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## Abstract

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The theory's point of departure is the classic contributions on labour market signalling, which are reinterpreted as models of evolutionary game theory. Firms are then defined with inspiration from the literature on organizational ecology and added to the game.

Firms compete through strategies for adaptively learning about the firms' own workforces, as well as learning to interpretation the signals sent by potential employees. The better a firm is at deciphering the ability of worker the lower its labour costs. The model is implemented as a computer programme and the results show that, under some market conditions, firms that have inert organisational structures are relatively effective at minimizing labour costs. While under other conditions the best strategy for minimizing labour costs includes frequent adaptation of the organisation and a high labour turnover.

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# Organisational adaptability through inertia and slack

## A theory of strategies for learning in an uncertain environment

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**Abstract**

A theory is suggested that combines the classic results from models of labour market signalling with processes of learning and reorganisation from routines. The result is a distinction between situation in which firms perform better if they have lean, adaptable organizations on the one hand, and situations where the superior strategy entails organisational structure that are inert to change and which have a tendency to retain slack resources.

The theory's point of departure is the classic contributions on labour market signalling, which are reinterpreted as models of evolutionary game theory. Firms are then defined with inspiration from the literature on organizational ecology and added to the game. They compete to minimize labour costs while attempting to reach a target scale of operation.

Firms compete through strategies for adaptively learning about the firms' own workforces, as well as learning to interpretation the signals sent by potential employees. The better a firm is at deciphering the ability of worker the lower its labour costs. The model is implemented as a computer programme[1] and the results show that, under some market conditions, firms that have inert organisational structures are relatively effective at minimizing labour costs. While under other conditions the best strategy for minimizing labour costs includes frequent adaptation of the organisation and a high labour turnover.

# 1 Introduction

Firms acting in uncertain environments cannot simply optimize. They must also allocate resources to mend the uncertainty of the environment. This not only entails the constant reproduction of routines but also continuous adaptation of

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[1]Thanks to Marco Valente for help with the practicalities of the coding at SIME in Strasbourg, May 2010.

routines to changes in the environment. This learning process involves decoding signals received regarding this environment and initiating behavioural routines in response. Routines for decoding may be described as parts of the organization's knowledge: the better suited these routines are for analysing changes in the firm's environment, the more apt the behavioural response will be.

An organization's knowledge evolves adaptively in a trial-and-error process. A signal is observed, an action is taken, the outcome is evaluated and the routine for interpreting signals is updated. This does not mean, however, that organizations become continuously better at interpreting signals. Organizations may lose knowledge when key employees are lost and environmental shifts may entail that the information embodied in a given signal changes too.

In the typology of Brenner (1999), firms engage in routine learning and improve their behavioural routines. But long before the routines converge on stable behaviour changes in the environment will entail that the cognitive model, upon which the firms' routine learning is based, has become unsatisfactory. A new cognitive model must then be established through what Brenner terms associative learning. In practice, as also noted by Brenner, the division of learning into associative and routine parts is an abstraction.

In this paper a model for the processes involved in such learning and adaptation is suggested. The theory takes its point of departure in very well-trodden ground: models of asymmetric information in the labour market. The basic premise of such models is that firms cannot know the ability of a worker prior to hiring her and they therefore need to infer these from the signals that she is sending. The classic models (e.g. Stiglitz (1975); Arrow (1973); Spence (1973)) focus on the role of education as a signal under the assumption that education neither has value in production nor in consumption but strictly acts as a signal of inherent qualities. Education is but one of many ways of signalling. Some signals can readily be affected, e.g. such as daily appearance, while others are practically fixed, e.g. sex.

There are several qualities of workers by which a firm cannot directly sort them. Some because they are unobservable (perseverance, punctuality) and others because it is often illegal (health, smoking/drinking habits). Knowledge of these skills is a classic example of asymmetric information. Workers hold information that the firm would benefit from having. The ability of firms to infer this information from observed signals is of great importance to their performance, as holding this information would allow for a better utilization of the worker's abilities. In some cases it would also be in the interest of the worker to communicate the information, for example with promotion or wage negotiation in mind, but it may not be possible to signal the information credibly. In the current paper firms are assigned a worker with random characteristics when they wish to hire. Focus is exclusively on the firms and workers are treated as completely passive: they have no say in their choice of employer and they do not quit their jobs. These simplifications set the model apart from models of job matching, where the problem of optimizing the fit of employee characteristics and job requirements is studied (Thompson and Pintea, 2008; Dagsvik et al., 1985; Jovanovic, 1982, 1979).

The suggested theory considers only costly signals where the cost to the sender of signalling is negatively correlated with quality for the receiver. In classic models this signal is referred to as education with the assumption that inherently high productivity workers suffer less disutility from taking education.

And the role of this signal is considered in only one scenario: the hiring and firing decisions of firms when there is an abrupt shift in the environment. Firms readjust their scale continuously and some more efficiently than others. They build up organisational slack and they learn about the abilities of the members in the organisation. “Learn” here means that through experience and interaction the various members of the organisation, not least any given worker’s superiors, learn what others are capable of; their strengths and their weaknesses. Learning allows the organisation to assign work hierarchically according to abilities and it allows colleagues to know to whom to turn to solve particular tasks. However, all this relies on the ability of organisations to decode the abilities of its members.

The aim of this paper is to analyse the interdependencies among market conditions and firms’ strategies when adjusting scale under asymmetric information. The theory is analysed as a computer model which, as opposed to empirical studies, will allow for complete control over the external conditions that induce firms to hire and fire as well as allow for observable and comparable quantifications of learning and routines for learning. The simulations presented in the paper focus on strategies for solving the explicitly assumed information asymmetry of signalling models and show how a variety of strategies perform under different market dynamics. These dynamics consist of firms having to adjust their size of operation and thus workforce continuously with incomplete information about the individual workers.

The paper is structured as follows. Section 2 reviews earlier models of labour market signalling while section 3 introduces and discusses earlier models of firms’ behaviour based on routines. Section 4 presents an evolutionary signalling model in which firms continuously adjust their labour force under asymmetric information in order to comply with an exogenously evolving target for activity level. The theory undergoes analysis in section 5. Results are extracted by exploring the performance (i.e. labour costs) of a variety of strategies under a variety of market conditions. The concluding section, section 6, sums up and indicates directions for further development.

