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Nathalie CHUSSEAU

LEM UMR 9221 / nathalie.chusseau@univ-lille.fr

Jacques PELLETAN

LED, University of Paris 8

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*Nathalie Chusseau*and Jacques Pelletan***

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(*) LEM-CNRS (UMR 9221), University of Lille. Campus Cité Scientifique. Building SH2 – Office 123. 59655 Villeneuve d'Ascq Cedex FRANCE. Phone: +33 3 62 26 85 35, E-mail: Nathalie.Chusseau@univ-lille.fr.
(**) LED, University of Paris 8.

Abstract

From a continuous time, overlapping generations model in which individuals make optimal schooling choices, we analyse the impact upon production of a 6-months and one-year vocational training policy across working life.

Each individual chooses her optimal schooling time during which she will accumulate human capital before entering the labour market. We consider however that a share of the working population may be impacted by a skill obsolescence (particularly specific skills) due to technological changes that have not been anticipated.

We simulate two scenarii which will be compared in the long-run and correspond to stationary equilibria: (i) individuals have no access to vocational education and their human capital is fully determined by the length of standard schooling even after the technological shock; (ii) individuals are able to pursue a retraining programme to offset the depreciation of their human capital due to the technological shock.

By assuming that returns of vocational education are lower than those of standard education, we find an increase in production by 2.5% or 3.4% for a 6-months or a one-year access to vocational studies.

Keywords. Education, Vocational training, OLG model, Calibration

JEL Classification. I21 / I26 / O11/O40

1. Introduction

Vocational training is a key issue for our economies: an aging population leads to the opportunity of working longer, and creative-destruction due to innovation generates a polarization of the labor force with the disappearance of middle-class jobs compared to those at the bottom requiring few skills and those at the top requiring greater skill levels. Considering individuals, unemployment deteriorates living conditions if they cannot improve their skills. It is thus crucial to reform vocational education across working life, particularly in France where vocational training is not very efficient. Only 36% of adults are involved into vocational training each year compared to 53% in Germany and 56% in the UK (OECD). Moreover, the unskilled and the elderly working population do not benefit from vocational training whereas they both face the highest probability to be unemployed (Domingues Dos Santos et Pelletan, 2015). Finally, the results of the recent OECD study on adult skills[1] (PIAAC) suggest that vocational training is essential to improve the educational level of French adults (Brandt, 2015).

French President Emmanuel Macron decided to devote 15 billion euros of the investment programme to vocational training to improve competitiveness, employability and innovation. The main objectives of this reform is (i) to improve the efficiency of French vocational education, and (ii) to generate substantial benefits to the country.

Four types of individuals must be specifically addressed: (i) people leaving the educational system without any degree, (ii) the unemployed negatively affected by a technological shock through an obsolescence of their human capital, (iii) the working population knowing a depreciation of part of their skills due to technological progress in services and manufacturing, and (iv) people who would like to pursue a retraining programme.

A first study by Chusseau (2017) put forward the positive impact of such a measure targeted at people leaving the educational system without any degree upon (i) the general skill level, (ii) the income per head, and (iii) the intergenerational social mobility and the disappearance of under-education traps.

This paper proposes a model to evaluate the impact for an individual and the economy of an access to a one year (or 6-months) vocational training program across her working life if she faces a skill depreciation due to a technological or sectoral shock. Lots of studies have analysed

[1] The difference between the mean scores of adults who have completed tertiary education and those that have obtained less than upper secondary education is larger in France than in most other countries.

the empirical impact of vocational training (Dearden et al., 2006; Goux and Maurin, 2000, Arulampalam and Booth, 2001; Bartel, 2000; Fakhfakh and Taymaz, 2006). There is however few theoretical modelling to understand the channels by which vocational education may influence the economic equilibrium and the growth level.

In this paper, we build a dynamic continuous time, overlapping generation model. The dynamic accumulation of human capital is made through standard education (no vocational training). Each individual chooses her optimal schooling time during which she will accumulate human capital before entering the labour market. We consider however that a share of the working population may be impacted by a skill obsolescence (particularly specific skills) due to technological changes that have not been anticipated (10% of the jobs according to Autor, 2015; Arntz et al., 2016; the COE report, 2017, and Frey and Osborne, 2017). We assume that this skill obsolescence corresponds to a 20% loss of individuals' human capital.

