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Training or not: what is at stake during an economic downturn?

Andrea Doneschi
Rossana Patron

La educación bajo la lupa

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Andrea Doneschi

Departamento de Economía, Facultad de Ciencias Sociales, Universidad de la República, Uruguay. E-mail: andrea@decon.edu.uy

Rossana Patron

Departamento de Economía, Facultad de Ciencias Sociales, Universidad de la República, Uruguay. E-mail: rossana@decon.edu.uy

Abstract

This article discusses training decisions and the economy-wide consequences of training provision, particularly during an economic downturn. This approach considers as key elements, the wage gap and the probability of employability gap pre- and post training, taking the gains from these two elements as the key to the decision to undertake training. As public training provision may not be attractive enough for unskilled workers because of the limited benefits reported to potential trainees, this article also discusses the role of training for development, providing a novel approach to assess its value. As it may speed the development process by the abatement of key adjustment parameters, also with favorable impact on wage disparity, it is argued that these effects reveal the true value of easing mobility. Thus the analysis highlights the relevance of improving training attractiveness and effectiveness.

Key words: training, labor mobility, restructuring, development

JEL: I28, J24, J68, O15

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1 Introduction

External shocks, changing patterns in demands, or innovation cause alterations in sectoral activities, which necessarily induce resource reallocation. However, factors may prove difficult to move speedily, or may be inadequate for alternative uses. An important limitation is when those factors are in fixed supply in the economy and new sectors are expanding. Education and training may ease the intersectoral mobility of workers, allowing the reallocation of workers to jobs in booming sectors or in sectors. Ideally, education policies should be designed with a forward-looking perspective, considering the challenge that the future would bring, in particular, considering the economic trends in trade, technology, and innovation. However, it seems that the past is very much relevant in designing remedial training programs for dislocated workers during unemployment crisis, paying attention to riskier jobs during an economic downturn, to be able to have adequate contingency plans in place as stand by.

Training programs can be very differently designed, whether they are to be used as contingency plans either as a continuous support to upgrade skills according to changes in technology or as requirements of expanding sectors. However, what could seem a good training program as a contingency plan may not be the better option for continuous training programs. If there is a role for the public sector in training, it is to ease workers' mobility in a crisis or to accompany changing patterns in demand and technical progress, as public intervention would reduce productivity loss and/or unemployment. Much is written on the role of the government as provider of education and training (e.g. Poterba, 1994, Beauchemin, 2001, Trostel, 2002; De Fraja, 2005, OECD et al. 2010, among others) and on evaluation of the performance of public training programs (e.g. Sims, 1993; LaLonde, 1995, Courty and Marschke, 1997, 2003, 2007; Greenberg et al. 2003, 2004; Dmitrijeva and Hazans, 2007, among many). These issues will not be discussed in this article, as the focus will be instead on workers' decision to undertake training, in particular public training. Education and training is essentially a decision to invest in human capital (as noted by the pioneering work by Becker, 1962, and Ben-Porath, 1967, among others), but there is also a vast literature exploring the fundamentals for not engaging in further qualifications (e.g.,Comay et al., 1976; Manski,1989; Koshal et al., 1995; Eckstein and Wolpin,1999; Thomas et al. 2002; and Oureopoulos,2003).

The evidence on effectiveness of retraining programs is inconclusive, as can be seen, e.g. in the studies by Cansino and Sanchez (2011), Arellano (2010), Rosholm and Skipper (2009), and in the works surveyed by Heckman et al. (1999) and Green et al (2000). However, a broader and more realistic way to assess the value this training activity is by referring to the contra-factual situation, as presented in the study by Lee and Wolpin (2006). The present study follows closely this line of research, discussing the dynamics of the labor market, which can provide useful information for the design and management of skills formation strategies, and help in improving the efficiency of the "adjustment technology." This study provides a methodological approach to discuss and assess this cost, paying particular attention to the short- and medium-term effects, thus understanding the fundamentals of training decisions also becomes central to the analysis.