## 2 Showing off one’s feathers: Signalling

The idea of using signals to communicate quality is long established in biology: animals signal their reproductive qualities to attract potential mates and to deter potential rivals (Hurd, 2006; Maynard Smith and Harper, 2003). The concept of signalling in economics is ascribed to Michael Spence and refers to a process of remedying asymmetric information, as it does in biology. In this process, the informed party works to convey the information to the uninformed party through signals, which the uninformed party must interpret. Signalling models are contrasted by screening models in which the uninformed party tries to lure the informed party into revealing the information; i.e. by offering her a menu of contracts that creates incentives for self-selection of the informed parties.[2] For a signal to function it must in some credible way be correlated with the attribute of interest. In classic models this is education: it is easier for relatively high skill workers to take education than it is for relatively low skill workers. This makes it possible for firms to offer a wage that increases in education but without workers of all ability levels experiencing net gains from

[2] Two relatively recent overviews of this literature are Löfgren et al. (2002) and Riley (2001).

taking education. The focus on education in classic models has lead to attempts of testing the models empirically. But the results are generally indistinguishable from the predictions of human capital theory: that education is the source of workers' productivity (Chevalier et al., 2004; Ilmakunnas et al., 2004; Jones, 2001; Black and Lynch, 1996; Weiss, 1995; Kroch and Sjoblom, 1994)

There are few recent contributions to the signalling literature of a purely theoretical nature (one exception is Delfgaauw and Dur (2007)). But there has been a number of recent contributions in experimental economics. This experimental research has confirmed the classic analytical result that screening models (where the employer moves first and starts by setting a wage menu) have only one equilibrium while signalling models (where employees move first and start by choosing a level of education) have multiple equilibria, and it has been shown that this discrepancy is caused by differences in learning (Kübler et al., 2008): The task of the worker-subject is much more complicated in the signalling case than in the screening case and this learning can be manipulated through manipulation of the setting of the game; i.e. the context story that the subjects are given for the game, but research also show that subjects are capable of transferring what they learn in signalling games under one setting to other settings (Cooper and Kagel, 2008, 2003). Thus learning to act strategically in the signalling game does not start over when the game changes but is cumulative and the order in which agents move have genuine importance. That is, agents do not anticipate each other's moves and formulate contingent strategies so that the game becomes practically simultaneous rather than sequential. Rather, their behaviour in consistent with trial-and-error learning.

## 2.1 First models

The two papers from 1973 by Spence and Arrow respectively (Spence, 1973; Arrow, 1973) both use the signalling value of education in the labour market as an example of asymmetric information mended by signalling. For Spence it is a matter of constructing a model of investment under uncertainty: the firm invests in labour resources but the returns to the investment are uncertain. One way for the firm to estimate the returns is by observing any characteristics or indicators that the workers exhibit and then estimating their worth from this information. Arrow's model is very similar. The main difference is that he focusses on the signalling value of higher education in particular and that he explicitly wants to break with the orthodox human capital tradition of explaining the correlation between wage and education by the accumulation of productive skills.

In the models of both papers it is assumed that there can be neither reputation nor trust, that workers are perfect substitutes in production, that firms are risk neutral and that education has value in neither consumption nor production. Firms' learning in both models consists of firms performing the econometric exercise of estimating workers' worth to the firm from signals before offering wages. The conclusions of the models are described by equilibrium situations in which the firms have stopped learning: their current beliefs are reaffirmed by what they observe when hiring. In the terms of Brenner (1999), the firms' cognitive model has stopped evolving and their routine learning has converged on stable behaviour. The characteristics of the equilibrium depends to a great extent on the firms' incentives for learning: their labour costs. As wage schedules depend directly on firms' knowledge, this means that the equilibrium depends on the initial beliefs given to the firm at the beginning of the game. There exist numerous equilibria, as the initial beliefs of a firm determine how he interprets the first signal he receives, thus which wage he offers to a worker sending this signal and thus the incentive of the workers to signal.

Spence employs his model to explain the existence of gender-wise wage discrepancy when there is no discrepancy in ability: the prejudice of the firm leads him to expect a certain productivity of educated/non-educated men/women respectively and pays them accordingly. But if the financial incentive of women does not allow for the costly signalling of ability by this wage, they will all remain uneducated and be paid according to their overall average productivity. Stiglitz (1975) uses a more or less identical model to argue that differences in education choice by social backgrounds are affected by the subjective beliefs of the employers: when a concrete social background (e.g. growing up in an infamous neighbourhood) is interpreted as a concise indicator of ability, the worker will be deemed to posses this level of ability regardless of education and thus not capture her ability rents.[3]

In the theory suggested in section 4 are an important motivator for firms' learning. But firms do not set wages: occupation category determines wage. The theory specifies two occupation categories and higher wage discrepancy among them are expected to increase selection pressure on strategies for learning.

## 2.2 Worker education and firm learning

In classic signalling models the differences in quality and abilities of workers are often referred to as differences in productivity. However, it is to be understood as productivity in an abstract sense. Whereas human capital models conceptualise workers as machines that can churn out more output per unit of input if the right programmes are loaded into them, productivity in signalling models should be interpreted as qualitative differences. Education is a signal of these qualitative differences rather than productivity differences (Weiss, 1995).

The qualities and abilities signalled by workers are generally those learned in early life, through socialization rather than education. Signalling is the sorting of workers by qualities and skills that are unobservable or by which firms are otherwise prohibited from sorting; e.g. by law. Perseverance, punctuality, health, drinking, smoking, absenteeism, patience, cooperation and so on. These qualities are results of upbringing; a function also served by the early school years. Children that are brought up to perform tasks when asked to, to hang in and not give up when a task is difficult, not to shirk from school and that are endowed with a social heritage fostering healthy eating and drinking habits possess qualities that are valuable to future employers, and will generally also perform well at school. This argument follows Weiss (1995) to a large extent. But as also pointed out by Weiss, at the very lowest levels education is also the accumulation of skills necessary for wealth creation, e.g. literacy.

The model of the current paper is also based on the assumption that workers have inherent qualities that are useful to firms. Workers send a signal, referred to as education, and sending this signal has no effect on the quality of the worker. Neither does the quality of the worker grow with her experience. That

[3] Stiglitz is often credited with the concept of screening but even though his 1975 paper includes the term screening in the title, he uses it for what is nowadays called signalling.

is, the quality of a worker does not increase with time (there is learning by doing in the sense of Thompson (2010)). Firms, on the other hand, learn by doing. Every time a firm hires a new worker it has an initial expectation of her usefulness–and this expectation is revised as the worker is observed doing her job. But it is not an automatic learning process as in Thompson (2010) (and to some extent in Arrow (1962)). Rather, it is an active process of learning through interaction with the labour market and its institutions; similarly to the processes described by Andersen (1992). Learning requires that firms commit resources to learning (Arrow, 1974, ch. 2). In the model presented below such investment is captured by keeping employees that are not strictly needed for production, but which represent accumulated knowledge to the firm. The prevalence of such investment is one of the strategy parameters that differ across firms.

Firms' learning creates other benefits than those captured privately by themselves (Arrow, 1962). The signal (e.g. education) is an institution of the economic system and it evolves as a by-product of learning among the system's objects (Johnson, 1992). In the model presented in later sections firms contribute to the institution of the signal through their learning but they may also rely on the information embodied in the institution as a supplement or even substitute to their own learning. Thus strategies for learning include a parameter describing the balance between building own knowledge through investment or following herd behaviour by relying on the conventional interpretation embodied in the institution of the signal. In this respect the theory is similar to the one suggested by Orléan (1998).

Simplifying workers to objects with completely fixed characteristics and the labour market to an adaptively evolving algorithm ignores the acquisition and development of skills in a workforce. Even though such processes are very important in research, which has inspired the current paper (e.g. Jensen et al. (2007); Nelson and Winter (1982). But focus here is strictly on the learning processes within firms and endogenous modelling of worker behaviour would complicate this aim considerably. This issue is also discussed in the concluding section.