We propose to measure the impact of the access throughout life to a one-year and a 6-months retraining program compared to a standard schooling situation without vocational training.

We model and simulate two scenarii which will be compared in the long-run and correspond to stationary equilibria: (i) individuals have no access to vocational education and their human capital is fully determined by the length of standard schooling even after the technological shock; (ii) individuals are able to pursue a retraining programme to offset the depreciation of their human capital due to the technological shock.

The rest of this paper is organised as follows. In Section 2, we present the general framework of the model. We first solve the model in partial equilibrium with constant wage and interest rates, and then turn to general equilibrium analysis concentrating on the steady state. We analyse the effect upon the steady state of a technological shock depreciating human capital, comparing the case where individuals have no access to vocational education (and their human capital is thus fully determined by the length of standard schooling even after the technological shock), to the case where individuals are able to pursue vocational training to offset the skill obsolescence. Section 3 exposes the parameters and scenarii that have been calibrated. In Section 4, we present and discuss the results. Section 5 concludes.

2. The model

From a continuous time, overlapping generations model in which individuals make optimal schooling choices, we analyse the impact upon production of a 6-months and one-year free vocational training policy across working life.

2.1. General framework

We build an overlapping generation model in which individuals face a per unit of time probability of dying ρ which is constant throughout life. A cohort born at time *b* has a size as of time *t* equal to $\rho e^{-\rho(t-b)}$. We normalise the size of the population to 1.

At time t_0 we assume that a share *p* of the working population is impacted by a skill obsolescence due to a non-deterministic technological shock. The human capital of this population may be written: $h = \mu e^{f(s)}$ for $t > t_0$ with $\mu \in [0,1]$. We study the steady state equilibria after the shock by considering as a benchmark the situation where the individual is unable to retrain after the shock. The moment t_0 when the shock appears is distributed according to a distribution function presented below.

We shall compare two different cases:

(i) it is not possible for the individual to be retrained after the initial schooling (initial schooling has a duration equal to *s* and the corresponding schooling function $f(s)$ presents the following standard properties: $f_s > 0$ and $f_{ss} < 0$ (Willis, 1986), and human capital *h* becomes $h = \mu e^{f(s)}$ after the shock

(ii) the individual can be retrained after the shock with a duration *s'* which will be optimally chosen by the individual facing the shock. The corresponding schooling function $g(s')$ has the same standard properties as function *f*: $g_{s'} > 0$ and $g_{s's'} < 0$. For $t > t_0 + s'$, the human capital becomes: $h = \mu e^{f(s)+g(s')}$. If it is not possible to be retrained after the shock (benchmark scenario), then $s' = 0$

2.2. Individual's Maximization Problem

Individuals are born with no wealth. They are endowed with one unit of time and receive utility only from consumption. They invest in education at the beginning of their lives, then work. Their wages depend on their human capital, which is given by a standard function of schooling. There is no education cost except the foregone earnings.

The earnings of an individual who is no longer in school are:

$$E = wh(s) \tag{1}$$

with w the wage per unit of human capital.

By writing $\ln(E) = \text{constant} + f(s)$, human capital will be given by:

$$h = e^{f(s)} \tag{2}$$

The exponential is based on the regression of the logarithm of individual wages on years of schooling (Mincer's earnings regression). In a usual Mincerian specification (1974), the log of wages/earnings can be linearly related to years of schooling: Mincerian returns to education can be estimated. In case of diminishing returns, we have standard assumptions about f: $f_s > 0$ and $f_{ss} < 0$ (Willis, 1986).

At time t_0 we assume a non-deterministic shock μ concerning a share p of the population. The human capital of this population is thus depreciated and may be written:

$$h = \mu e^{f(s)} \tag{3}$$

for $t > t_0$ with $\mu \in [0,1]$

If the individual decides to pursue vocational training after the shock, her human capital will become:

$$h = \mu e^{f(s)+g(s')} \tag{4}$$

In this extended model with vocational education, we still regress the logarithm of individual wages on years of education, both initial schooling and vocational education. We can estimate the Mincerian returns to education, at the same time for initial schooling and vocational education. We assume that the human capital accumulation processes in initial and vocational education are independent. In case of diminishing returns for both types of education, we have standard assumptions about f : $f_s > 0$ and $f_{ss} < 0$ as well as about g : $g_{s'} > 0$ and $g_{s's'} < 0$[2].