The rest of the article is organized as follows. In Section 2, the fundamentals of training decisions are analysed; Section 3 discusses the economic role of training; Section 4 analyses the provision of training in Uruguay, discussing the underlying fundamentals of the current situation; and the Section 5 concludes. A final Appendix provides supplementary mathematical detail.

2 Training or not? Key elements

Education and training determine the qualifications of the labor force, and the nature of those qualifications may affect labor mobility. Workers with different skills have different productivity and wages, as well as differing in their intersectoral mobility and opportunities of finding a job.

The complete specification of workers' decision would require the specification of the parameters corresponding to the probability of unemployment, the cost of training, and the expected wage gain with training. In a two-period model, assuming constant wages, lifetime income for an individual with and without training is

$$I_{NT} = w_2 p_{NT} + w_2 \, p_{NT} \beta$$

where w_2 is the wage rate of an unskilled worker, p_{NT} is the probability of remaining employed, β is the subjective discount factor, $\beta = 1/(1+d)$, d is the discount rate. For those workers who undergo training, lifetime earnings are

$$I_T = \theta w_2 + w_1 p_T \beta$$

where θ is the proportion of an unskilled wage rate that the individual pays for or receives as stimulus to receive training, including opportunity costs ($\theta \geq 0, \theta \leq 0$).

The wage gap can be expressed as $g_1 = w_1/w_2$, $g_1 > 1$, the employability gap between trained and not trained can be expressed as $g_2 = p_T / p_{NT}$, $0 < g_2 < 1$. In general terms, a worker will choose training if $I_T > I_{NT}$, normalizing $w_1 = 1$

$$\beta\left(g_1 - \frac{1}{g_2}\right) > 1 - \frac{\theta}{p_{NT}}$$

Given the above expression, and considering the parameters involved, a worker is more likely to choose training when

- The greater is the wage gap (g_1), as this makes training more attractive.
- The greater is the gain in probability of employability if trained (g_2).
- The greater is the payment to workers during training, and the higher is the probability of being unemployed of those untrained.

Personal traits also play a role, as lower the discount is (high β), so the less impatient individuals are more likely to undertake training.

3.- What is at stake?

3.1 Adjustment in the labor market

Labor mobility costs have been extensively studied in the literature (e.g. Hammermesh and Pfann, 1996; Hammermesh, 1995). In this section, adjustment cost modeling fit many of the usual reasons to assume the existence of imperfect labor mobility, with the

rather less frequent assumption that labor friction implies economy-wide losses, rather than firm's losses. A quadratic form for the adjustment cost is assumed, which introduces the dynamics in the process. Though the functional form may be explained by the congestion cost in the market, the assumption of a quadratic functional form is not essential for the results, but significantly simplifies the presentation.

This section develops a multiperiod dynamic model with quasi-fixed labor, as defined by Oi (1962). Labor is imperfectly mobile across sectors; in the movement of factors, individuals need to undergo training to acquire mobility or endure unemployment; hence, the labor endowment is allocated as:

$$L_t{}^A + L_t{}^B + L_t{}^M = \bar{L} \qquad \forall t \tag{1}$$

$$L_t{}^M = \frac{a}{2}(L_t{}^i - L_{t-1}{}^i)^2 \qquad \forall\, t \quad a > 0 \tag{2}$$

where $L_t{}^M$ represents a training sector that makes individuals capable of working in alternative allocations – this is an only-time-input activity. Otherwise it may represent temporary unemployment. The quadratic functional form for $L_t{}^M$ is assumed to be explained by the congestion in the market, which increases with the amount of workers moving.

The parameter a is the key in the model. If there is no friction to the movement ($a = 0$), then workers are perfectly mobile and (1) gives a linear input transformation function, where labor across sectors are perfect substitutes with an infinite elasticity of substitution. However, when the labor units differing in allocation are imperfect substitutes, there is imperfect mobility; training may ease the moving from contracting to expanding sectors by conferring suitable skills to the individuals.