### 2.3 From classic games to evolutionary theory

The focus on learning to decode signals and on adapting behaviour to new knowledge and to the changes in behaviour of other agents plus the focus on out-of-equilibrium processes in signalling models make them well suited for evolutionary theorizing.[4]

The original exposition in Spence (1973) really lends itself more to evolutionary game theory than to the classic sort. Especially when considering his description of learning dynamics (Spence, 1973, pp. 359-360) and the phase diagram depicting the feedback loop of these dynamics (Spence, 1973, figure I). Spence's game is evolutionary in the sense of Maynard Smith (1982) (see also Hofbauer and Sigmund (2003); Nowak (2006)) in that the fitness of a worker's strategy depends on what other workers are doing and what the current state

[4]Notice that this characteristic of signalling models apply mostly to the early ones (e.g. Spence, Arrow and Stiglitz). Modern game theory is mostly concerned with refinements of equilibria that solves the asymmetric information. See e.g. the survey in Riley (2001). Some of these refinements even build on adaptive learning (Jacobsen et al., 2001) but nevertheless focus only upon conditions for selection among equilibria.

of the environment is. I.e. if everyone is taking education irrespective of ability then education is not a credible signal of ability, wages will not correlate with education and taking education is a waste of resources. Unless, of course, the prejudices of firms are such that uneducated workers are held in more or less outright contempt: firms only interact with educated workers and thus only know off the abilities of educated workers.

From the perspective of the firms the situation is somewhat similar: the consequence of following a given configuration of routines depends not only on the relative abundance of strategies for signalling among workers but also upon the behaviour of other firms. In particular, some firms might opt to adapt their workforces continuously relying on the information discerned from the education signal—but the credibility of this signal depends on the willingness of other firms to commit resources to learn about the meaning of the education signal. The information of the signal is an institution that evolves as firms learn. Firms may commit themselves to build private knowledge of the abilities of workers as well and they may free-ride and not contribute to the evolution of the institution at all. This preference is one half of firms' strategies (the other half is introduced below). Some prefer selection for minimizing labour costs; firing workers that perform unsatisfactorily and hiring workers based on interpretation of the education signal. Others prefer learning about the abilities of workers to exploit these; keeping on excess workers in order not to jeopardise the investment in knowledge that they represent.

The focus of this paper is on the firms. The labour market will be modelled with an infinite number of workers and the relative abundances of the strategies evolve by standard replicator dynamics. If firms were left to be exogenous the model would thus be a reinterpretation of Spence (1973) in the framework of evolutionary game theory. Instead firms are explicitly modelled. Their number is finite and their strategies are fixed, though their behaviour is not—execution of the behavioural routines is contingent not only upon strategy but also the signals received and the ability to interpret these. Firms do not interact directly but play the field in the sense that their performance is determined by interaction with a labour market consisting of evolving supply and other firms' demand.

# 3 Firms

The theory described in detail in section 4 does not allow firms to change the basic structure of their routines. Routines differ across firms by parametrization—as determined by the strategy of the firm—and by firms' current knowledge. The modelling of firms that follows contributions in the field known as organisational ecology or population ecology. In this field focus is on the evolution of the population as a whole but emphasis is nevertheless given to the role of the diversity of organizations in the population and their interaction (Hannan and Caroll, 1992; Hannan and Freeman, 1984, 1977).

## 3.1 Inertia

A central argument of the organizational ecology literature is that economic selection favours inertia and accountability (Kelly and Amburgey, 1991; Hannan and Freeman, 1984, 1977). The inertia argument has particular relevance for the theory suggested here: when an organization changes it looses accumulated, specific knowledge—in the current setting, this means loosing knowledge of the abilities of its employees. It has been suggested (Farber, 1999) that wage schedules in which wage increases with tenure are offered precisely for this reason: worker quality is uncertain ex ante and only learned gradually, so firms will use pay to encourage long term employment relationships. As workers are not modelled explicitly in the current paper this incentives device is ignored.

The traditional argument for the primacy of inertia entails that a firm undertaking reorganization risks an increased probability of exit and thus that the evolution of organizational structure in a population is driven by entry and exit dynamics rather than intra firm organizational change. However, more recent contributions have acknowledge the complementary role of intra firm change (Aldrich and Ruef, 2006; Kelly and Amburgey, 1991) and empirical tests of the ecology model provide neither conclusive evidence for or against it (Barnett and Freeman, 2001; Kelly and Amburgey, 1991). Arguments concerning the role of intra firm change go back a long time and stress how acting in an uncertain environment must entail continuous updating of behaviour. An action leads to an outcome which is evaluated and behaviour is updated; a process sometimes referred to as trial and error learning (Alchian, 1950).

There is, of course, more to the literature on organizational ecology than the inertia argument. Accountability, in the sense of procedural rationality, is also held to be important for selection, and the role of inertia is complex: it depends on age and size of the organization as well as on the environment. Here, environment includes considerations of industry, technology and institutions. These refinements may well play a role in the diverging results of empirical tests. The primary inspiration from the ecology literature for the model developed here is the inertia argument: firms differ by their degree of inertia in the sense that their organizations differ by the tolerance for external change. Some firms reorganize whenever they experience even the smallest external change while others do business as usual unless there is a major external disruption. This inertia parameter is the second half of firms' strategy, the first being the hiring/firing parameter mentioned earlier.[5] Consequently, an important parameter to vary when studying the performance of strategies is the stability of the external environment.

It is argued in the ecology literature that firms function by routines and that the these need to be reproduced continuously as they decay quickly with disuse. The behaviour of firms in the model developed in this paper will be determined by routines though the routines will be fixed so the question of reproducibility is not relevant. They will, however differ in execution depending on strategy (inertia and preference for selecting versus learning) and over time as the interpretation of the education signal evolves.

## 3.2 Routines

Firms act by decision rules (or algorithms) and some of these rules are rules for learning about signals in the labour market. Such rules are action patterns:

[5] I.e. the preference of sorting among workers according to the information embodied in the institution of the signal versus investment in building private knowledge of worker quality conditional on her signal.

basic elements of behaviour and stores of capabilities at the firm. That is, the set of rules available to a firm is what the firm employs in order to act. Such rules are commonly labelled “routines”, though there is some discrepancy in the literature (Becker et al., 2005; Feldman and Pentland, 2003; Dosi et al., 1999, 1996; Cohen et al., 1996; Nelson and Winter, 1982). Routines evolve through use. The more a firm enacts its routines for acting in the labour market, the more it learns about the education signal.

Learning follows routines. Learning is what agents do when they encounter situations, of which they possess imperfect understanding. Agents then strive to make sense of the situation based on categorisations and heuristics (Dosi et al., 1996). Such learning in signalling models goes all the way back to Spence: Firms categorise workers based on workers' signals and ascribe to workers of each category the average ability previously observed for this category. When this expectation turns out to be wrong, the beliefs are updated by the new observation. A realistic feature of such a heuristic is that it allows for systematic bias relative to rational expectations.