Each individual born at time b maximizes her intertemporal consumption which is financed by her intertemporal income (income due to the amount of assets possessed and to the level of human capital).

Individuals maximize expected utility from consumption:

$$\max \int_b^{\infty} \left[\ln\left(c(z)\right) e^{-(\theta+\rho)(z-b)} \right] dz \quad (5)$$

In the first step we address the optimization process for the share p of the population facing the technological shock.

We can calculate the accumulation of assets:

(i) For the individuals who are not retrained after the initial schooling:

$$\dot{k} = (r+\rho)k + \mu e^{f(s)} w - c \text{ in the interval } [t_0, +\infty[\quad (6)$$

The initial value of $k(t_0)$ is that given by the accumulation process before the shock (Kalemli-Ozcam, Ryder and Weil, 2000):

$$k(t_0) = \frac{w e^{f(s)}}{r+\rho} \left(e^{-(r+\rho)s} e^{(r-\theta)(t_0-b)} - 1 \right) \quad (7)$$

(ii) For those who can be retrained[3]:

The accumulation of assets is described by the equations:

$$\dot{k} = (r+\rho)k - c \qquad \text{in the interval } [t_0, t_0 + s'[\quad (8)$$

$$\dot{k} = (r+\rho)k + \mu e^{f(s)+g(s')} w - c \qquad \text{in the interval } [t_0 + s', +\infty[\quad (8')$$

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[2] In their model, Bils and Klenow (2000) assume a function $e^{f(s)+g(a-s)}$ where the terms a-s is considered as professional experience. In this paper, the central point is not experience but vocational education.

[3] We present this case in the following equations because the first case corresponds to the standard model with only initial schooling.

Within the first scenario with only initial schooling, the differential equation describing the optimal path of consumption c is the same as that presented in the seminal article by Kalemli-Ozcam et al. (2000):

$$\frac{\dot{c}}{c} = r - \theta \tag{9}$$

That we can solve in the following way:

$$c(z) = c(t_0)e^{(r-\theta)(z-t_0)} \tag{10}$$

We can thus solve the differential equation characterising the path of assets by taking into account the limit condition in t_0:

$$\dot{k} = (r+\rho)k - c \quad \text{in the interval } [t_0, t_0 + s'[\tag{11}$$

$$\dot{k} = (r+\rho)k + \mu e^{f(s)+g(s')}w - c \quad \text{in the interval } [t_0 + s', +\infty[\tag{12}$$

with:

$$k(t_0) = \frac{we^{f(s)}}{r+\rho}\left(e^{-(r+\rho)s}e^{(r-\theta)(t_0-b)} - 1\right) \quad \text{(equation 7)}$$

In the interval $[t_0, t_0 + s'[$ the evolution of assets is given by equation (13):

$$k(z) = \frac{we^{f(s)}e^{(r+\rho)(z-t_0)}}{r+\rho}\left(e^{-(r+\rho)s}e^{(r-\theta)(t_0-b)} - 1\right) + \frac{c(t_0)}{\theta+\rho}\left(e^{(r-\theta)(z-t_0)} - e^{(r+\rho)(z-t_0)}\right) \tag{13}$$

To solve the differential equation in the interval $[t_0 + s', +\infty[$ we assume that k is a continuous variable. We get:

$$\begin{aligned} k(z) = {} & \frac{we^{f(s)}e^{(r+\rho)(z-t_0)}}{r+\rho}\left(e^{-(r+\rho)s}e^{(r-\theta)(t_0-b)} - 1\right) + \frac{c(t_0)}{\theta+\rho}\left(e^{(r-\theta)(z-t_0)} - e^{(r+\rho)(z-t_0)}\right) \\ & + \frac{\mu we^{f(s)+g(s')}}{r+\rho}\left(e^{(r+\rho)(z-t_0-s')} - 1\right) \end{aligned} \tag{14}$$

We can write the transversality condition as following:

$$\lim_{z\to+\infty}\left[e^{-(r+\rho)z}k\right]=0$$

By imposing transversality, we obtain the following value for $c(t_0)$:

$$c(t_0)=\frac{\theta+\rho}{r+\rho}\left[we^{f(s)}\left(e^{-(r+\rho)s}e^{(r-\theta)(t_0-b)}-1\right)+\mu we^{f(s)+g(s')}e^{-(r+\rho)s'}\right] \tag{15}$$

By maximizing the initial level of consumption with respect to *s*, individual chooses the optimal level of schooling. The first order condition is $f_s=r+\rho$ which says that an individual goes to school until his marginal rate of return from schooling is equal to the effective interest rate. This is the condition from Rosen's model of optimal schooling (See Willis, 1986).