The intertemporal problem to determine the optimal allocation presuming that labor is moving from sector B to A will consider the mobility friction and then incorporate the restriction in (4),

$$L_t{}^M = \frac{a}{2}(L_t{}^A - L_{t-1}{}^A)^2 \qquad \forall\, t \quad a > 0 \tag{3}$$

$$L_t^B = \bar{L} - L_t^A - \frac{a}{2}(L_t^A - L_{t-1}^A)^2 \tag{4}$$

The intertemporal workers' income maximization program, in discrete time, is as follows:

$$\begin{aligned} &Max \quad \sum_0^{\infty}\left[w_t^A L_t^A + w_t^B\left(\bar{L} - L_t^A - \frac{a}{2}(L_t^A - L_{t-1}^A)^2\right)\right]\frac{1}{(1+r)^t} \\ &\left\{L_t^A\right\} t=0,\ldots,\infty \\ &\qquad s.t.\ 0 \le L_t^A \le \bar{L} \\ &\qquad initial\ allocation\ given \end{aligned} \tag{5}$$

The first-order conditions take the following form:

$$w_t^A - w_t^B\left(1 + a(L_t^A - L_{t-1}^A)\right) + w_{t+1}^B \frac{a}{1+r}(L_{t+1}^A - L_t^A) = 0 \quad \forall t \tag{6}$$

Under perfect competition in good markets, the maximizing behavior of firms in the productive sectors implies that workers will be hired up so as the wages equalize the value of the marginal productivity in each sector as:

$$w_t^i = P_t^i \, MP_{Lt}^i \qquad i = A,B \qquad \forall t \tag{7}$$

where P_t^i is the good price and MP_{Lt}^i is the marginal productivity of labor.

For a *T* big enough, and a terminal condition assuming steady-state values for the period *T+1*, the expressions (4), (6), and (7) conform a system of four equations and four unknowns (w_t^A, w_t^B, L_t^A, L_t^B) times *T+1*, from *0* to *T* (*T+1* periods), given the values for the initial allocation, prices, and interest rate. Using (6), it is possible to solve the problem recursively as follows:

$$t = 0 \qquad w_0^A - w_0^B\left(1 + a(L_0^A - L_{-1}^A)\right) + w_1^B \frac{a}{1+r}(L_1^A - L_0^A) = 0 \tag{8}$$

$$t = 1 \qquad w_1^A - w_1^B\left(1 + a(L_1^A - L_0^A)\right) + w_2^B \frac{a}{1+r}(L_2^A - L_1^A) = 0 \tag{9}$$

By inserting w_2^B from (8) in (9) and analogously $\forall\, t$ also considering that $L_{T+1}^A - L_T^A = 0$, the following equilibrium condition along the optimal path is obtained:

$$w_t{}^B\, a\,(L_t{}^A - L_{t-1}{}^A) = \sum_t^T (w_t{}^A - w_t{}^B)\frac{1}{(1+r)^t} \qquad (10)$$

The individuals' behavior would put the economy on the same path as if decisions were taken in a central way by the suppliers of labor (see Appendix).

The consolidate of labor recycled is $LT = \sum_0^T \frac{a}{2}(L_t{}^i - L_{t-1}{}^i)^2$, regulated by the parameter a, and, thus its economic value is given by the output produced by these labor units.

3.2 – General equilibrium adjustment

The model in partial equilibrium for the labor market with imperfect mobility in the previous section can be extended to a general equilibrium setup to serve the purpose of an economy-wide assessment of the value of training. The discussion follows a simple model with short-term rigidity in a multi-period context with labor demand dynamic, characterized by: two sectors producing final goods, two factors (capital and labor); constant returns to scale production functions; fixed factor supplies; two representative consumers (no savings); a price-taker economy; and no assumption of distortions or trade barriers.

In this context, some scenarios are of special interest, in particular those related to changes in economic environment or in policy. For instance: What is the difference when there is an external shock and labor is quasi-fixed rather than perfectly mobile? The presence of adjustment costs in the model gives rise to gradualism whose speed is inversely related to the level of the cost (parameter a). Thus, the reallocation induced by the shock causes a "temporary destruction" of a part of the labor force, because some labor units are not used for productive purposes during the transition. This causes a temporal contraction of the production possibilities frontier, with implications on distribution and welfare depending on the level of the adjustment costs involved.

