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Abstract

Empirical research on the consequences for firms' performance of labour turnover rates often has problems measuring labour turnover in a way that allows for strict investigation of common hypotheses in the literature. In this paper, a model developed for studying firms' acting under asymmetric information is adapted to shed light on the relationship between turnover and performance, and to contribute to the understanding of the causal relationships between labour turnover and performance.

It is show that voluntary turnover has the expected negative effect on performance while the relationship between involuntary turnover and performance is complicated. This complication stems from labour turnover and firms' performance both being consequences of strategies for solving labour market information asymmetries rather than turnover affecting performance directly.

The labour market is modelled with heavy inspiration from Michael Spence's classic labour market of asymmetric information. There are two types of workers and these may choose to take education or not in order to signal their type. The signalling behaviour of workers depends on the benefits to signalling, i.e. on the wage premium that they can expect to receive if they choose to take education.

Firms aim at producing a given amount of homogeneous output and labour is the only input to this. Firms must hire workers based only on the observation of the signal. In order to maximise performance, which in the model means minimising unit labour costs, firms need to identify the able type of workers from the less able. Firms' strategies differ according to their organisational inertia and slack. Inertia means stability and thus more efficient routines but it also means that bad matches of occupation and ability persist. Slack means deliberately hiring more workers than is expected to be needed. This comes at a costs but it also acts as an insurance of available labour, should the firm have overestimated the abilities of its workforce.

The performance of firms' strategies depends on environmental factors; some of them endogenous via the labour market and others exogenous. In this paper focus is on varying exogenous factors that have a direct impact on labour turnover: the rate of voluntary turnover and the speed at which routines improve when firms' organisation is stable. Varying the latter is sufficient for radically changing the evolution of the labour market; for example developments where education is a credible signal of ability, developments where the unable attempt to bluff and earn the wage premium to education, and developments where the premium to education is so low that education cannot function as a signal. Often, the model switches back and forth between these three extreme cases.

The specific characteristics of the asymmetry in the labour market do not have a large effect on the performance of firms' strategies. Strategies that are effective at minimising labour costs in the long run tend to be superior in coping with any labour market. However, focus here is on the relationship between labour turnover and performance; not in identifying superior strategies.

Generally, very low total turnover is associated with very low performance, as these are characteristics of overtly inert firms. For less inert firms, however, performance is generally higher and total labour turnover varies widely. This result pertains to involuntary turnover, as voluntary turnover is exogenous. Varying the parameter for the rate of voluntary turnover yields the expected result of decreasing performance: firms lose knowledge about the labour market asymmetry when they lose employees.

The model is thus in line with the literature on labour turnover as voluntary turnover has a negative effect on performance. And it explains why empirical research, which often is based on measures of total turnover, have difficulties testing hypotheses regarding the effect on performance: involuntary turnover is generally necessary for high performance but the extent varies widely with stochastic shocks and firms' path-dependent development of routines.

Key Words:
Labour turnover; Voluntary Turnover; Involuntary turnover; Performance effects; Asymmetric information; Signalling model; Routines; Simulation model

1. Introduction

Firms acting in uncertain environments will perform badly if they attempt myopic optimisation. They must also allocate resources to mend the uncertainty of the environment. This entails managing their labour force with the twin aims of maximizing productivity in the short run while minimizing the uncertainty created from labour turnover in the longer run. Routines for efficient production must be in place which do not conflict with routines for interacting with the labour market

The ideal trade-off between short run efficiency and long run management of the organisation can be expected to depend on the environment, specifically its uncertainty. On the one hand uncertainty creates a need for learning which suggests that short run efficiency must be sacrificed. On the other hand too much uncertainty may mean that learning is too expensive and firms need to focus on short run efficiency. Wages are an important parameter for interacting with the labour market as signalling games and principal-agent models have demonstrated in general, and which Henry Ford's efficiency wages demonstrated in particular. By paying wages that were significantly higher than the market level Ford traded short run optimisation for long run efficiency by decreasing labour turnover and increasing workers' average tenure. The model developed in this paper is an extension of the model developed in (Holm, 2011, Ch. 2).[1] The focus of the original exposition was to explain the heterogeneity across labour markets as a consequence of how firms manage their workforce in interaction with the uncertainty of firms' environments. It the current paper focus is on the effect of voluntary labour turnover on the performance of firms in such uncertain environments.

There exists a large number of studies on the effects of labour turnover (recent reviews of this literature includes Shaw (2011); Hausknecht and Trevor (2011); Holtom et al. (2008)). A distinction is generally made between voluntary turnover; i.e. workers quitting their jobs, and involuntary turnover; i.e. workers being fired. The distinction is consistently made in contributions to theory

[1] The paper represents a further development and at the same time a condensation of chapter 2 of my PhD thesis (Holm, 2011). The PhD degree was awarded in February 2012. Compared to the thesis version this paper presents a slightly simplified model and a much condensed analysis focussing on a single aspect: the relationship between labour turnover and unit labour costs. A pdf-version of the thesis is available upon request.

while empirical research generally cannot distinguish between voluntary and involuntary turnover. Thus it is common to measure turnover as the gross outflow of labour over a given period.

The literature on labour turnover generally focusses on the problem of retaining valuable workers and replacing them should they choose to quit. Whether focus is on the antecedents or consequences of involuntary a common moderator is theorised to be human resource management practices, organisational structure the diversity of the workforce and the occupational categories of the organisation. Empirically, however, many of the theoretical relationships have been illusive -- not least for want of adequate measures of voluntary turnover (Shaw, 2011; Hausknecht and Trevor, 2011). In the simulation model of chapter 2 in Holm (2011) voluntary turnover is set by a common parameter value for all firms but involuntary turnover - and thus total turnover - varies widely as a consequence of heterogeneous strategies for solving an imposed labour market asymmetry.

