which will replace the expensive and demanding ARV treatment production.[1] The difficulty is that if future technological innovations can solve actual constraints, then this progress will have consequences on current ART production decisions. That is, the anticipation of future change makes current ART production relatively inefficient - which consequently leads to actual under-investment

[1] Indeed, developed countries are currently investing in research and development of a therapeutic vaccine, which is considered as one of the most promising and innovative strategies to deal with HIV/Aids infection. This type of vaccine would be a partially effective, first-generation vaccine, which would not prevent the infection but would 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, Arraes, Ferreira, 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.

(see for instance Dixit and Pindyck (1994)). The question we thus address in this paper is which financial tool 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 (i.e., lower treatment requirements) 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, one of the main shortcomings of this idea is that there is simply too much money involved for a single insurance company to bear the risk.

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 a large insurance contract. This financial asset would be available at the time decisions to produce ART are made, with payoff on the day a successful vaccine is released. Somewhat similar types of derivatives are weather derivatives, with the common idea that the option has no underlying real asset.

Central to designing our asset is the specification of payment conditions from issuers verifiable by an international Court of Law, stating a mechanism to check the effectiveness of the vaccine. Since public as well as private pharmaceutical firms must comply with scientific tests from national control agencies (for instance, the Food and Drug Agency in the US) before commercializing any drug, approval from any such agency carries the legal condition for payment.

Our derivative has a natural demand from governments of course, but also from pharmaceutical companies producing drugs. This last aspect is financially important in developed countries since those drugs are still patented there, whereas patents are usually broken in developing countries as for instance in Brazil (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).[2]

[2] On this issue and a detailed discussion on patents and ARV generic drugs, see Dumoulin and Flori (2003).

In the next section, we propose a two-period model representing a typical HIV/Aids care decision setting, in order to test the relevance of Arrow securities. In our framework, the government allocates resources to the enhancement of national consumption, production of a public good and production of ARV drugs for a given level of endowments (e.g., a given level of international subsidies). We assume that in the second period a vaccine is available with strictly positive probability. Arrow securities are issued by a large number of risk-neutral equity companies setting prices so as to break even. We show that, in equilibrium, the price of an Arrow security paying off one unit of consumption good equals the probability of the appearance of a vaccine. We then show that if the level of international subsidies decreases (as a consequence of the availability of the vaccine for instance), the government will increase its security holdings. We also show that the introduction of Arrow securities improves welfare improvement. Finally, the holding of securities guarantees a higher number of treated patients and a higher level of public good provision.

Another aspect of our work is that public R&D investment in "free access" treatment for current diseases in developing countries, even where private investments have no economic returns, is an economic disincentive to current treatment investment. That is, those countries are expected to rationally under-invest in current treatment production, depending on the anticipations of future innovations. This issue includes the case of Aids, but also large epidemics such as tuberculosis. The availability of a financial tool to hedge the government's actual investment decisions against future innovations will not only increase efficiency, but also constitute an incentive to invest in treatment production. Practically, this means 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 proposed 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

[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).

availabilities of technologies to manipulate governments' current investment decisions and the options' price. Consequently, full transparency of the scientific progress is absolutely necessary to guarantee the efficiency of our proposition.

2 The formal model

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 $I = [0, p]$ be the infected population for some $0 < p \leq 1$, and let $NI = [p, 1]$ 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] and scientific and technical knowledge exists already to produce it. The other one is a vaccine into which research currently investigates and which will be available in the second period with exogenous probability $\alpha > 0$.

2.1 The government

We now describe the government decision problem. The government has an input good with which it can produce either the ARV drugs or a public good or transform it in a consumption good. Therefore, the government faces a trade-off between national consumption, drug supply to the population and provision of a public good.

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 direct taxation and/or international subsidies. In period 1, if the vaccine is not available, the government has an endowment of input good $w_1 \geq 0$ and $w_2 \geq 0$ otherwise.

[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 (See Luchini et al. (2003) who examine the current provision of ARV drugs in developing countries.

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 the drugs is distributed to the population at no charge (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 patient will have been vaccinated.

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

2.2 The financial tool

We assume that economic agents trade securities to hedge against the appearance of the vaccine. The need for this hedging opportunity is motivated by the loss in value of the prior investment in the drugs production in case a vaccine could be made available.

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 and payment contingent on the discovery of the vaccine. If the vaccine is not discovered in period 1, the Arrow securities become worthless.

Arrow securities are issued by a large number of identical equity companies, which set their price. We assume perfect competition for the Arrow securities market. This assumption implies that prices are such that equity companies break even in every period. 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 the security.

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 otherwise with a holding z of Arrow securities it is given by

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

The government derives an utility from a sequence (c_0, c_1, c_2, d, g, z) given by

$$\begin{aligned} u(c_0) \quad &+ \quad \beta\alpha[u(c_1) + v(g) + \Gamma(d)] \\ &+ \quad \beta(1-\alpha)[u(c_2) + v(g)], \end{aligned} \tag{4}$$

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, eventually 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.,*

$$\overline{p} * \overline{z} - \alpha * \overline{z} = 0.$$

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

$$\bar{p} = \alpha. \tag{5}$$

3 Welfare analysis

We now study some 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 securities holding. The intuition is that, when facing the risk of a drop in contingent endowment, the need to smooth out the loss of drug production becomes more and more necessary to the government, and the security is the only way in our economy to achieve this goal.