Because of equation (10), we get:

$$c(z)=\frac{\theta+\rho}{r+\rho}\left[we^{f(s)}e^{-(r+\rho)s}e^{(r-\theta)(z-b)}-we^{f(s)}e^{(r-\theta)(z-t_0)}+\mu we^{f(s)+g(s')}e^{-(r+\rho)s'}e^{(r-\theta)(z-t_0)}\right] \tag{16}$$

We can thus calculate the value of assets:

(i) In the interval $\left[t_0,t_0+s'\right[$:

$$k(z)=\frac{we^{f(s)}}{r+\rho}\left(e^{-(r+\rho)s}e^{(r-\theta)(z-b)}-e^{(r-\theta)(z-t_0)}\right)+\frac{\mu we^{f(s)+g(s')}}{r+\rho}\left(e^{-(r+\rho)s'}e^{(r-\theta)(z-t_0)}-e^{(r+\rho)(z-t_0-s')}\right) \tag{17}$$

(ii) and in the interval $\left[t_0+s',+\infty\right[$

$$k(z)=\frac{we^{f(s)}}{r+\rho}\left(e^{-(r+\rho)s}e^{(r-\theta)(z-b)}-e^{(r-\theta)(z-t_0)}\right)+\frac{\mu we^{f(s)+g(s')}}{r+\rho}\left(e^{-(r+\rho)s'}e^{(r-\theta)(z-t_0)}-1\right) \tag{18}$$

2.3. General equilibrium and Aggregation

We are able to compute the aggregate human capital, the aggregate capital stock and the aggregate consumption. Then we will calculate the aggregate production from a Cobb-Douglas production function.

We first calculate the aggregate variables by considering only the share *p* of the population facing the technological shock. To derive these variables, we sum over generations. In a second step, we integrate according to the times when the shock may appear (we assume a distribution of the shocks over time).

We can first write:

$$K(z,t_0)=\int_{-\infty}^{z} k(b,z)\rho e^{-\rho(z-b)}db \qquad (19)$$

$$C(z,t_0)=\int_{-\infty}^{z} c(b,z)\rho e^{-\rho(z-b)}db \qquad (20)$$

$$H(z)=\int_{-\infty}^{z-s-s'} h(b,z)\rho e^{-\rho(z-b)}db \qquad (21)$$

Regarding equation (21), we only take into account the human capital for people who contribute to production, meaning those who are working.

Considering individuals facing the shock and able to pursue vocational training[4], their human capital is given by equation (4): $h=\mu e^{f(s)+g(s')}$.

From equation (21) and (4), we obtain:

$$H(z)=\int_{-\infty}^{z-s-s'} \mu\rho e^{f(s)+g(s')}e^{-\rho(z-b)}db \qquad (22)$$

And thus:

$$H(z)=\mu e^{f(s)+g(s')}e^{-\rho(s+s')} \qquad (23)$$

From equation (20) and equation (16)[5] we get equation (24):

$$C(z,t_0)=\frac{\theta+\rho}{r+\rho}w\left[\frac{\rho e^{f(s)}e^{-(r+\rho)s}}{\rho-r+\theta}-e^{f(s)}e^{(r-\theta)(z-t_0)}+\mu e^{f(s)+g(s')}e^{-(r+\rho)s'}e^{(r-\theta)(z-t_0)}\right] \qquad (24)$$

And by integrating function *k* (equation 19) according to equations (17) and (18):