Theories concerning the effect of (voluntary) turnover on performance appear in several forms but they all rely on the premise that when members quit an organisation it looses firm specific human capital and social capital, experiences a disruption to its routines and incurs various forms of search and training costs in connection with replacement. Theories differ to the form of these effects: some argue that the relationship is linear negative. Others that the marginal effect of voluntary tenure decreases; i.e. an attenuated negative relationship. This is based on the idea that organisations experiencing high turnover rates develop structures and routines to manage the negative effects. Yet a third group of theories hypothesise an inverted u-shape: a low rate of turnover is healthy as it invigorates the organisation and makes it open to new ideas from without. But after some threshold the aforementioned negative effects come to dominate. However, empirical evidence for the inverted u-shape is scant (Hausknecht and Trevor, 2011).

As mentioned above, empirical research tends to rely on total turnover whereas theory generally refers to voluntary turnover. Despite this much empirical research nevertheless supports the notion of a negative effect of turnover on performance. The model analysed in the current paper illuminates on the effects that lead total turnover to be associated with performance even when voluntary turnover is uniform across firms. Weak performance and high total turnover are shown to both be consequences of labour market information asymmetries.

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 employers cannot know the ability of a worker prior to hiring him and they therefore need to infer his ability from the signals he 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.

The model considers only costly signals where the cost to the potential employee of signalling is negatively correlated with his quality to the employer. In classic models this signal is referred to as education with the assumption that inherently high productivity workers suffer less dis-utility from taking education. The role of costly signals is considered in only one scenario: the hiring and firing decisions and effects on organisational structure of firms. Firms readjust their scale continuously and some more efficiently than others. They build up slack resources 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 in order to have particular tasks solved. However, all this relies on the ability of organisations to decode the abilities of its members.

The paper is structured as follows. Section 2 present earlier contributions that the model of the current paper builds upon. The section discusses contributions in evolutionary economics and population ecology that form the basis for the theory of firm behaviour, and it discusses classic models of labour markets with asymmetric information that has inspired the model of the current paper. Section 3 develops an evolutionary signalling model and the relationship between labour turnover and performance are analysed in Section 4. Section 5 concludes. All figures are placed after the main text and references of the paper.

2. Firms: routines and learning processes

The modelling of firms in this paper follows contributions in the field of organisational ecology (Hannan et al., 2007; Barnett and Freeman, 2001; Carroll and Hannan, 2000; Hannan and Carroll, 1992; Kelly and Amburgey, 1991; Hannan and Freeman, 1984, 1977). This literature generally focusses on the evolution of populations of firms through entry and exit, while incumbent firms are argued to be highly inert. The model in the current paper includes only incumbent firms and their organisational structures and the algorithms of routines are fixed. But firms' labour forces and firms' knowledge evolve through adaptation. Firms' knowledge evolves through trial-and-error in hiring and firing decisions and in assigning occupations to workers.

Firms' behaviour

Firms act by decision rules (or algorithms). Such rules are action patterns: basic elements of behaviour and stores of capabilities at the firm. Such rules are commonly labelled “routines”, though there is some discrepancy in the literature (Nelson, 2009; 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 signals sent by workers. And learning also follows routines. Learning is what agents do when they encounter situations that their current routines fail to deal with in a satisfactory manner. Agents then strive to make sense of the situation based on categorisations and heuristics (Dosi et al., 1996). Such learning in signalling models goes back to the earliest contributions: Firms categorise workers based on workers' signals and ascribe to workers of each category the average ability previously observed for this category (Spence, 1973). 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 model 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 mean 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 to the latter: Firms may differ in behaviour (phenotype) even with identical strategy parameters (genotype) because of different past experiences in interacting with the labour market. Similarly, differences in experience can in principle lead to firms with different strategies behaving in the same way. But in no case will phenotype affect genotype: strategies are permanent.

It is a central element of models in the organisational ecology literature that routines are stable. Economic selection favours firms with high reproducibility of routines and thus indirectly it favours inert firms. Firms may attempt to change but this increases their risk of exit as new action patterns must become routinised and reproducibility must be re-established. This implies that low labour turnover is desirable, as Henry Ford discovered. The model presented in the current paper does not allow for firms to implement new routines but labour turnover is a central element and it has an effect similar to what Ford observed: higher turnover means lower average tenure and thus that the production routines have less scope for improving through learning by doing. A secondary effect is that firms will find it much more difficult to assign occupations when workers have lower tenure as there will be more uncertainty regarding their abilities.

Workers are strongly simplified in the model. Their abilities are inherent and based on this endowment they must decide which signal to send. The assumption that signal is costly and that this cost is negatively correlated with ability means that the signal has the potential of being a credible indicator of ability.

Signalling

The concept of signalling in economics is ascribed to Michael Spence and refers to a process of remedying asymmetric information. In this process, the informed party works to convey information to the uninformed party through signals, which the uninformed party must interpret.[2] The two 1973 papers 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.

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 firms have stopped learning: their current beliefs are reaffirmed by what they observe when hiring.

The original exposition in spence, 1973, 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 for signalling depends on what other workers are doing and what the current state 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.

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. 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.

In the theory suggested in Section 3 wage costs reflect firms' learning about information embedded in signals. But firms do not set wages: occupation category determines wage. Firms must learn about workers' abilities and sort them into occupations correctly to minimize labour costs.

[2] Two relatively recent overviews of this literature are Löfgren et al. (2002) and Riley (2001). See (Hurd, 2006; Maynard Smith and Harper, 2003) for the extensive research on the biological evolution of signalling behaviour.