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 appears. 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 vaccine is available, the government finds it optimal to hold a positive amount of Arrow securities. One can also notice that, by equation (5), 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.

Proposition 3 also shows that government investment in Arrow securities leads to a strictly higher social welfare when the security is available, since the government always has the choice not to purchase it.

We next study the impact of the introduction of the Arrow security at the equilibrium on the supply of drugs and the public good. We first define a notion of equilibrium in absence of tradable 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 states that if contingent endowments are significantly low, the introduction of the Arrow security increases drug production and public good delivery to the population at the equilibrium.

This result gives a qualitative property of the introduction of the Arrow security. Availability of the security allows the government to increase the number of treated patients and still be efficient. Since this increase was impossible without the security, we have thus establish the importance of our financial tool.

References

ANRS (2004). Anrs research on hiv vaccine. Scientific Information and Communication Office. Paris, France.

Cleary, S., A. Boulle, D. McIntyre, and D. Coetzee (2004). Cost-effectiveness of antiretroviral treatment for hiv-positive adults in a south african township. Durban: Health Systems Trust, Technical report.

Dixit, A.K. and R.S. Pindyck (1994). *Investment under uncertainty*. New Jersey, USA: Princeton University Press.

Dumoulin, JP Moatti; B Coriat; Y. Souteyrand; T. Barnett; J. and Y.A. Flori (Eds.) (2003). *Economics of AIDS and access to HIV/Aids care in developing countries. Issues and challenges.* Sciences Sociales et Sida, address = Paris, France,. ANRS.

Luchini, S., B. Cisse, S. Duran, M. de Cenival, C. Comiti, and J-P. Moatti (2003). Decrease in prices of antiretroviral drugs for developing countries: from political "philantropy" to regulated markets? In JP Moatti; B Coriat; Y. Souteyrand; T. Barnett; J. Dumoulin and Y.A. Flori (Eds.), *Economics of AIDS and access to HIV/Aids care in developing countries. Issues and challenges*, Sciences Sociales et Sida, pp. 169–211. ANRS.

Moatti, JP., I. N'Doye, S.M. Hammer, and M. Kazatchkine (2003). Antiretroviral treatment for hiv infection in developping countries: an attainable new paradigm. *Nature Medicine*, **9**, 1449–1452.

UNaids (2003). Progess report, the global response to hiv/aids epidemic, 2003: follow-up to the 2001 united nations general assembly. Geneva, New York: UNAids, Technical report. Session on HIV/Aids.

Wei, L., L.C. Arraes, W.T. Ferreira, and J.M. Andrieu (2004). Therapeutic dendritic-cell vaccine for chronic hiv-1 infection. *Nature Medecine*, **10**, 1359 – 1365.

A Appendix

We now prove the technical results stated earlier.

A.1 Proof of Propositions 2

We first start with the proof of Proposition 2. The proof 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

$$\text{Max}_{d,g\geq 0,z}\ u(w_0 - pz - d - g) + \beta\alpha(\Gamma(d) + u(w_1)) + \beta(1-\alpha)(u(w_2 + z) + v(g). \tag{6}$$

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

$$\mathcal{L} = u(w_0 - pz - d - g) + \beta\alpha(\Gamma(d) + u(w_1)) + \beta(1-\alpha)(u(w_2 + z) + v(g). \tag{7}$$

Taking the first order conditions give the following relations:

$$u'(w_0 - pz - d - g) = \frac{\beta(1-\alpha)}{p} u'(w_2 + z), \tag{8}$$

$$u'(w_0 - pz - d - g) = \beta\alpha v'(g), \text{ and} \tag{9}$$

$$u'(w_0 - pz - d - g) = \beta\alpha\Gamma'(g). \tag{10}$$

Rearranging the above equations and using the price relation (5), we obtain that

$$u'(w_2 + z) = \delta v'(g), \text{ and} \tag{11}$$

$$u'(w_2 + z) = \delta\Gamma'(d), \tag{12}$$

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 (8), we must have that

$$w_0 - p\overline{z}^1 - \overline{d}^1 - \overline{g}^1 > w_0 - p\overline{z}^2 - \overline{d}^2 - \overline{g}^2. \tag{13}$$

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

$$\overline{d}^2 - \overline{g}^2 > \overline{d}^1 - \overline{g}^1. \tag{14}$$

Moreover, by equations (11) and (12), we also have that $\overline{d}^1 > \overline{d}^2$ and $\overline{g}^1 > \overline{g}^2$. This contradicts equation (14), 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 (8), 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 (11) and (12) 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 (11) and (12) that the equilibrium quantities of public good and drugs must satisfy the following relations

$$u'(w_2 + \overline{z}) = \delta v'(\overline{g}), \text{ and} \tag{15}$$

$$u'(w_2 + \overline{z}) = \delta \Gamma'(\overline{d}), \tag{16}$$

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

$$u'(w_2) = \delta v'(\tilde{g}), \text{ and} \tag{17}$$

$$u'(w_2) = \delta \Gamma'(\tilde{d}), \tag{18}$$

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.