[4] They can decide to pursue a retraining programme: $s'>0$ or not: $s'=0$

[5] We integrate the value of individual consumption given by (16)

$$K(z,t_0)=\frac{we^{f(s)}}{r+\rho}\left(\frac{\rho e^{-(r+\rho)s}}{\rho-r+\theta}-e^{(r-\theta)(z-t_0)}\right)$$
$$+\frac{\mu we^{f(s)+g(s')}}{r+\rho}\left(e^{-(r+\rho)s'}e^{(r-\theta)(z-t_0)}-e^{-\rho(s+s')}-e^{(r+\rho)(z-t_0-s')}\left(1-e^{-\rho(s+s')}\right)\right) \tag{25}$$

In a second stage, aggregation is made by assuming the following density of distribution of the shock: $\gamma e^{-\gamma(z-t_0)}$. The probability of facing a shock at time z is normalised to 1: $\int_{-\infty}^{z}\gamma e^{-\gamma(z-t_0)}dt_0=1$.

We suppose that the probability to be impacted by a new shock over time is higher than to be impacted by older shocks, the older shocks being absorbed by the economy.

Under these assumptions, we can write:

$$K(z)=\int_{-\infty}^{z}K(z,t_0)\gamma e^{-\gamma(z-t_0)}dt_0 \tag{26}$$

$$C(z)=\int_{-\infty}^{z}C(z,t_0)\gamma e^{-\gamma(z-t_0)}dt_0 \tag{27}$$

And we still have:

$$H(z)=\mu e^{f(s)+g(s')}e^{-\rho(s+s')}$$

We find:

$$C(z)=\frac{\theta+\rho}{r+\rho}w\left[\frac{\rho e^{f(s)}e^{-(r+\rho)s}}{\rho-r+\theta}-\frac{\gamma e^{f(s)}}{\gamma-r+\theta}+\frac{\mu\gamma e^{f(s)+g(s')}e^{-(r+\rho)s'}}{\gamma-r+\theta}\right]$$

which can be rewritten as following:

$$C(z)=\frac{\theta+\rho}{r+\rho}we^{f(s)}\left[\frac{\rho e^{-(r+\rho)s}}{\rho-r+\theta}-\frac{\gamma}{\gamma-r+\theta}+\frac{\mu\gamma e^{g(s')}e^{-(r+\rho)s'}}{\gamma-r+\theta}\right] \tag{28}$$

And:

$$K(z)=\frac{we^{f(s)}}{r+\rho}\left(\frac{\rho e^{-(r+\rho)s}}{\rho-r+\theta}-\frac{\gamma}{\gamma-r+\theta}\right)$$
$$+\frac{\mu we^{f(s)+g(s')}}{r+\rho}\left(\frac{\gamma e^{-(r+\rho)s'}}{\gamma-r+\theta}-e^{-\rho(s+s')}-\frac{\gamma e^{-(r+\rho)s'}\left(1-e^{-\rho(s+s')}\right)}{\gamma-r-\rho}\right) \tag{29}$$

We assume a Cobb-Douglas production function: $Y = AK^{\alpha}H^{1-\alpha}$.

Both factors (human capital and physical capital) are paid at their marginal productivity:

$$w = A(1-\alpha)\left(\frac{K}{H}\right)^{\alpha} \quad (30)$$

$$r = A\alpha\left(\frac{K}{H}\right)^{\alpha-1} \quad (31)$$

And:

$$\frac{K}{H} = \frac{w\alpha}{r(1-\alpha)} \quad (32)$$

2.4. General equilibrium for both types of populations

We now consider the general equilibrium for the share *p* of the population facing the technological shock (from the accumulation paths of assets, human capital and consumption presented in the previous section), and the share $(1-p)$ of the population who is not impacted. For this second type of population, we have the following results:

$$H(z) = e^{f(s)-\rho s} \quad (33)$$

$$C(z) = \frac{\theta+\rho}{r+\rho} we^{f(s)}\left[\frac{\rho e^{-(r+\rho)s}}{\rho - r + \theta}\right] \quad (34)$$

And:

$$K(z) = \frac{we^{f(s)}}{r+\rho}\left[\left(\frac{\rho}{\rho - r+\theta}+\frac{\rho}{r}\right)e^{-(r+\rho)s} - \left(1+\frac{\rho}{r}\right)e^{-\rho s}\right] \quad (35)$$