Figure 1 Labor in transit for alternative mobility levels.

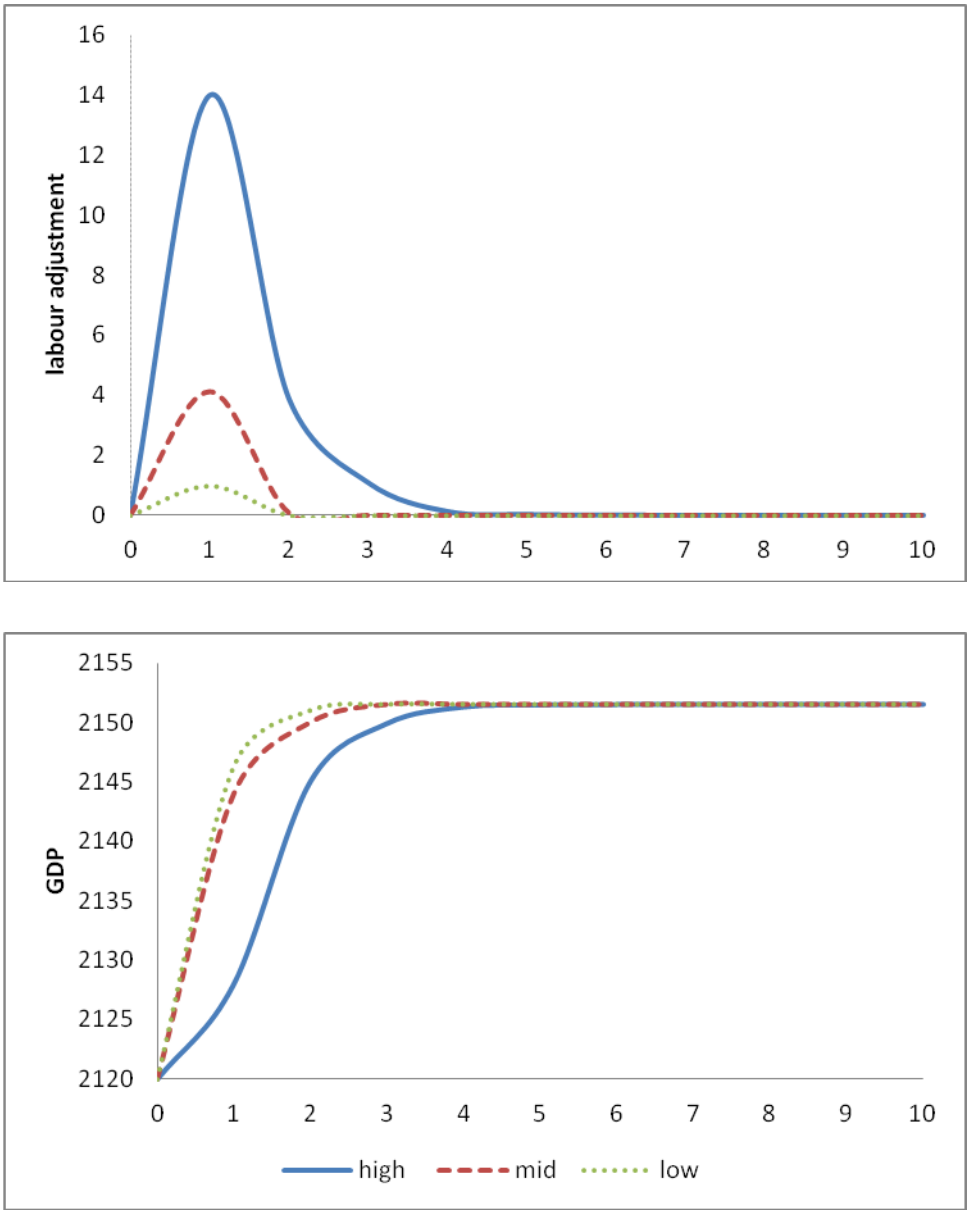


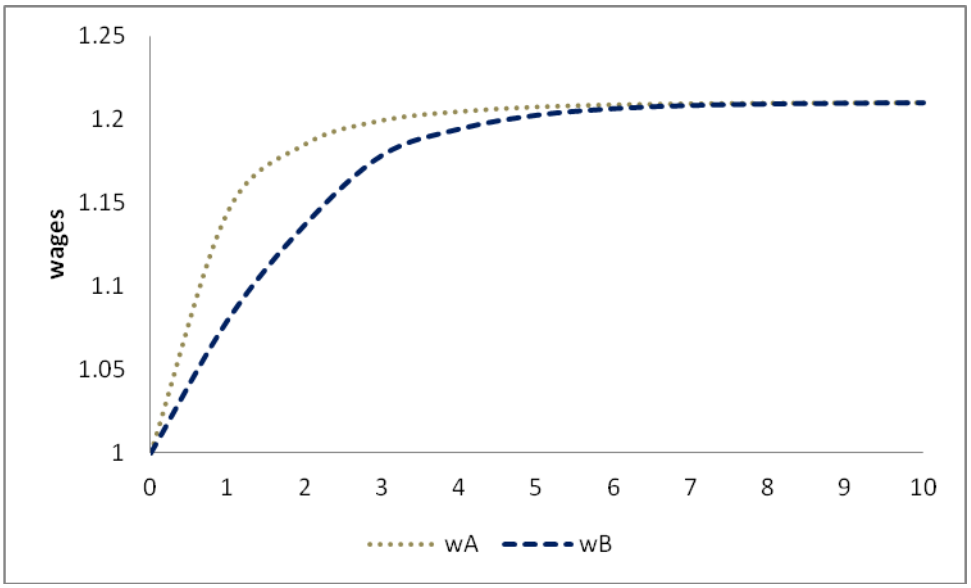
Figure 1 illustrates this point. The figure shows that for a small a (low adjustment costs), the transitory unemployment is present only for a short while, whereas for high adjustment costs, unemployment takes longer to recede.

The upper panel of the figure shows the paths of the "labour in transit" variable for alternative levels of mobility costs. The amount of labor unused for productive ends during the transition process reaches its highest level at the beginning, decreasing steadily until the end of the transition.

Labor lost in training is equivalent to transitory unemployment; hence, a more efficient "adjustment technology" reduces output losses. The possibility frontier for each period depends on the adjustment cost level, because the loss for labor in transit, temporary unemployment, or auto-retraining undermines the actual possibilities in productive sectors; this situation is illustrated at the bottom of Figure 1. Therefore, the present value of the differences between the output level with and without adjustment costs provides a measure of the economic value of easing mobility.

The presence of imperfect mobility also generates a wage gap across the sectors during the adjustment process, with distributional effects between workers across the sectors. Figure 2 illustrates this situation. The costlier the adjustment is, the longer is the period needed for the wage convergence to take place. Therefore, workers' fate during transition also relies heavily on the level of adjustment costs. Consequently, the efficiency on the adjustment technology also has distributional effects. These two effects reveal the true value of easing mobility.

Figure 2 Wage gap during transition, high mobility costs.



4 Examining the Uruguayan case.

Available data on training in 2006 from the National Census Bureau in Uruguay allows presenting a fairly complete description of the provision of training. The Panel A of Table 1 shows that the majority of participants in training programs finance the courses

themselves, and that there is an important participation of firms in the provision of training, higher than that for the public sector. It is noteworthy that the unskilled workers group undertaking training is by far the smallest one.