In the theory presented below routines are persistent characteristics of firms. In their most abstract form routines are identical across firms but differences in firms' strategies mean that the routines are implemented differently for given environmental (market) conditions. And differences in learning about the labour market means that also for a given strategy and environment, the implementation of a routine differs over time. This duality is an important part of the routine concept going back at least to Nelson and Winter (1982) (e.g. p. 14) and which has been given different names and slightly different definitions in later contributions. E.g. performative and ostensive aspects by Feldman and Pentland (2003) or phenotype and genotype by Hodgson and Knudsen (2006). A major difference is that the former definition allows for Lamarckian mechanisms, where performative aspects have effect on ostensive aspects (pp. 108-9); while the latter explicitly denies any possibility of phenotype affecting genotype. The routines modelled below adhere mostly to the latter.

Although firms learn by interacting with the labour market a firm's accumulated experience with hiring and firing will not be a good indicator of its knowledge. In the terminology of Brenner (1999) the decisions of hiring and firing are important enough for firms to engage in cognitive learning. For this, they must posses a cognitive model relating a worker's characteristics to her usefulness to the firm. A firm's cognitive model is described by its expectation of ability conditional on signal. As firms observe the abilities of workers hired earlier, and as the institution of the signal evolves, the cognitive model evolves too. Based on their respective cognitive models firms adaptively improve their routines for interacting with the labour market. This is a process of routine based learning and the adaptive character of the learning routine is made necessary by the uncertainty of the environment. Such adaptive routine based learning would in the long run converge in what Brenner refers to as stationary behaviour (and this conclusion is similar to what Arrow (1962) terms the equilibrium response pattern), were it not for changes in the labour market leading firms to update their cognitive models.

Following Brenner's terminology the changes in the labour market are also a type of learning process. The labour market is modelled as a distribution of signalling strategies evolving by replicator dynamics. The fitness of the signalling strategies is a function of the institution of the signal. This corresponds to a population of infinitely many workers who's behaviour is are rewarded and punished by the institutions of the economic system so that, consequently, the frequency of behavioural strategies evolves. This process of reinforcement learning is similar to what Brenner labels a Bush-Mosteller model (see his ch. 6 in particular).

# 4 A theory of continuous scale adjustment under asymmetric information

The model presented here comprises of two more or less separate objects. The supply side of the labour market, which draws heavily on the classic signalling models, and the demand side, which is comprised of a number of firms competing to achieve a given target scale with minimum labour costs. Firms interact directly with the labour market but only indirectly with each other through their actions in the labour market.

The model is a good deal more complex than classical signalling models and includes both stochastic events and non-linear feedbacks (i.e. where the result is different from the sum of the parts) between firms and the labour market, so it has had to be implemented as a computer programme and the following exposition is correspondingly concrete.[6]

## 4.1 A Spence–style labour market

The starting point for the model is a Spence–style labour market after Spence (1973). It is the simplest form of a labour market of asymmetric information and is very similar to the labour markets of Arrow (1973) and Stiglitz (1975). There are two types of workers: Type Low and type High corresponding to what may be termed quality or ability. Formally, worker $w$ has inherent ability $\theta_w$ and $\theta$ takes on only two values, $H > L$. The type of a worker is known only to the worker herself. Based on her ability she chooses to send the signal 1 or 0, which in the following is referred to as taking education or not ($\sigma_w \in \{1, 0\}$). Taking education is more expensive to type Low than it is to type High. Thus if firms appreciate High workers sufficiently relative to Low workers, and this is reflected in the wage offered, type High will be able to signal their type through education.

From the firms' perspective there are thus two categories of workers offering labour services: the educated and the non-educated. But there are, in fact, four categories: High/Low type with/without education. The relative abundances of these types evolve completely adaptively with categories having above mean fitness increasing at the expense of categories with less than average fitness. As such, the labour market is an evolutionary game in which agents play four different strategies, i.e. courses of action contingent on inherent type:

1. Never take education ($\sigma_w = 0$)
2. Only take education if type is Low ($\sigma_w = 1$ if $\theta_w = L$ else $\sigma_w = 0$)

[6] The programme was written using the software Laboratory for Simulation Development, which is available as open source from `www.labsimdev.org` (Valente, 2008). The computer version of the model is available upon request.

3. Only take education if type is High ($\sigma_w = 1$ if $\theta_w = H$ else $\sigma_w = 0$)
4. Always take education ($\sigma_w = 1$)

The share of workers of type High is set randomly and this share is denoted by $h$. $1-h$ is thus the share of workers with low ability. It is important to notice that the evolution of the labour market is strictly adaptive but that the evolution still follows lines consistent with learning in a population of workers. If there is benefit to taking education then the number of workers taking education will increase; but through replicator dynamics rather than deliberation on behalf of workers. To see how this works consider the following. Equation 1 is the average pay to a worker pursuing strategy $\phi \in \{1, 2, 3, 4\}$ from the list above. $w_1$ and $w_0$ are the average wages paid to educated and non-educated workers respectively in the economy. The magnitude of the wage discrepancy between workers sending the signal and those that do not is a reflection of the role of the signal in the economy. The larger the role played by the signal when firms sort workers into jobs the larger the discrepancy will be. $C_H$ and $C_L$ are the costs of taking education for types High and Low, and $C_L > C_H$. As all variables refer to the same time step the $t$ subscripts are suppressed.

$$
\begin{aligned}
P_\phi =& h a_H(\phi) + (1-h) a_L(\phi) \qquad (1)\\
&\text{where}\\
a_H(\phi) =& \begin{cases} w_0 & \text{if } \phi \in \{1,2\} \\ w_1 - C_H & \text{if } \phi \in \{3,4\} \end{cases}\\
&\text{and}\\
a_L(\phi) =& \begin{cases} w_0 & \text{if } \phi \in \{1,3\} \\ w_1 - C_L & \text{if } \phi \in \{2,4\} \end{cases}
\end{aligned}
$$

$$F_\phi = \frac{P_\phi}{19 + e^{P_\phi}} \qquad (2)$$

The fitness of each strategy is then standardized to a value in the open interval $]0, 1[$ using a logistic equation, equation 2. And the change in the relative abundance of the four strategies is updated by equation 3, where $x_{\phi,t}$ is the relative abundance in the labour market of strategy $\phi$ at time $t$. I.e. if the fitness of a strategy is ten percent greater than average fitness then the share of workers following this strategy increases by ten percent.[7]

$$x_{\phi,t} = x_{\phi,t-1} \frac{F_{\phi,t}}{\sum_{\phi=1}^{4} x_{\phi,t-1} F_{\phi,t}} \qquad (3)$$

The fitness of each strategy depends on expectations in the market. If firms expect educated workers to be worth a great deal more to their organisations than non-educated workers strategy 4 will come to dominate, as workers following this strategy never waste resources on signalling. In other words, if $w_1$ is so much larger than $w_0$ that even type Low worker are better off taking education,

[7]The constant '19' might seem random in equation 2. Often the logistic equation would have a '1' but this means that fitness would be 1/2 when $P_\phi = 0$. Using instead 19 the fitness of 0 becomes 1/20.

then no strategy beats number 4. If the firms, on the other hand, expect that the contribution of a worker is largely similar regardless of education strategy 1 will come to dominate. Somewhere in-between these two extremes are the beliefs that will allow strategy 3 to dominate and all sorts of situations, where several strategies co-exist. Strategy 2, however, is not of practical relevance as it will always be relatively inferior.