In the classic models firms never uncover the true ability of workers, they only observe differences according to category of signal and form prejudices accordingly. This will be adapted in the current model. The time dimension plays a large role in modelling of learning processes and firms will in time find out whether their initial prejudices were justified. Thus only recently hired workers are judged - and paid - according to signal, while longer tenure means that their ability has been uncovered and their occupation and wage adjusted accordingly. This points to a complication that is also relevant for classic models but which becomes emphasised here by the explicit inclusion of a time dimension: the comparison undertaken by the worker of the costs of sending the signal (taking education) and wage premium to the educated. In classic models it is necessary to assume either that workers compare the cost of signalling to the discounted value of all future earnings (as is implicit in Spence's comparison to investment) or that the cost of signalling is incurred at each time step. When time is considered explicitly and firms learn about workers by employing them, workers will, in time, end up with a wage that corresponds to their abilities regardless of their signal. Thus the signal is an indicator used by the firm as a substitute for information and primarily affects wages early in the employment spell. This is quite realistic when considering wage as a costly signal: it is a stylized fact that the longer experience a person has in the labour market, the lower the correlation of wage and education.

In the current model this means that workers observe per period wages when deciding whether to take education even though they can expect the wage to depend on their signal in multiple rounds; not just the first.

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 skills and so on. These qualities are results of upbringing. 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 which 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 it has a limit: 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. Furthermore, early school years are also part of a person's upbringing.

The model of the current paper is similarly 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 do workers become more able through experience. But firms' production routines become more efficient as the average tenure of their workforce increases. This is a sort of passive learning, as the learning by doing models of Thompson (2010); Dasgupta and Stiglitz (1988); Jovanovic (1982); Arrow (1962), but it is applied here to the routines of firms and not to individual workers. It is argued in the organisational population ecology literature that firms' routines become consistently better through use but that these gains are transient and easily lost if firms change their routines. When firms change their organisational structure they will also change routines. This is captured in the current model by letting the efficiency of production routines depend on the average tenure of workers. And organisational change will generally entail a decrease in average tenure.

Employers also learn by doing in a second sense. Every time she hires a new worker it has an initial expectation of his usefulness---and this expectation is revised as the worker is observed doing his 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.

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 central in some of the 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 focus considerably.

3. An evolutionary signalling model

The model comprises of two more or less separate objects. The supply side 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 wage costs. Firms interact directly with the labour market but only indirectly with each other through their actions in the labour market.[3]

Firms produce some unspecified output, Y, in a target quantity. The “firm” or “employer”, as referred to in the model, is a production plant, a department of computer engineers writing code, a branch office of a service company or a work gang in a construction company. The main feature of the firms in the model is that there are two types of work to be done: the menial production/coding/customer handling/construction work and coordination and supervision of the menial work.

The uncertainty of the model concerns workers' ability for supervising and coordinating. The amount of effective menial labour supplied by a set of workers is known but employers must learn to interpret signals and thereby infer who has the ability to supervise the set of menial workers. A supervisor can supervise 1 or H effective menial labour units depending on whether he has the ability to supervise or not.[4]

In this model employers only have a single mechanism for estimating the ability of a potential employee: estimation of the probability that he has the ability to supervise conditional on his education.[5] In line with classical signalling models it is assumed that the ability to supervise is

[3] The programme was written using the software Laboratory for Simulation Development (v5.9), which is available as open source from www.labsimdev.org (Valente, 2008). The computer programme of the model is available upon request.

[4] The model is highly inspired by Spence, (1973) and therefore workers capable of supervising H menial workers are referred to as type High workers while others are type Low. The idea of employing workers in two complementary occupations is inspired by Arrow, (1973) and in the current model menial workers are referred to as alpha workers or workers in alpha occupation while supervisors are referred to as beta workers or workers in beta occupation. No association is intended with the alpha and beta prefixes of biology and software development respectively.

[5] Again, the kinship with Spence and other contributions in the signalling literature means that “take education” and “send signal 1” are used synonymously in this paper. Also: “not take education” and “send

inherent and not acquired through education but that education is easier to acquire for those with the ability. After some time of employment the firm observes the actual inherent ability of its employees and it uses this information to gauge the relationship between education and ability. Thus firms' hiring decision depends on past random events.

Workers are not confined to the occupations they are given when hired in the model. If it turns out that an unable worker is working as a supervisor and an able as menial worker, then the employer may fire the former and move the latter to supervisor occupation.

The hiring, firing and moving of workers takes place before production. If a firm fails to have sufficient aggregate supervision ability when production takes place (that is, the sum of effective labour in supervising occupation is less than target output) then it is forced to hire supervisors under the assumption that none of them have the ability. This mechanism imposes relatively high costs on the firm and mimics the assumption that not meeting target scale is expensive.

The structure of the hiring and firing processes means that variables describing the expectation of ability conditional on education are path-dependent and firm specific. This suggests that the model should be simulated rather than solved analytically. Analytical treatment of a simplified version is possible and has been explored earlier (Holm, 2011, Ch. 2).

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 where type High has the supervisor ability and Low does not. Formally, worker *w* has inherent ability θ_w, and θ_w takes on only two values, *H* or 1. $\theta_w = 1$ is referred to as type Low and $\theta_w = H$ as type High. *H* is a parameter that can be varied but which should always be greater than one.

The type of a worker is known only to the worker himself. Based on his ability he chooses to send the signal 1 or 0, which in the following is referred to as taking education or not ($\sigma_w \in \{1,0\}$). Workers base their choice of signal on their type and taking education is more expensive to type Low than it is to type High.