Table 1 Structure of training programs by skill group and source of funding (%) - Uruguay 2006

\	PANEL A			
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Publicly funded	3	10	3	17
Financed by firms	3	16	6	25
Paid by the worker	1	37	12	49
Training scholarship	6	2	1	9
Total	12	66	21	100
	PANEL B			
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Publicly funded	19	61	20	100
Financed by firms	11	66	23	100
Paid by the worker	1	76	23	100
Training scholarship	64	28	8	100
Total	12	66	21	100
	PANEL C			
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Publicly funded	26	16	16	17
Financed by firms	23	25	27	25
Paid by the worker	5	56	54	49
Training scholarship	46	4	3	9
Total	100	100	100	100

Source: Own elaboration with data from National Census Bureau (INE, 2006). Workers groups: Unskilled (less than 9 years of schooling), Medium skilled (9 –15), Skilled (16 or more).

The Panel B of Table 1 shows the provision of public training is allocated to about 60% of the medium skilled, and around 20% each to the skilled and unskilled. The structure of provision of the private sector is quite similar (though with a stronger participation of the skilled). Regarding Panel C, as might have been suspected, the unskilled rely almost absolutely on the provision of training by firms or the public sector, contrary to the higher qualified groups that in their absolute majority finance training themselves.

The structure of participants in training courses by employment status (employed or unemployed) is similar to that in the entire labor force, though interesting details arise. The Panel A of Table 2 shows that the vast majority of trainees are medium skilled employed workers (58%). Panel B shows that there is not much difference among the less skilled (unskilled and medium skilled) in undertaking training, being employed or not. The final Panel C in Table 2 shows that although training for the employed favor the more skilled (skilled and medium skilled), training programs for the unemployed prioritises the provision to the less skilled (unskilled and medium skilled); in any case the dominant group is the medium skilled.

Table 2 Participants in training by employment situation (%) – Uruguay 2006

PANEL A				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	10	58	20	89
Unemployed	2	8	1	11
Total	12	66	21	100
PANEL B				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	85	88	93	89
Unemployed	15	12	7	11
Total	100	100	100	100
PANEL C				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	12	66	22	100
Unemployed	17	71	13	100
Total	12	66	21	100

Source: Own elaboration based with data from INE (2006).

The information in Table 3 is restricted to public training programs, where it is worthwhile noting in Panel C that the allocation of training resources has a strong emphasis on the unskilled between the unemployed, however, that is not the case for the employed.

A final dimension is given by the percentage of those receiving training by qualification and employment status, as shown in Table 4. Firstly, in all categories, the share of participants in training in the entire workforce is very small. Secondly, this share is

increasing with the level of qualification. Thirdly, the higher participation is for the unemployed for all qualification levels, but the difference is not that relevant.

The picture Table 4 presents seems odd and difficult to explain. For instance, the participation in training is low even for public programs; unemployed people do not reveal a strong demand for training, nor do the unskilled workers. . Why are people not engaging much in training? Is not a rentable enough activity? Is there a shortage of funds to offer public training programs? Is the available supply of training courses inadequate? Should incentives be stronger? The analytical approach may assist us to shed some light on these points.

Table 3 Structure of participants in public training programs – Uruguay 2006

PANEL A				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	15	53	18	86
Unemployed	4	8	1	14
Total	19	61	20	100
PANEL B				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	77	87	94	86
Unemployed	23	13	6	14
Total	100	100	100	100
PANEL C				
	Unskilled	**Medium skilled**	**Skilled**	**Total**
Employed	17	61	21	100
Unemployed	32	60	8	100
Total	19	61	20	100

Source: Own elaboration based with data from INE (2006)

The approach presented before is applied to the Uruguayan case. The computations below assume a base training program of one year and prospective trainees'working life of 30, 10, or 5 years, respectively, to accommodate for different types of prospective jobs (in particular, temporary jobs nonrenewable) as well as taking into consideration the characteristics of workers to receive training (in particular age). The actual length of training programs is highly variable; therefore, the one year training program assumed in the baseline is arbitrary. In the baseline, unskilled workers would choose whether to undergo training; untrained workers will continue to receive unskilled wage rate, trained

workers are assumed to start receiving medium skilled wage rate (this assumption will be relaxed). Wages are computed to each skill category with data for the year 2009.