The one thing missing from the labour market is a specification of the evolution of wages. Wages are paid to employees depending on their occupations and the formation of $w_1$ and $w_0$ is described in detail below.

If the evolution of the labour market described so far is allowed to play out, equilibrium will at some point be reached and the labour market will exhibit the characteristics of classic signalling models: there is an infinite number of equilibria and it is the ability of the firms to interpret signals that determines which equilibrium is reached.

Locking into equilibrium does not appear to be particularly realistic however. There are at least two different ways of avoiding this lock-in: either type High workers become more and more valuable to firms as time goes by and new (educational) institutions emerge for workers to signal their ability, or alternatively what is understood by "High" type changes over time, as technology and society evolves. I.e. the lists of characteristics considered vices and virtues change over time. Thus the share of type High workers (or equivalently: the chance of any new worker being assigned type High) is conceptualised as a random walk bounded by 0 and 1 and equilibrium situations are avoided.

## 4.2 Output market

On the other side of the model—opposing labour supply—is an industry consisting of a number of firms each trying to reach an exogenously given target scale, $\bar{Y}_t$. This target is the same for all firms.

The target evolves as a mean reverting random walk with mean $\gamma = \bar{Y}_0$. The process is described in equation 4 where $\upsilon_1$ and $\upsilon_2$ are parameters determining the volatility of the target and $W_t$ is a random variable following a standard normal distribution.

$$\bar{Y}_t = \bar{Y}_{t-1} + \upsilon_1(\gamma - \bar{Y}_{t-1}) + \upsilon_2 W_t \tag{4}$$

The higher the value of $\upsilon_1$ or the lower the value of $\upsilon_2$ the less volatile the target will be. This stochastic process together with the one in the labour market described earlier presents firms in the economy with a continuously evolving problem of coordination: they must reach a given level of output but the only input, labour, is of a continuously evolving quality and the indicator of quality—the signal sent by workers—also evolves over time.

## 4.3 Firms

Firms consist of a number of workers organised into two occupational categories, which interact to produce output. Firms' strategies differ along three lines:

- The tolerance level for change in target output required to initiate a reorganisation of the firm (i.e. inertia or sluggishness), $\tau_i$

- The tendency to build up organisational slack. That is, retaining excess labour, thus incurring extra costs but also avoiding loss of knowledge, $\epsilon_i$
- Reliance on own knowledge versus relying on the institution of the signal for interpretation. I.e. imitation/herd behaviour versus own learning, $\mu_i$

### 4.3.1 Production

Adjusting scale means adjusting production. Each firm seeks to match $\bar{Y}_t$ with as low labour costs as possible. Output is produced by a Leontief production function taking only labour—but two categories of labour—as inputs. Output is the minimum of the number of efficient units of labour in each of the two occupation categories: alpha and beta. $\alpha_{i,t}$ and $beta_{i,t}$ are the sets of workers in the occupation at firm $i$ at time $t$.[8] "Firm" is probably not the best conceptualisation of this production technology. A production line or perhaps a project group or work gang would be more apt: there is a small number of managers/supervisors/skilled/beta workers and a large number of relatively low skill/alpha workers. I shall keep with tradition and continue to refer to the model's $i$-elements as firms.

The minimum of efficient labour units in alpha and beta is the potential output ($Y_{i,t}$) of the firm and this will exceed the target in most periods, as there is generally excess beta labour. The number of efficient labour units in alpha occupation is the number of workers in that occupation ($\#\alpha$) irrespective of their abilities. In the beta occupation, by contrast, the number of efficient units of labour is equal to the sum of the workers' inherent abilities, i.e. types, $\theta_w$. Firms do not know these inherent abilities but have estimates of them as described in section 4.3.3. Thus the expected number of efficient labour units in alpha is, correctly, the number of workers in alpha, while the expected number of efficient labour units in beta will differ from the actual number.

$$Y_{i,t} = \min(\#\alpha_{i,t}, \sum_{w=1}^{\#\beta_{i,t}} \theta_w) \tag{5}$$

$$Y^e_{i,t} = \min(\#\alpha_{i,t}, \sum_{w=1}^{\#\beta_{i,t}} \theta^e_{w,t}) \tag{6}$$

Equation 5 is actual output while 6 is expected output. Firms compete to set $Y_{i,t} = \bar{Y}_t$ with minimum labour costs by minimizing the difference between $\theta^e_{w,t}$ and $\theta_w$ in the beta department of the firm. This will be achieved by learning about the abilities of the workers and becoming better at interpreting the education signal.

When a worker is hired the firm ascribes to her an expected productivity based on current beliefs or the institution of the signal. As time goes by the firm learns about the actual abilities of those that it employs, and after $T^L$ periods the true type of the worker is revealed.

[8]The idea of a signalling model with complementary types of labour is inspired by Arrow (1973). In e.g. Spence (1973), where workers are perfect substitutes, the firm has no incentive to learn about the actual abilities of the workers: it simply pays workers according to average ability. By instead following the suggestion by Arrow the firm is given an incentive to sort workers by ability for the different task required for production.

| Department | Role | Efficient labour units | Cost pr. worker |
|---|---|---|---|
| Alpha | Menial/Production | No. workers | 1 |
| Beta | Challenging/Managerial | $\sum \theta$ | $\pi$ |

Table 1: The occupations

Firm performance is measured by labour costs. As there is no output market and no measure of profit there are no constraints on labour costs. Labour costs is the sum of the wages paid to workers doing menial tasks in alpha occupations and the wages paid to workers doing advanced tasks in beta occupations. It is assumed that firms are wage takers and the wage in alpha is standardized to unity. The wage to workers in beta is denoted by $\pi$. Equation 7 describe this relationship.

$$C_{i,t} = \#\alpha_{i,t} + \pi\#\beta_{i,t} \tag{7}$$

The Leontief production function means that firms have no preference for workers when hiring for alpha occupations but prefers type High workers with for beta occupations. Varying the parameter for the premium on having workers perform beta work allows for strengthening the selection pressure and thus incentive for minimizing slack. The characteristics of the occupations are summarised in table 1.