By aggregating over generations:

$$H(z) = p\mu e^{f(s)+g(s')}e^{-\rho(s+s')} + (1-p)e^{f(s)-\rho s} \quad (36)$$

$$C(z)=\frac{\theta+\rho}{r+\rho}we^{f(s)}\left[\frac{\rho e^{-(r+\rho)s}}{\rho-r+\theta}-p\frac{\gamma}{\gamma-r+\theta}+p\frac{\mu\gamma e^{g(s')}e^{-(r+\rho)s'}}{\gamma-r+\theta}\right] \quad (37)$$

And:

$$K(z)=\frac{we^{f(s)}}{r+\rho}\left[\left(\frac{\rho}{\rho-r+\theta}+(1-p)\frac{\rho}{r}\right)e^{-(r+\rho)s}-(1-p)\left(1+\frac{\rho}{r}\right)e^{-\rho s}-p\frac{\gamma}{\gamma-r+\theta}\right]$$
$$+p\frac{\mu we^{f(s)+g(s')}}{r+\rho}\left[\frac{\gamma e^{-(r+\rho)s'}}{\gamma-r+\theta}-e^{-\rho(s+s')}-\frac{\gamma e^{-(r+\rho)s'}\left(1-e^{-\rho(s+s')}\right)}{\gamma-r-\rho}\right] \quad (38)$$

3. Simulations

We assume the appearance of a unanticipated technological shock, the distribution of which is smoothed over time. 10% of the population faces a depreciation of her human capital. Individuals can decide to retrain or not (during six months or one year). We suppose that this skill obsolescence corresponds to a 20% loss of individual's human capital.

3.1. The scenarios

We simulate the model by considering two scenarii which will be compared in the long-run and correspond to stationary equilibria:

- individuals have no access to vocational education and their human capital is fully determined by the length of standard schooling even after the technological shock $(s'=0)$;
- individuals are able to pursue vocational training to offset the depreciation of their human capital due to the technological shock. They can be retrained during 6 months $(s'=0.5)$ or during a whole year $(s'=1)$.

From the system of equations (36), (37), (38), (30), (31), and the first order condition $f_s=r+\rho$, and by considering $s'=0$ (benchmark scenario) and $s'=0.5$ or $s'=1$, we can find a unique value for the endogenous variables r, K, H, C, w and s (initial optimal schooling time). These values correspond to a stable equilibrium[6]. To calibrate the model, we need to characterize the education functions $f(s)$ and $g(s')$. Following Kalemli-Ozcam, Ryder and Weil (2000) to compare our results for the benchmark scenario with initial schooling only, we will use the estimates made by Bils and Klenow (1998, 2000) (see below).

3.2. Parameters

Table 1 presents the parameters used for the calibration of the model.

Table 1: The parameters

ρ	Φ	θf	θg	α	θ	A	p	μ	γ	s'
0.012	0.58	0.32	0.16	0.3	0.03	1	0.1	0.8	0.1	0 ; 0.5 ; 1

As in Kalemli-Ozcam et al. (2000), we choose $\rho = 0.012$ which corresponds to a life expectancy of 83 years.

We assume that 10% of the population will face a skill obsolescence because of non-anticipated technological shocks (Autor, 2015; Arntz et al., 2016; the COE report, 2017, and Frey and Osborne, 2017): $p = 0.1$. This skill obsolescence leads to a 20% loss of the individual's human capital: $\mu = 0.8$.

$\alpha = 0.3$ is the share of capital in total income (Cobb-Douglas production function).

s' takes different values according to the simulated scenario: no vocational training; a 6-months retraining programme or a one-year retraining programme.

We use the following form of the $f(s)$ function estimated by Bils and Klenow (1998, 2000):

$$f(s) = \frac{\theta_f}{1-\Phi} s^{1-\Phi}$$

[6] The unicity of the equilibrium has not been analytically proved, but a large range of simulations shows a unique and positive solution for *r, K, H, C, w* and *s*.

The Mincerian return to schooling is thus $f'(s)=\frac{\theta_f}{s^{\Phi}}$. Using data from Psacharopoulos (1994) on a sample of 56 countries, Bils and Klenow regressed estimates of Mincerian returns on country schooling levels[7] to estimate Φ and θ_f: Their estimates are $\Phi = 0.58$ and $\theta_f = 0.32$.

Thus: $f(s)=\frac{\theta_f}{1-\Phi}s^{1-\Phi}=\frac{0,32}{0,42}s^{0,42}$.