Table 4 Participants in training by employment status (% over relevant group)- Uruguay, 2006

Total training programs			Public training programs		
	Employed	Unemployed		Employed	Unemployed
Unskilled	1.3	1.5	Unskilled	0.3	0.6
Medium skilled	5.2	5.5	Medium skilled	0.8	0.9
Skilled	7.1	8.3	Skilled	1.1	1.1
Total	4.0	3.9	Total	0.7	0.8

Source: Own elaboration with data from INE (2006)

Table 5 shows the expected benefits of training. Panel A of the table shows that in any case for standard discount rates around 3% training is always beneficial, with subsidy equal to zero, even for short-term jobs, but this is not always the case for higher discount rates or shorter term jobs. Panel B of Table 4 shows the expected benefits of training in the case the subsidy is higher than zero (θ=0.10), which makes the benefits from training always positive.

Table 5 Expected gains from training

PANEL A: No subsidy		I_T-I_{NT}		
θ	d	30 years	10 years	5 years
0	0.03	0.21	0.06	0.01
0	0.10	0.07	0.03	-0.01
0	0.50	-0.03	-0.03	-0.03
0	0.90	-0.04	-0.04	-0.04
PANEL B: with subsidy				
θ	d	30 years	10 years	5 years
0.1	0.03	0.28	0.13	0.07
0.1	0.10	0.14	0.09	0.06
0.1	0.50	0.04	0.04	0.03
0.1	0.90	0.02	0.02	0.02

Source: Own elaboration.

Still, a couple of assumptions remain to be relaxed. The prospective trainee will count in his or her computation the skill premium to receive for a better qualification (g_1) as well as an improvement in his or her employability probability (g_2). In the above computations, these gaps, g_1 and g_2, have been assumed to be the difference between

an unskilled and a medium skilled worker; however, receiving a short training may not produce such dramatic benefits. Therefore, alternative scenarios are designed, assuming other options for both key wedges in the training decision. The target is to explore the slackness in computations in Table 5, that is, trying to determine if the gains of training are not equal to those corresponding to a medium skilled level, which levels would be the thresholds to maintain the training option still attractive.

Table 6. Training as an option: margins at work

	A	A1	A2
g_1	1.51	1.20	1.51
g_2	0.82	0.82	0.67
I_T-I_{NT}	0.13	0	0

Source: Own elaboration.

Alternatives are presented in Table 6. The benchmark scenario is A where d =0.03, and θ=0.10. The length of training programs is one year, expected working lifespan 10 years, skill premium 1.51 ($g_1 = w_1/w_2$ computed for 2009), the employability gap is 0.67 ($g_2 = p_T/p_{NT}$ computed for 2009). Scenario A1 computes the maximum reduction in the wage gap that would still induce individuals to engage in training, whereas scenario A2 computes the maximum reduction in the probability of employability to still be interested in undergoing training. Table 5 shows that even a skill premium of 20% instead 51% (other factors equal) will still make training attractive; similarly a gain in probability of employability of 67% instead 82% (other factors equal) would still make training courses attractive. At least in the case of Uruguay only a small subset of the available programs could generate such benefits, for instance, only occasionally a course would allow the worker to take up a job with a salary 20% higher after training (without considering the employability gap).

5 Conclusions

Changes in technology and markets result in the transformation of economic structure: When labor is quasi-fixed due to short-term specificity, changing conditions may imply either temporary unemployment or the need of retraining to enable mobility across the sectors. Training may raise mobility, but workers' decisions to engage in training are rather complex, as indivuals' costs and benefits need to be considered.

Training may speed up the development process as it can reduce the cost of the adjustment by the abatement of key parameters in the process; the efficiency of the adjustment process has direct implications on the output growth and also has distributional implications. It is forcefully argued that these effects reveal the true value of easing mobility, contrary to conventional related literature. Thus, training seems to be a powerful "machine," increasing workers' mobility in economic slums as well as booms, and could make a key contribution for development. Indeed, in today's context of global turmoil, improving the effectiveness in the provision of training seems to be essential. In particular, considering that in the Uruguayan case training seems an unattractive activity, there is a lot to be gained for development by improving the attractiveness and effectiveness of training provision.