#### 4.3.2 Strategies

Firms operate in two different modes. In most time periods they operate by a business-as-usual rule but when the change in target scale is sufficiently large they follow an algorithm for reorganising the firm. Firms' strategies have three dimensions, as listed page 12: the inertia that the organisation has to changes in target scale before enacting the reorganisation algorithm ($\tau_i$), the choice of learning versus imitating ($\mu_i$) and the tendency for building up slack for increasing the number of efficient labour units in beta occupations ($\epsilon_i$). Some firms fire the lowest ability workers whenever they become expendable but this also means hiring new workers whenever the target increases again and thus starting over learning about their abilities. On the other hand some firms keep on workers, even though there is a surplus of workers, in order not to lose the knowledge of their abilities; they hoard labour. Whether primary focus on learning or selection is the best strategy is expected to depend on the volatility of target scale and the premium on labour costs for workers in beta occupation. Whenever the premium is high and/or the target is very volatile it is expected that selection is the best strategy. If it is expensive to keep excess workers employed or there is high need to adjust both up and down costs should be lower in firms that are quicker to adjust the labour force. On the other hand, firms that invest in learning about their employees abilities are expected to fare better when the cost of keeping excess workers is relatively low and/or organisational readjustment is needed so rarely that slack is stable. If target volatility is high the number of excess worker will be varying widely and the costs of keeping excess workers on will potentially be very high.

In the current paper focus is on the $\tau$ and $\epsilon$ parameters. $\mu$ will only be allowed to take on values of 1 or 0 indicating complete reliance on either own knowledge or imitation, firms are not allowed mixed strategies in this respect. For consistency firm that do not tolerate slack—and thus are expected not to learn—should not rely on their own knowledge. I.e. when $\epsilon_i$ is close to 1 $\mu_i$ should be 1. But strategies are randomised in the simulations. The formal roles of the parameters in learning is described in the following.

#### 4.3.3 Firms' learning

Firms each have a cognitive model representing their knowledge of the labour market. Firms continuously reproduce their routines for interacting with the labour market; i.e. routines for hiring and firing. Firms' production routine is also reproduced at each time step, and firms strive to improve it at each reproduction based on their cognitive model. Improving the production routine means minimizing labour costs but it should be kept in mind that target output also evolves.

Firms' cognitive models can in principle fall into three different categories as described by equation 8. A firm may believe that $\sigma_w = 0$ indicates a High ability worker, that the signal does not indicate ability or that $\sigma_w = 1$ indicates a High ability worker.

$$p(\theta_w = H|\sigma_w = 1) \gtreqless p(\theta_w = H|\sigma_w = 0) \tag{8}$$

However because of the structure of the model only the last case, i.e. when the left hand term of equation 8 is the greatest, has relevance. The problem for firms is to identify the reliability of the signal. Denote this belief $p^+_{i,t}$. This is the cognitive model of firm $i$ at time $t$. Not all firms trust in their own knowledge, they rather rely on the institution of the signal. This means imitating what the inferred cognitive model of the average firm at $t-1$ and is denoted by $S^+_t$.

$p^+_{i,t}$ is updated by firms examining their own workforce. After $T^L$ rounds of employment the true type of a worker is revealed. But because of changes in the labour market the relationship between ability and signal evolves over time. So firms consider only workers with at least $T^L$ but less than $T^D$ tenure. The share of educated workers that are type High and with tenure satisfying this constraint at $t-1$ is the firm's $p^+_{i,t}$. $S^+_t$ is updated by inference of the cognitive model of the average firm; it is the inverse of output per beta worker in the economy as a whole at $t-1$. That is, $S^+_t = \frac{\sum_i \#\beta_{i,t-1}}{\sum_i Y_{i,t-1}}$.

$S^+$ should be superior to $p^+_i$ at any time step as it uses more information in its computation. But if no firms follow the information prescribed by their cognitive models then $S^+$ will not evolve in correspondence with the labour market. This is a classic principle: herd behaviour is free-riding and it only works if others are not free-riding. Whether firms rely on one or the other estimate is described by the $\mu$ parameter of their strategies. In the current paper firms are not allowed to mix the estimates so $\mu$ only takes value of 0 or 1. The estimate that firms act by is referred to as $\rho_{i,t}$, cf. equation 9

$$\rho_{i,t} = S^+_t \mu_i + (1-\mu_i) p^+_{i,t} \tag{9}$$

Firms now the values of the parameters $L$ and $H$ when estimating ability and they always expect uneducated workers to have ability $\theta^e_{w,t}(\sigma_w = 0) = L$.

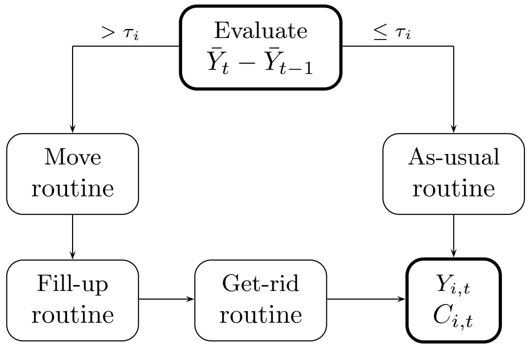


Figure 1: The four routines

Educated workers, on the other hand, are expected to have ability $\theta^e_{w,t}(\sigma_w = 1) = L + (H - L)\rho_{i,t}$. When tenure exceeds $T^L$ then $\theta^e_{w,t}(\sigma_w) = \theta_w$.

### 4.4 An algorithm for reorganising a firm

Whenever the absolute change in target scale exceeds the tolerance ($\tau_i$) of a firm the firm reorganises. This has three steps. First the firm evaluates its current workforce. Workers in alpha occupations, for which the firm has learned their true ability and found that $\theta_w = H$, are moved to beta occupations at the expense of a type Low worker in beta. This continues as long as there are known type Low workers in beta and known type High workers in alpha.

After moving workers from alpha to beta there may yet be too many or too few workers in either occupational category relative to $\bar{Y}_t$. The firm first hires workers as needed. A new worker is a random draw based on the current composition of the labour market (i.e. the $h_t$ random walk and the relative abundances of the strategies for signalling). The firm allocates educated workers to beta work as long as $\sum_{w=1}^{\#\beta_{i,t}} \theta^e_{w,t} < \bar{Y}_t$, and non-educated workers to alpha as long as $\#\alpha_{i,t} < \bar{Y}_t$. When the firm has sufficient labour in one occupation it adds new workers to the other occupation irrespective of their type.

As the last step in the algorithm the firm gets rid of a share of surplus workers. The exact share is dictated by the firm's strategy parameter $\epsilon_i$. For example, $\epsilon_i = 0.9$ means that firm $i$ fires 90 percent of workers estimated to be redundant. Firms fire workers with the longest tenure first. This is simple but perhaps not realistic. It must though also be kept in mind that workers do not have endogenous behaviour: they do not quit and they do not die. Firms would prefer to have type High workers on reserve in alpha occupation though type High workers would prefer to get beta occupations and earn a higher wage. Thus, as workers cannot quit, it makes sense not to allow firms to keep then indefinitely.

Figure 1 illustrates the different modes of operation for firms. If $\bar{Y}_t - \bar{Y}_{t-1} > \tau_i$ the firm goes through the three subroutines of the routine for reorganisation and otherwise the firm employs the as-usual routine. See appendix A for flowcharts of the subroutines and further details.