From the firms' perspective there are two categories of workers offering labour services: the educated and the uneducated. 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. action contingent on inherent type:

1. Cautious (*C*): Never take education ($\sigma_w = 0$)
2. Only take education if type is Low ($\sigma_w = 1$ if $\theta_w = 0$ else $\sigma_w = 0$)
3. Honest (*H*): Only take education if type is High ($\sigma_w = 1$ if $\theta_w = H$ else $\sigma_w = 0$)
4. Bluff (*B*): Always take education ($\sigma_w = 1$)

Strategy 2 is of no practical relevance as the structure of the model entails that it is never viable. The remaining three strategies are referred to by their behavioural pattern. Strategy 1 is the

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signal 0". It is argued below that the signalling problem extends beyond signalling "supervision ability" by education.

cautious (*C*) strategy as is means never risking to waste resources on signalling. Strategy 3 is the honest (*H*) strategy as it means employing the signal as employers will generally expect: only type High take education. Strategy 4 is the bluff (*B*) -- taking education irrespective of ability.

The share of workers that are awarded type High is a parameter and this share is denoted by *h*. 1-*h* is thus the share of type Low workers. The evolution of the labour market is strictly adaptive but 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 $\phi \in \{C, H, B\}$ from the list above. ω_t^+ and $\omega_t^\div$ are the average wages paid to educated and uneducated workers respectively in the economy.[6] C_H and C_L are the costs of taking education for types High and Low, and $C_L > C_H$. The pay-off to strategy ϕ at *t* is determined by equation 1.

$$P_{\phi,t} = h a_{H,t}(\phi) + (1-h) a_{L,t}(\phi) \tag{1}$$

where

$$a_{H,t}(\phi) = \begin{cases} \omega_t^\div \ if \ \phi = C \\ \omega_t^+ - C_H \ if \ \phi \in \{H, B\} \end{cases}$$

and

$$a_{L,t}(\phi) = \begin{cases} \omega_t^\div \ if \ \phi \in \{C, H\} \\ \omega_t^+ - C_L \ if \ \phi = B \end{cases}$$

As with classic models the cost of education is only compared to the initial wage. As was mentioned above this can be dealt with by arguing that the wage and costs represent properly discounted sums of life long earnings and costs. Or by emphasising the stylised fact that the effect of education on income is strongest in the short run.

After determining the fitness of each strategy it is 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 three strategies is updated by Equation 3, where $x_{\phi,t}$ is the relative abundance in the labour market of strategy ϕ 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.

$$F_{\phi,t} = \frac{P_{\phi,t}}{19 + e^{P_{\phi,t}}} \tag{2}$$

$$x_{\phi,t} = x_{\phi,t-1} \frac{F_{\phi,t}}{\sum_\phi x_{\phi,t-1} F_{\phi,t}} \tag{3}$$

The fitness of each strategy depends on the demand side of the labour market. If firms strictly sort educated workers into high wage occupations and uneducated into low wage occupations then the wage discrepancy is maximised. In such a situation it may even pay for type Low workers to take education and thus the bluff strategy will come to dominate. In other words, if ω_t^+ is so much larger than $\omega_t^\div$ that even type Low worker are better off taking education, then no strategy beats bluffing. If the firms, on the other hand, do not base sorting into occupations on education then the cautious strategy will come to dominate, as wages to the educated and the uneducated will be very similar.

[6] Plus and minus are used as superscripts to denote with/without. The obelus (÷) is used for minus although, in English languages, this is not the tradition.

Somewhere in-between these two extremes is the sorting rigour that will allow the honest strategy to dominate and all sorts of situations where several strategies co-exist.

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, $\overline{Y_t}$. This target is the same for all firms.

The role of $\overline{Y_t}$ in the model is to make firms adapt continuously. It evolves as a mean reverting random walk with mean $\gamma = \overline{Y_0}$. The process is described in Equation 4 where υ_1 and υ_2 are parameters determining the volatility of the target and W_t is a random variable following a standard normal distribution.

$$\overline{Y_t} = \overline{Y}_{t-1} + \upsilon\_1 (\gamma - \overline{Y}_{t-1}) + \upsilon_2 W_t \tag{4}$$

The higher the value of υ_1 or the lower the value of υ_2 the less volatile the target will be. This stochastic process presents firms in the model with a continuously evolving problem of coordination: they must reach a given level of output by means of a single input, labour, without knowing the amount of effective labour (i.e. the sum of workers' abilities) that has been hired. Minimizing labour costs will entail learning to decode the education signal but this process depends highly on the characteristics of the workers encountered by firms, which is randomly determined depending on the strategies (ϕ) in the labour market.

Production

Firms consist of workers and routines. The population of workers within a firm is being continuously adapted to minimize wage costs conditional on the output target and this process is governed by a number of routines. The routine for creating output is a traditional production function while the routines for adapting scale are algorithms that differ across firms according to the parameterisation indicated by firms' strategies and their current prejudices.

Adjusting production to target output means adapting scale. Each firm seeks to match $\overline{Y_t}$ with as low labour costs as possible. Output is produced by a Leontief production function taking only labour - but two occupation 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 occupations at firm *i* at time *t*.[7]

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, as there is generally excess beta labour. The number of efficient labour units in alpha occupation is the number of workers in that occupation ($\#\alpha$) multiplied by $(1 + \bar{T}_{i,t}/L_{BD})$ which is one plus average tenure among alpha workers in firm *i* at time *t* scaled by a parameter for the speed of learning by doing. In the beta occupation the number of efficient units of labour is equal to the sum of the workers' abilities, i.e. types, θ_w. But the contribution of each worker is limited by the constraint that firms cannot extract more than expected ability from each, ($\theta^e_{w,t}$). Thus workers contribute at most with expected ability and firms counteract this by adding slack and by firing type Low workers when discovered in beta occupations. This is explained in detail below.

[7] 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.