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APPENDIX

1 Individual's decisions on labor allocation

To analyze the intertemporal substitutability of labor units, it is useful to simplify the notation, taking $i_t = \dot{L}_t{}^A$, as follows:

$$L_t{}^M = \frac{a}{2} i_t{}^2 \tag{A.1}$$

$$L_t{}^B = \bar{L} - L_t{}^A - \frac{a}{2} i_t{}^2 \tag{A.2}$$

Expression (A.1), relating $L_t{}^B$ and i_t , shows the intertemporal input transformation frontier of labor units moving from sector B to A; the marginal input rate of intertemporal transformation is given by (A.3, which shows the slope of the curve for infinitesimal changes; thus, the lower the mobility costs (a) is, the flatter is the curve.

$$-\frac{\partial L^B}{\partial i} = a\ i \tag{A.3}$$

This rate shows how many units of labor must leave one sector at time *t* to obtain a marginal unit of increment in the level of employment of the other sector at time *t*+1, accounting for the friction to the movement. The rate increases with the increasing employment in the expanding sector due to the quadratic form assumed; this feature is not essential for the results.

Workers will be aware of the presence of friction to the movement and will take into account the marginal input rate of intertemporal transformation when deciding the move. Thus, workers' decisions at time t_0 (infinitely lived workers) will be based on the following rule:

$$w_{t_0}{}^B\ a\ i \le \sum_{t=t_0}^{\infty} (w_t{}^A - w_t{}^B) \frac{1}{(1+r)^t} \tag{A.4}$$

where $w_t{}^i$ is the wage rate and r is the exogenous interest rate. When equality in (A.4) holds, the worker will be indifferent to the movement. Intuitively, the worker will be

willing to move as long as the return to the amount of labor units that must leave a sector now is less than the (discounted) future stream of the difference in the return between the alternative allocation of the marginal labor unit.. Expression (A.4) is equivalent to (10) in the text.

2 Dynamic path in continuous time: Allocation decisions centrally taken by labor suppliers

The intertemporal problem, in continuous time, when allocation decisions are centrally taken by labor suppliers is:

$$\underset{i}{Max} \int_0^{\infty} \left(w_t \, L_t{}^A + w_t \, L_t{}^B \right) e^{-rt} dt$$

$$s.t. \ \bar{L} = L_t{}^A + L_t{}^B + \frac{a}{2} i_t{}^2$$

$$i_t = \dot{L}_t{}^A$$

Using (A.2) it can be rewritten as:

$$\underset{i}{Max} \int_0^{\infty} \left(w_t \, L_t{}^A + w_t \, (\bar{L} - L_t{}^A - \frac{a}{2} i_t{}^2) \right) e^{-rt} dt \qquad (A.5)$$

$$s.t. \qquad i_t = \dot{L}_t{}^A$$

where r is the instantaneous discount rate (interest rate) taken as exogenous. The Hamiltonian for the program (A.5), where i_t is the control variable, $L_t{}^A$ is the state variable, and μ_t is the associated co-state variable, is as follows:

$$H = \left[w_t \, L_t{}^A + w_t{}^B (\bar{L} - L_t{}^A - \frac{a}{2} i_t{}^2) \right] e^{-rt} + \mu_t \ i_t$$

where the optimization conditions are:

$$-w_t{}^B \, a \, i_t \, e^{-rt} + \mu_t = 0 \qquad (A.6)$$

$$(w_t{}^A - w_t{}^B) e^{-rt} = - \dot{\mu}_t \qquad (A.7)$$

$$i_t = \dot{L}_t^{\,A} \tag{A.8}$$

By integrating (A.7) with respect to time and using (A.6), it results:

$$w_t^{\,B}\, a i_t\; e^{-rt} = \int_t^{\infty} \left(w_\tau^{\,A} - w_\tau^{B} \right) e^{-r(t-\tau)}\, d\tau$$

The expression shows that on the optimal path, the marginal cost of the movement is equal to the (discounted) stream of future benefits of the reallocation; this result is equivalent to (A.4) and (10) in the text.

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