In this paper, we use the same form for function $g(s')$. However, we suppose that the returns to vocational training are lower than the returns to initial schooling: $\theta_g < \theta_f$ and $g(s')=\frac{\theta_g}{1-\Phi}s^{1-\Phi} < f(s)=\frac{\theta_f}{1-\Phi}s^{1-\Phi}$. Within this calibration, the returns to vocational training are supposed to be twice lower than these of initial schooling.

4. Results and Discussion

Table 2 shows the steady state values of the endogenous variables r, K, H, C, w and s in each scenario: (i) the benchmark scenario (no vocational studies); (ii) a 6-months retraining programme for the share p of the population facing a technological shock; and (iii) a one-year retraining programme.

We can thus calculate the value of production Y in each scenario. The values of education functions in each scenario is depicted in Appendix.

[7] They estimated the following equation: $\ln(\hat{\lambda})=\ln(\theta)-\Phi\ln(s)+e$ with $\hat{\lambda}$ the Mincerian return to education, equal to $f'(s)$, and for which estimations are based on the regressions of logarithm of wages.

Table 2: Steady states values of the endogenous variables

	K	C	r	H	s	w	Y
Scenario 1: $s'=0$	237.19	31.75	0.039315	13.01	23.407	1.6724	31.084
Scenario 2: $s'=0.5$	242.88	32.72	0.039348	13.34	23.445	1.6718	31.856
Scenario 3: $s'=1$	245.03	33.084	0.03936	13.46	23.43	1.6715	32.15

Table 3 presents the changes in aggregated values at the steady state comparing each vocational training scenario with the situation in which the individual has no access to vocational studies.

Table 3: Increases in aggregated values at the steady state:

	K	C	H	Y
one-year retraining programme *versus* no retraining	+3.31%	+4.20%	+3.49%	**+3.43%**
6-months retraining programme *versus* no retraining	+2.40%	+3.05%	+2.52%	**+2.48%**

Table 3 shows, at the steady state, an increase in production by 2.5% for a 6-months retraining programme, and by 3.4% for a one-year access to vocational studies. Our results show that proposing after a technological shock a free access to retraining programmes may generate significant gains.

Alternative scenarios have been calibrated. In the seminal model, 10% of workers according to various contributions or literature (Autor, 2015; Arntz et al., 2016; the COE report, 2017, and Frey and Osborne, 2017) show a skill obsolescence, particularly for specific skills, due to unanticipated technological shocks. The magnitude of this shock is supposed to correspond to a depreciation by 20% of individual's human capital. Lastly, consumption during training is financed by individual savings. All of these assumptions can be relaxed.

Several sensitivity tests have been carried out. Firstly, we used different levels of technological shock (depreciation of the individual's human capital ranged between 20% and 5%). Secondly, we considered various shares of the population impacted by the shock (between 10% and 40%). On the one hand, the model is very sensitive to an increase in the share of the population retrained, which is not surprising because aggregated human capital almost linearly depends on this parameter. On the other hand, the size of the shock does not play a major role in relative variations of human capital and growth caused by vocational education itself. Indeed, stationary equilibrium mainly depends on technological shock, which sets a benchmark level of production. But the relative increase in production due to vocational training slightly depends on this reference level. In fact, the relative gain due to retraining (which appears to be significant) remains quite the same regardless of the magnitude of the technological shock.

Another alternative scenario has been calibrated. We assume that the wages during the six months – or one year – of retraining are maintained unchanged and financed by a tax on labour income. In this variant, it is assumed that the earnings that the worker would have received after the shock is entirely maintained during the training. We then consider an endogenous tax rate on labour income to finance the wage replacement during the retraining period. Under these assumptions, the gains in terms of production are respectively 2.49% for 6 months of full-time training, and 3.47% for one year, which is quite similar to the effects obtained without any public funding. We can thus conclude that the financing of individual consumption during the full-time retraining programme has no impact on macroeconomic equilibrium and growth. Nevertheless, in a context of technological or sectoral shock, the choice between the two alternative scenarii has a huge impact upon distributional issues and inequalities. The implementation of the policy described in the second scenario can be a puzzle. In France, the State would need 80 billion euros to replace the income of 3 million people during 6 months[8]. As it appears to be an unrealistic scenario, it would be necessary to smooth such a decision over at least a five-year period (corresponding to the political cycle).