This three step algorithm for reorganising the firm (1: move workers, 2: hire workers, 3: fire workers) is only activated when the change is target scale exceeds a firm's tolerance. In most periods firms follow a simple rule for business-as-usual. This means that if any department is under-staffed a random worker is hired to take the position. And if any department is over-staffed redundant workers are fired with probability $\epsilon_i$. It is possible that a firm will end up short on beta workers and not able to reach the target. In this case, the firm is assigned beta workers of random type with the assumption that $\theta_w^e = L$ irrespective of signal.

There are two groups of parameters of particular interest in this model. One group defines the volatility of the firms' external conditions; in particular target scale. The other group defines firms' strategies. With regard to firms' context primary focus is on the cost premium on workers doing the demanding beta work and the parameter determining the volatility of the target scale ($\pi$ and $\upsilon_2$). $\upsilon_1$ is not varied. In the other group focus is on inertia and excess labour ($\tau_i$ and $\epsilon_i$). $\mu_i$ is also varied but restricted to 0 and 1. In the following section the computer version of the model is explored for different combinations of these parameters.

# 5 Implications of the model

In order to compare the performance of different strategies for learning the model is simulated 100 times for 1000 time periods under 10 different market conditions (random combinations of target volatility $\upsilon_2$ and cost premium $\pi$ for beta work) with 20 firms all following random strategies (combinations of inertia $\tau_i$, slack $\epsilon_i$ and imitative behaviour $\mu_i$). Firm performance is compared by comparing average unit labour costs.

The results from these simulations are summarized in table 2 as tentative results. One of the most consistent results of the simulations is that the wage premium on beta work ($\pi$) does not matter much for the performance of strategies. But the lower the premium the more random the results. This makes very good sense, as the role of the parameter is to make competition more intense: the higher the cost premium on workers in the beta department the higher the importance of minimizing the number of workers in this department for overall labour costs.

The role of the building up slack ($\epsilon_i$) is not quite as anticipated. It was expected that lower labour turnover would mean a more accurate estimate of the probability that an educated worker has high ability. Larger target volatility increases turnover but firms can decrease this impact by accepting some slack. But under no market conditions is a strong focus on retaining workers for learning about their abilities a good strategy. However strategies with a strong focus on minimizing slack exhibit some interesting interactions with the other strategy parameter: inertia ($\tau_i$). Under medium to low volatility conditions an intermediate acceptance of slack combined with a high tolerance is the superior strategy. This means that firms that reorganise relatively infrequently but make sizeable cuts in the labour force when they do reorganise have the best performance. As volatility is increased the performance of this interesting combination fades and the superior strategy becomes to reorganise often (low tolerance) and accept no slack when adjusting scale.

To put the results concisely: A higher wage premium on beta work makes the differences in performance clearer while the relative performance of the

| *Parameter* | *Role* | *Result* |
|---|---|---|
| | Market conditions | |
| $\pi$ | Cost premium on beta work | The higher the value, the clearer the differences among strategies. |
| $\upsilon_2$ | Volatility of $\bar{Y}$ | The higher the value, the stronger the performance of high $\epsilon_i$ and low $\tau_i$ strategies. |
| | Strategies | |
| $\epsilon_i$ | Average share of redundant workers fired | High values perform well under high volatility, medium values perform well under low volatility. Low values never perform well. |
| $\tau_i$ | Tolerance towards change (inertia) | Low values perform well under high volatility, high values perform well under low volatility. |

Table 2: Summary of results

strategies depends mostly on the volatility of the target. For a very volatile target the best strategy is to adjust frequently and not accept slack, whereas for a less volatile target it is better to adjust infrequently and to keep some workers when they become redundant—but only up to a limit.

The results imply that there is no inherent contradiction between labour markets with high mobility and high average tenure both being efficient. Firms operating under highly volatile conditions need to adjust scale frequently and do not have the luxury of being able to keep the same workforce for long and thus do not learn about their abilities. However, if firms are operating under more stable conditions, it is preferable for the firm to follow a strategy of learning about the abilities of workers and not changing the organisation of the firm for relatively small shifts in scale.

# 6 Conclusions

This paper has argued for a theory of firm strategies for adapting to market changes when there is uncertainty about the qualities of labour. The theory takes its point of departure from classic signalling theories and combines it with insight into firms' routines as developed in evolutionary economics. The theory explains how and why firms benefit from slack and inertia towards organisational change and under which market conditions this applies. The main contribution of the paper is in constructing the theory and deriving tentative implications. There is yet much analysis to be undertaken of the model's implications.

One area that is especially important to pursue further is the model's knowledge externalities. As long as some firms base their actions on their own cognitive models it will pay for others to use more imitative strategies. I.e. the role of the $\mu_i$ parameter must also be included in the analyses. Preferably, some degree of consistency should be incorporated between the $\mu_i$ and $\epsilon_i$ strategy parameters: firms that rely on imitative behaviour should not invest resources in halting labour turnover and updating its cognitive model. That is, $\mu_i = 1$ should be accompanied by $\epsilon_i \lessapprox 1$ in firms' strategies. It is suspected that the superior performance of the low slack plus frequent adaptation strategies under volatile market conditions are a consequence of these firms free-riding on the market signals developed by firms focussing more on learning about the abilities of workers and the meaning of signals.

The theory presented in this paper has a some similarities to theories of job matching but also some important differences. Job matching models often have endogenously determined behaviour of workers, not just of firms, as such models seek to optimize the fit of heterogeneous jobs and heterogeneous workers. The model presented in the current paper, on the other hand, is one of firms striving to adjust their production technology/organisation without full knowledge of the quality of the inputs. Generalizing the model to include job matching would make the differences in performance of the strategies for learning stand out even stronger but it would also complicate the model a great deal. Currently, the labour market is represented by probability distributions and individual workers are only modelled explicitly when they are employed. Were they to be unique elements of the model with own behavioural rules, the hiring/firing and wage determination processes would have to take workers' outside options and motivation for supplying effort into account too. Such complications would make it even more pivotal for firm performance that the firm is capable of inferring the qualities of workers. It would thus exasperate difference in performance of strategies for learning.

Later research analysing more details of the theory is expected to generate insight of relevance for policy makers. There is an important characteristic of the environment that is implicitly assumed in the current paper: firms are allowed to decide for themselves what level of slack they prefer. This is most realistic for economies where there are very weak, if any, restrictions on firms firing workers. E.g. the Nordic and Anglo-Saxon economies. For policy it is interesting whether such a lack of restrictions on firing means a race to the bottom eroding institutions. Or whether policy should rather aim to create stable institutions, and allow for firms to free-ride and exploit them. And the tentative results already show that there is no a priori reason for policy to promote neither high job mobility nor long tenures: what is best depends on the volatility of markets

By building on a reasonable set of assumptions the theory presented here has cast some light on the process of decoding signals and inferring abilities; with special respect to questioning the desirability super efficient, no-slack organisations. Such organisations could have merit only in highly volatile market conditions but later research will show whether their performance in such environments still rely heavily on the existence of other organisations creating externalities for them to exploit.