The expected number of efficient labour units in alpha is, correctly, the number of workers in alpha times the learning by doing effect, while the expected number of efficient labour units in beta will differ from the actual number.

$$Y_{i,t} = min\left(\#\alpha_{i,t}\left(1+\frac{\bar{T}_{i,t}}{L_{BD}}\right), \sum_{w\in\beta_{i,t}} \min\left(\theta_w, \theta^e_{w,t}\right)\right) \quad (5)$$

$$Y^e_{i,t} = min\left(\#\alpha_{i,t}\left(1+\frac{\bar{T}_{i,t}}{L_{BD}}\right), \sum_{w\in\beta_{i,t}} \theta^e_{w,t}\right) \quad (6)$$

Equation 5 is potential 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 θ_w in the beta department of the firm. This will be achieved by learning about the abilities of workers and becoming better at interpreting the education signal, and by selection on workers so that workers in beta occupation are predominantly type High. Expected ability is a weighted mean of 1 and *H* depending on the firm's subjective prejudice that the worker is type High. *H* is a parameter to be set and describes the technology of the industry. If alpha workers are conceptualised as doing menial tasks with beta workers as supervisors, then an able worker (type High) doing beta can supervise *H* effective labour units in alpha. An unable worker (type Low) will only be able to supervise one effective labour unit in alpha.

Table 1: The two occupation categories of the model

Department	Role	Effective labour units	Cost pr. workers
Alpha	Menial/Production/Shop floor	No. workers times efficiency	1
Beta	Supervision/Coordination/Managerial	$\sum \theta$	π

Firm performance is measured by wage costs. As there is no output market per se there are no constraints on labour costs in the sense that firms are not constrained by their sales when paying wages. Output and wage costs are measured in standardised units and no equivalence relation among them is assumed. Output is referred to as “units of output” while wages are simply referred to by numbers; e.g. “a wage of 1”. Both output and wages are treated as real values but they are standardised to different baselines: 1 unit of output is the production of one supervised menial worker while 1 unit of wage is the wage paid to one effective unit of menial labour.

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 π. Equation 7 describes this relationship.

$$WC_{i,t} = \#\alpha_{i,t} + \pi\#\beta_{i,t} \quad (7)$$

The Leontief production function means that firms have no preference for workers when hiring for alpha occupations but prefers type High workers for beta occupations. The characteristics of the occupations are summarised in Table 1.

Strategies and prejudices

Firms consist of a number of workers organised into two occupational categories, which interact to produce output. Firms' strategies are described by two parameters, τ and ϵ. Tau is the tolerance level for change in target output required to initiate a reorganisation of the firm (i.e. inertia). Epsilon is the percentage by which firms aim to over-staff beta occupations to counter uncertainty of workers' abilities (i.e. slack).

In most time periods firms lose workers from voluntary turnover and hire and fire to keep up with the target. But when the change in target scale is sufficiently large they follow an algorithm for rationalising the labour force. Firms differ in strategy according to the inertia for activating the rationalisation routines. Initiating the routine means getting rid of beta workers that do not have the necessary ability for their job. But this also means hiring new workers whenever the target increases again and thus starting over learning about their abilities. The other dimension of strategies, slack or ϵ_i, may mend this by prescribing firms to keep on excess workers. On the other hand some firms do not initiate the rationalisation algorithm unless there is a large change to the target.

The performance of strategies is expected to depend on the environment. Low inertia means that the firm often fires all type Low in beta occupations and move able menial workers to beta occupations. This should generally be necessary in order to minimise labour costs. But it relies on the firm having knowledge of abilities. Otherwise the main effect will be to decrease average tenure and thus efficiency in production. The effect of slack is more complicated. On the one hand slack is expensive but without it firms risk having insufficient effective labour in beta. The greater the uncertainty regarding ability, the more prudent slack will be and the lower the relative labour costs for high slack strategies.

When a worker is hired the firm ascribes to him an expected ability, $\theta^e_{w,t}$, based on his signal and the firm's current prejudices regarding the meaning of the education signal. A firm's prejudices are described by two probabilities, $p^+_{i,t}$ and $p^{\div}_{i,t}$: the probability that an educated worker is type High and the probability that an uneducated worker is type High. As time goes by firms learn about the actual abilities of their employees. Thus at each time step the true type of a currently employed worker is revealed to the employer with probability $1/T_L$. “Revealed” means that $\theta^e_{w,t} = \theta_w$ for all subsequent *t*.

Until the true type of a worker is learned he is expected to have the ability assigned to him when he was hired as described by Equation 8. T_w is the time step at which he was hired.

$$If\ \sigma_w = 1\ then\ \theta^e_{w,t} = 1 + (H-1)p^+_{i,T_w}$$

$$If\ \sigma_w = 0\ then\ \theta^e_{w,t} = 1 + (H-1)p^{\div}_{i,T_w} \quad (8)$$

$p^+_{i,t}$ and $p^{\div}_{i,t}$ are updated by firms examining their own workforce. The longer a worker has been employed at the firm the greater is the change that the firm has learned his true ability. The firm updates its prejudice by computing the probabilities of type conditional on signal from its own workers of known type.

An algorithm for adapting a firm

Whenever the absolute change in target scale exceeds the tolerance of a firm (τ_i) the firm rationalises. This means that all workers employed in beta occupation (i.e. supervisors) but which have turned out to be type Low are fired. Then any workers employed in alpha occupation (i.e. menial tasks) which have turned out to be type High are moved to beta. The number moved in the second step cannot exceed the number fired in the first step and those moved are treated as newly hired workers. That is, they have zero tenure and unknown type. This corresponds to workers promoted from the shop floor to supervisors having to go through the same initiation process as other new supervisors. At each time-step the firm looses workers through voluntary turnover regardless of whether the Rationalise routine is initiated. In this phase each worker quits with probability χ.