[8] In this alternative scenario, for six months of full-time training, the tax rate would be equal to 10.5% of labour income in the country, i.e. approximately 80 billion for 3 million workers.

Finally the assumptions on human capital accumulation process are central in our model. We used the education function $f(s)$ (initial schooling) proposed and estimated by Bils and Klenow (1998, 2000): $f(s)=\frac{\theta_f}{1-\Phi}s^{1-\Phi}=\frac{0,32}{0,42}s^{0,42}$

The value of the parameter θ_f is crucial to determine the impact of education upon growth. However, contrary to the literature related to the estimate of the returns to schooling, the estimates of the returns to vocational training are not so clear. In the paper, we suppose that the returns to training are not as high as these of initial schooling, and we assume that they are twice lower ($\theta_g = 0.16$).

Such a choice appears to be in line with the average estimations of returns to training, even if it seems quite difficult to find converging estimates. For example, Dearden et al. (2006) find an elasticity of 0.6 in the use of vocational training: if training is used 10% more in a firm (most frequently around one month), there will be an increase by 6% in productivity (3% of which being transferred to wages). This would mean that a 10 percentage point increase in the training measure at the firm level is associated with a 6% increase in productivity and a 3% increase in wages. But, we have to notice that (i) the relationship between wage increases and productivity gains can vary according to the structure of the labour and product markets, and is sensitive to whom will pay the costs of training, and (ii) the wage is not always a correct measure of productivity and human capital.

Such values correspond to a parameter θ_g which would be higher than in our calibration. But, average values found in the literature, mostly based on the individual impact of training upon wages (and not productivity at the firm level as in Dearden et al., 2006), are most of the time lower (Acemoglu and Angrist, 2000; Barrett and O'Connell, 2001; Black S.E. and L.M. Lynch, 1996; Carriou and Jeger, 1997; Leuven, 2004). The OLS estimates are generally less than 10% at individual level in case of training. Fixed-effects and difference-in-differences estimates are slightly lower, falling between 0% and 5% (Goux and Maurin, 2000; Arulampalam and Booth, 2001). The effects of training are certainly heterogeneous. This heterogeneity is in part driven by differences in the type of training chosen by different employees (i.e. heterogeneous treatments), and these choices are likely to be correlated with both observed and unobserved employee characteristics.

5. Conclusion

From a continuous time, overlapping generations model in which individuals make optimal schooling choices, we studied the impact upon production of a 6-months and one-year vocational training policy across working life.

Individuals are born with no wealth. They are endowed with one unit of time and receive utility only from consumption. They invest in education at the beginning of their lives, then work. Their wages depend on their human capital, which is given by a standard function of schooling. There is no education cost except the foregone earnings.

By maximizing her intertemporal consumption utility financed by her intertemporal income, each individual chooses her optimal schooling time during which she will accumulate human capital before entering the labour market.

We consider however that a share of the working population may be impacted by a skill obsolescence (particularly specific skills) due to technological changes that have not been anticipated. We can compute the aggregated values of consumption, assets and human capital, and calculate the level of production.

We simulated two scenarii which have been compared in the long-run and correspond to stationary equilibria: (i) individuals have no access to vocational education and their human capital is fully determined by the length of standard schooling even after the technological shock; (ii) individuals are able to pursue a retraining programme to offset the depreciation of their human capital due to the technological shock: a 6-months or a one-year retraining programme.

By assuming that returns to vocational education are lower than those of standard education, we find an increase in production by 2.5% for a 6-months access to vocational studies and of by 3.4% for a whole-year retraining programme. Our results show that organizing an individual access to vocational training for workers impacted by a technological change may have significant effects upon growth. Our simulations also put forward that financing the individual consumption during the full-time retraining programme through a tax on labour incomes has no impact on macroeconomic equilibrium and growth. Nevertheless, in a context of technological or sectoral shock, the choice between the two alternative scenarii has a huge impact upon distributional issues and inequalities.

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Appendix

Values of education functions in each scenario:

	$g(s')$	$f(s)$
Scenario 1: $s' = 0$	0	2.86761
Scenario 2: $s' = 0.5$	0.285	2.86629
Scenario 3: $s' = 1$	0.381	2.86566