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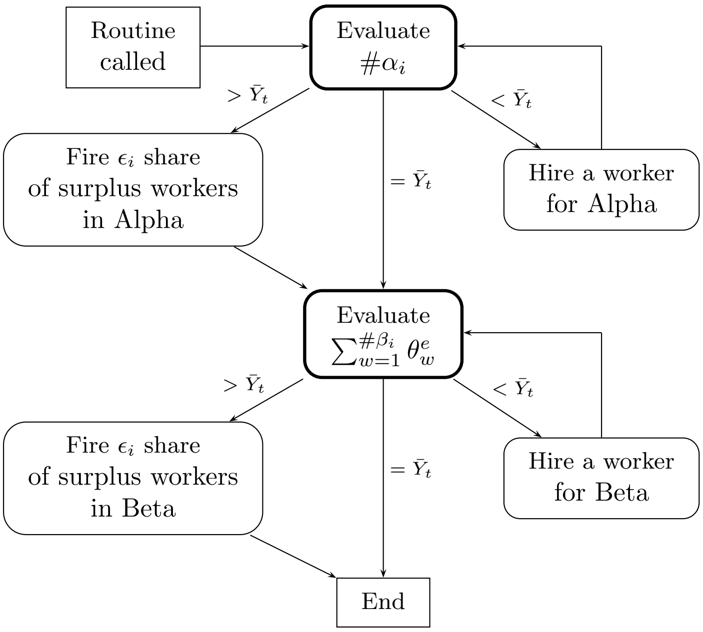


Figure 2: As-usual

# A Algorithms and routines

This appendix describes the minute details of the routines employed by the firms. Figure 1 page 16 shows how the routines are connected and under which conditions they are initiated. The appendix contains several references to the amount of productive labour in alpha and in beta occupations, and to expected output without $t$ subscripts. This is because these three variables are updates repeatedly during each time step as the firm adjusts to organisation to the current target, $\bar{Y}_t$.

When the firm is not reorganising it employs the as-usual routine depicted by the flowchart of figure 2. The firm first evaluates whether the number of workers in alpha occupations is sufficient and secondly whether the expected number in beta is sufficient.

The hiring and firing subroutines of the as-usual routine are not mere mirror images of each other. Hiring is a random draw based on the distribution of types in the labour market ($x_\phi$, $\phi = 1 \dots 4$ and $h$) and the worker is hired in the occupation category currently being evaluated irrespective of her qualities. Firing, on the other hand, is undertaken by first determining the amount of productive labour to be shed, then selecting the sufficient number of workers and firing a share, $\epsilon_i$, of the selected workers.[9]

Thus under the as-usual routine firms maintain the amount of slack set by their strategy and hire workers that are not necessarily well equipped for the occupation assigned to them.

[9] Technically, $\epsilon_i$ is the probability that any given of the selected workers is fired and it thus only equal to the share of fired workers on average.

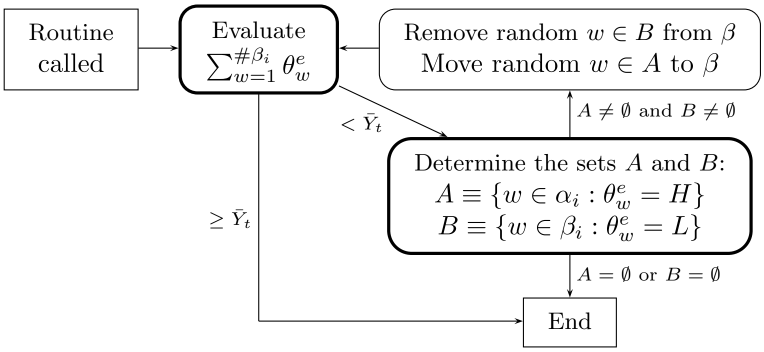


Figure 3: Move

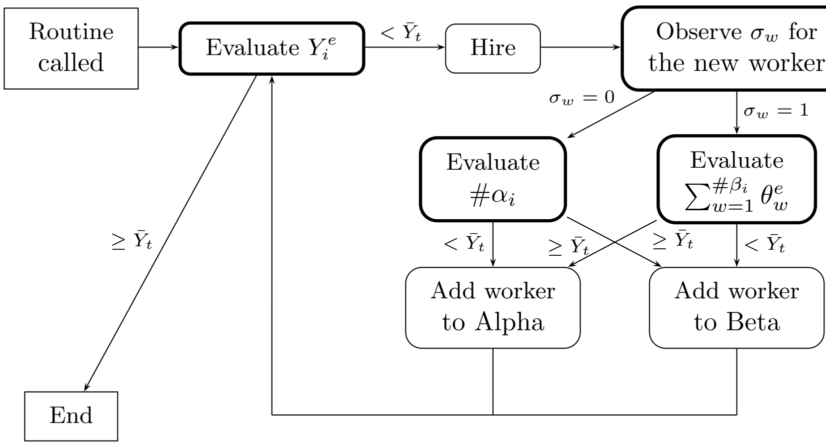


Figure 4: Fill-up

## A.1 Reorganisation

When the there is a change in the market that exceeds the tolerance of a firm ($\bar{Y}_t - \bar{Y}_{t-1} > \tau_i$) the firm reorganises by going through three steps: moving around workers in the firm, hiring as needed and firing as required.

The first step is the move routine, as depicted in figure 3. If there is insufficient effective labour in beta occupations the firm compares the workforces in the two occupations. If there is a type High worker in alpha and a type Low worker in beta, then the latter is fired and the former takes her place. This continues as long as there is insufficient effective labour in beta or no more moves are possible.

After moving workers from alpha to beta the fill-up routine is initiated. Figure 4 is a flowchart of fill-up. In the case that $Y_i^e < \bar{Y}_t$ then at least one of the departments need further workers and the firm hires a worker.[10] This is a random draw and if the worker has education she is hired in a beta occupation. Otherwise, she goes into alpha. If either department is already full the worker goes into the other department.

[10] And $Y_i^e = \min(\#\alpha_i, \sum_{w=1}^{\#\beta_i} \theta_w^e)$, cf. main text.

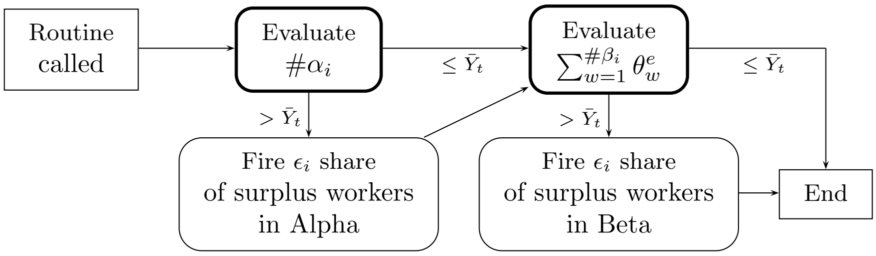


Figure 5: Get-rid

Once both departments have at least the number of workers necessary the routine terminates and the get-rid routine is initiated.

Figure 5 illustrates the get-rid routine by a flowchart. It first evaluates whether there is surplus workers in alpha, fires them if this is the case, and then does the same for beta. As with the as-usual routine the firm keeps on slack as determined by $\epsilon_i$. Obviously the impact of each subroutine on a firm's workforce depends on whether the target scale is increasing or decreasing.