After thus having lost workers to voluntary turnover and/or fired workers through rationalisation the firm may have too few or too many workers in either occupation relative to target scale. 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 relative abundances of the strategies for signalling). The firm allocates educated workers to beta work as long as $\sum_{w=1}^{\#\beta_{i,t}} \theta_{w,t}^{e} < \bar{Y}_t(1+\epsilon_i)$ and uneducated workers to alpha as long as $\#\alpha_{i,t}(1+\bar{T}_{i,t}/L_{BD}) < \bar{Y}_t$. The uncertainty regarding θ^e motivates firms to add slack resources in the beta occupation category. When the firm has sufficient labour in one occupation it adds new workers to the other occupation irrespective of their signal.

The firm then fires surplus workers. When determining surplus in beta occupation the firm includes an allowance for slack in the target. Thus it only removes labour in excess of $\bar{Y}_t(1+\epsilon_i)$. The probability that any given worker is fired is inversely proportional to the tenure of the worker. This means that workers of unknown type are more easily fired than workers of known type.

Of course, firms rarely hire and fire workers in the same round. Even though firms do not know the true ability of workers they will generally have surplus effective labour in beta occupations; because they do not fire all redundant workers but also because of the modularity of labour. Output is determined after the routines for rationalisation, hiring and firing have been executed. If a firm has, at this stage, severely underestimated the ability of its beta workers so that even the intentionally acquired slack cannot make up for it, the firm will have to add effective labour under the assumption that those hired are all type Low ($\theta_{w,t}^{e} = 1$ irrespective of signal). In subsequent periods θ^e is determined as above for these workers. The wage costs per efficient labour unit bought in the extra hiring routine are thus higher than those paid during the first hire routine. Keeping slack (ϵ_i) adds extra costs every round but it decreases the likelihood that a firm will have to pay the high wage costs of the Extra Hire routine and it increases the number of workers available when the Rationalise routine is initiated.

Figure 1 illustrates the different modes of operation for firms. If $(\bar{Y}_t - \bar{Y}_{t-1})/\bar{Y}_{t-1} < \tau_i$ the firm goes through the Rationalise routine. It then hires, fires and output is computed. If this falls short of target, then the firm is forced to purchase expensive labour through the Extra Hire routine.

4. Performance and labour turnover

In order to study the implications of the model a fitness landscape will be constructed and presented in a three-dimensional plot. The landscape is a plane for unit labour costs as a function of the two strategy parameters, ϵ and τ. It is constructed by averaging over 20 simulations of 400 time-steps each. With the assumption that selection favours low labour costs the lowest points in the plane are the fittest.

The parameterisation of the model is determined in the following section but firms' strategies will be determined randomly (within relevant bounds). Strategies will not systematically cover the fitness landscape. This is necessary in order to estimate the plane from the points identified with each firm. But it creates an element of density dependence, the role of which is left for further research. The effect of density dependence would be to make strategies more or less viable when other firms follow similar strategies.

Parameterisation

The parameterization of the output market will be $\gamma = 300$, $\upsilon_1 = 0.01$ and $\upsilon_2 = 5$. The output market is a very abstract element of the model and these three numbers have no empirical equivalence. γ is chosen high enough to give firms a meaningful scale but not so high that it becomes computationally burdensome. υ_1 is chosen to make the mean reversion of the series relatively slow while υ_2 is chosen to be large enough to give some shocks to output. The parameterization means that target scale evolves as specified in Equation 9.

$$\bar{Y}_t = \bar{Y}_{t-1} + 0.01\,(300 - \bar{Y}_{t-1}) + 5W_t \tag{9}$$

$\bar{Y}_0 = \gamma$ and $W_t \sim N(0,1)$ is a random draw from a standard normal distribution. An example of how this evolves over 1200 time steps is shown in the top part of Figure 2. The bottom part of the figure shows the distribution of percentage change in target in this example. Thus firms with $\tau_i > 0.077$ would never activate the rationalisation routine in this simulation, while firms with $\tau_i = 0.02$ would rationalise very often. Firms will be given τ_i values in the interval]0,0.1[.

The other strategy parameter, ϵ_i, is set in the interval]0,0.2[. This means that firms aim to have up to 20 percent slack in beta occupations measured by the amount of effective labour. This interval should cover most empirical cases.

As mentioned earlier strategies are determined randomly in the two dimensional strategy space. 50 combinations of ϵ_i and τ_i are plotted. The choice of 50 firms is a practical one: the aim is to have enough firms to make construction of a fitness landscape possible while keeping the model within the bounds of available computational resources. The 50 strategies are plotted in Figure 3. Each simulation will be carried out 20 times and the average performance of each strategy will be evaluated.

Spence labour market

The parameterisation of the labour market takes some consideration. The difference between wages paid to the educated and the non-educated determines whether the best strategy is to bluff, be honest or be cautious. If the difference is denote by ω_p then $x_C \to 1$ if $\omega_p < C_H$, $x_H \to 1$ if $C_H < \omega_p < C_L$ and $x_B \to 1$ if $\omega_p > C_L$. The wage premium to taking education is a function of the wage discrepancy among the two types of work (π parameter), and it is to some extent path dependent as it depends on the historical correlation of education and ability. But it basically depends on the rigour of firms' sorting on new workers based on the signal; which in turn depends on the scarcity of type High in the labour market.

The supply of type High must be scarce relative to demand for the ability to supervise to have value. If the ability is abundant firms will always have workers in the alpha department that have known type High and these can be moved to beta occupation as necessary. Firms would thus only hire new workers for alpha and would have no incentive to try and interpret the signal. In the absence of learning-by-doing in production (i.e. $L_{BD} \to \infty$) one type high worker can supervise *H* menial workers so the equilibrium abundance of the ability is $h^* = 1/(1+H)$. Thus the parameterisation should satisfy $h < 1/(1+H)$. However, it was argued above that learning-by-doing effects in production are necessary. They illustrate how routines become more and more efficient when undisturbed and they add the realistic effect that a given supervisor (beta employee) can meet his production target with fewer production (alpha) workers if his workers are more experienced. This means that the equilibrium of supply and demand depends on the value of the learning by doing parameter and on the average tenure of alpha workers at the aggregate level ($\bar{T}_t$): $h^*(\bar{T}_t) = \bar{T}_t/(\bar{T}_t + HL_{BD})$. But this result only holds when workers' type is revealed. As firms' are uncertain about recently hired beta workers' ability to supervise (depending on T_L) they will over-staff beta (as determined by their strategy) and average supervisory ability of workers in beta occupation will be somewhat lower than *H*.

$\bar{T}_t$ is endogenously determined by voluntary turnover (χ parameter) and involuntary turnover as jointly determined by firms' strategies and the volatility of the output market. $\bar{T}_t$ may thus vary considerably and it is not possible to choose a value for h such that $h < h^*(\bar{T}_t)$ at all times. Notice that this equilibrium value is at the aggregate level. It is possible that type High are scarce aggregately while some firms have workforces of so long tenure that they find type High abundant.

Based on these considerations the following initial parameterisation is chosen: $T_L = 6$, $\pi = 11$, $C_H = 2$ and $C_L = 5$ which means that it takes on average six time-steps for an employer to learn an employee's true type, that workers in beta earn 11 wage units per period (workers in alpha earn 1) and that taking education costs 2 wage units for type High workers while it costs 5 for type Low workers. And $H = 4$, $h = 0.1$, $L_{BD} = 500$ and $\chi = 0.01$. Thus $h^*(\bar{T}_t) = \bar{T}_t/(\bar{T}_t + 4 * 500)$ and $h = 0.1 < h^*(\bar{T}_t)$ as long as $\bar{T}_t < 200/0.9 \approx 222$. The value of 500 for L_{BD} is rather high as it means that efficiency in alpha will only double when average tenure reaches 500 but it is chosen high so that it may be compared to a lower value later. Recall, however, that the average ability in beta will generally be less than H and thus the threshold of $200/0.9$ is upward biased. The average tenure among alpha workers needed for ability to be relatively abundant is likely to be less.

Figure 4 shows the evolution of the labour market that is the results of this parameterisation. The evolution is summarised by ω_p from which the abundance of signalling strategies can be inferred. The evolution is also shown for three alternative values of L_{BD}: 10, 100 and 300. These all represent faster learning-by-doing in production.

In the first 200 rounds the wage premium to taking education hovers around C_L meaning that at some points the bluff signalling strategy has highest fitness and everyone takes education. This decreases the value of the signal to firms and they become less rigours in their sorting. Thus the premium drops to below C_L and the fittest strategy becomes being honest and only able workers take education. This, again, increases firms sorting by the signal and the bluffers are allowed to re-enter. However, near round 200 something interesting happens: average tenure among alpha reaches the critical value at which there is abundant supply of supervisor ability. Thus firms can find all the supervisors they need from their current stock of menial workers and only hire new workers for alpha. They thus do not consider the signal at all when hiring and the premium to taking education decreases sharply - in this case to just below C_H at which the dominant signalling strategy is to be cautious and never risk resources by taking education ($x_C \to 1$). However, the period of abundant type High comes about as the result of path dependence and stochastic events and after a couple of rounds firms start sorting workers by signal again. Thus ω_p starts to rise.

Figure 4 also shows the evolution of ω_p for lower values of L_{BD}; that is, where learning-by-doing in production is faster. Some values will create stable labour markets - e.g. of honest signalling when $L_{BD} = 100$ - or other forms of oscillations as when $L_{BD} = 10$ and the cautious strategy of never signalling is generally the fittest but the labour market periodically allows for honest signalling too. The main point is to illustrate that the Spence labour market covers several different forms of labour markets and that it is necessary to take this into account when extracting results from the model.

The labour market side of the model follows classic signalling models closely but it is not a self-contained model of labour markets. It depends on interaction with firms and the assumption about their routines. The assumption that employers adjust the labour force of their firms at each time-step according to expected requirement suggests that "time-step" should be thought of as a relatively short period; e.g. a month.

Turnover

Figure 5 shows the results of simulating the model with the parameterisation described above. The top part of the figure shows the average unit labour costs over 400 time steps and 20 simulations across the strategy space of Figure 3. The bottom part of figure 5 shows the associated total turnover rates. Unit labour costs are defined as total wage costs divided by target output ($ULC_{i,t} = WC_{i,t}/Y_t$). In this simulation *ULC* varies from 5 to 10 wage units. The dominating factor in determining *ULC* is inertia, τ. If firms rationalise each time target scale changes by more than a few percent they will have *ULC* between 5 and 7. But if they are more inert than this, then their labour costs will be higher.

For low inertia the amount of slack, ϵ, does not matter much for *ULC*. There may be a slight tendency for values of ϵ in the middle of the]0,0.2[range to result in lowest overall *ULC* but there also seems to be a large stochastic element that is not evened out by the 20 simulations of 400 time-steps. At high inertia, on the other hand, *ULC* increases with slack, cf. the movement from grey to black as slack increases in the top part of the landscape.

The top part Figure 5 thus illustrates two conclusions: in an environment described by the current parameterisation it can be expected that dominating firms have low inertia and heterogeneous amounts of slack. But if this part of the strategy space in unavailable - for example if labour market institutions make firing difficult so that low values of τ are not feasible - then it may be expected that dominant firms have low slack.

The bottom part of figure 5 illustrates the average labour turnover rates for the simulations. At high levels of inertia turnover is about 2-3 percent at each time-step; including the 1 percent voluntary turnover. But low inertia results in turnover rates that vary from a few percent to 13 percent. And turnover is higher for low slack: firms with the highest turnover rates are those pursuing a combination of low slack and low inertia.

The plots suggest that the correlation of performance (*ULC*) and total turnover rates is negative but week. Very low turnover is a consequence of high inertia in the model and such strategies result in weak performance. Low inertia results in high performance but it does not necessarily result in high turnover; rather, the resulting turnover depends on the slack of the organisation. Firms can have high performance in combination with low turnover if they have high slack.

As discussed earlier, the literature on the relationship between turnover and performance emphasises the distinction between voluntary and involuntary turnover in theory but mostly resorts to total turnover in empirical research. To investigate the effect of voluntary turnover in the current model the simulations have been redone with $\chi = 0.1$. That is, with a voluntary turnover rate of 10 percent. Furthermore, It was demonstrated earlier that the labour market of asymmetric information can take on various guises depending on the parameterisation and thus the simulations have also been undertaken with $L_{BD} = 100$. That is, with learning-by-doing in production which is five times faster than in the results presented above. Finally, the simulations have been done with both of these changes to the parameterisation. The results are presented in Figures 6, 7 and 8.

Increasing voluntary turnover makes the fitness landscape more “flat”, cf. Figure 6. The lowest points are still connected to firms with low inertia but the effect of inertia on performance has become weaker. This was to be expected as higher voluntary turnover has an effect similar to re-organising for firms: they must more often search for new workers to perform the beta occupations. Thus it becomes less imperative to reorganise often.

The u-shaped effect of slack that was noticed in the earlier results has become more pronounced. For a given level of inertia it is generally best to have $\epsilon \approx 0.1$ i.e. to aim at having 10 percent more effective labour in beta occupation than is necessary for production target. However, this does not affect the conclusion regarding the relationship between turnover and performance: The low performance and lowest turnover rates coincide but high performance can be associated with a multitude of turnover rates.

Varying the speed of learning-by-doing in production has implications for signalling behaviour in the labour market (cf. earlier; and Figure 4 in particular) but it has practically no effect on the relationship between turnover and performance (compare Figures 5 and 7). However, when learning-by-doing is made faster and voluntary turnover is simultaneously increased then the landscape changes, as shown in Figure 8.

In Figure 8, where $\chi = 0.1$ and $L_{BD} = 100$ as opposed to $\chi = 0.01$ and $L_{BD} = 500$ in the initial parametrisation, slack and inertia interact in determining performance. For firms with no or very low slack performance is mediocre irrespective of inertia. But among firms with more slack performance depends on inertia. More inertia means weaker performance. For firms with low inertia, performance is better if they have a bit of slack but slack becomes too much at some point. For firms with higher inertia slack is unanimously bad for performance.

This complicated fitness landscape does, however, not alter the conclusions based on previous simulations. Low turnover is associated with relatively high unit labour costs but high turnover does not guarantee low unit labour costs. Firms with low unit labour costs can have either high or low labour turnover.

5. Conclusion

Firms navigating a labour market with asymmetric information need to have labour turnover to adapt as information becomes available. But they also need to retain workers in order to retain information. Thus a model of firms interacting with a labour market with asymmetric information can shed light on the relationship between performance and labour turnover and this model presented in the current paper goes some distance towards this goal.

The model presented in this paper is an adaptation of the model presented in chapter 2 of Holm, (2011). It is a model that combines a classic labour market of asymmetric information with a theory of firms based on contributions within evolutionary economics and population ecology. Firms' strategies are defined by parameters for slack and inertia and these two parameters determine how firms deal with the information asymmetry and thus affect the labour market.

Having slack means having excess employment and acts as a buffer against the information asymmetry: if there are excess workers in the firm there are less costs associated with weak estimates of their abilities. Inertia means stability. Instability decreases the effectiveness of routines and means that firms lose employees of known ability. But it also allows firms to reorganise work according to employees' abilities.

Firms' performance is evaluated by their unit labour costs. Unit labour costs are here not to be understood as a measure of short term cost competitiveness. The model is explicitly structured to take into account that firms have an interest in retaining workers; and thus avoid having to start over training a new worker and to start over learning about the ability of a new worker.

The model is used here to study the relationship between performance and labour turnover. It is hypothesised that the effect of turnover on performance may be negative linear, attenuated negative or inverted u-shaped. Empirical studies of these hypotheses often use total turnover even though the hypotheses build on voluntary turnover. In the model of the current paper voluntary turnover is exogenous and it is the relationship between total turnover and performance which is explored.

The empirical result that very low turnover leads to weak performance is replicated by the model. When firms have high inertia they will have high unit labour costs and low turnover. So some turnover is necessary for good performance---as suggested by the theory of an inverted u-shape. The simulations suggest why empirical research based on total turnover has difficulties rejecting or failing to reject the hypothesised relationships between (voluntary) turnover and performance: firms' heterogeneous strategies for slack and stochastic events in the path dependent development of their routines means that firms with high performance have varying rates of total labour turnover. The negative relationship between voluntary turnover and performance was replicated by the model in that increasing the voluntary turnover rate from 1 to 10 percent meant that the distribution of unit labour costs narrowed from the 4-10 interval to the 7-10 interval.

An aspect of the model that has yet to be studied is the effects of density. That is, the effect of the distribution of strategies on the performance of each firm. It is likely that some firms in effect are free-riding: that some firms have relatively low turnover and high costs because they invest in solving the information asymmetry and thereby create credibility in signals. While others exploit the information embedded in the signals to select works, thus have high turnover coupled with low costs from not investing. This extension is left for further development of the model.

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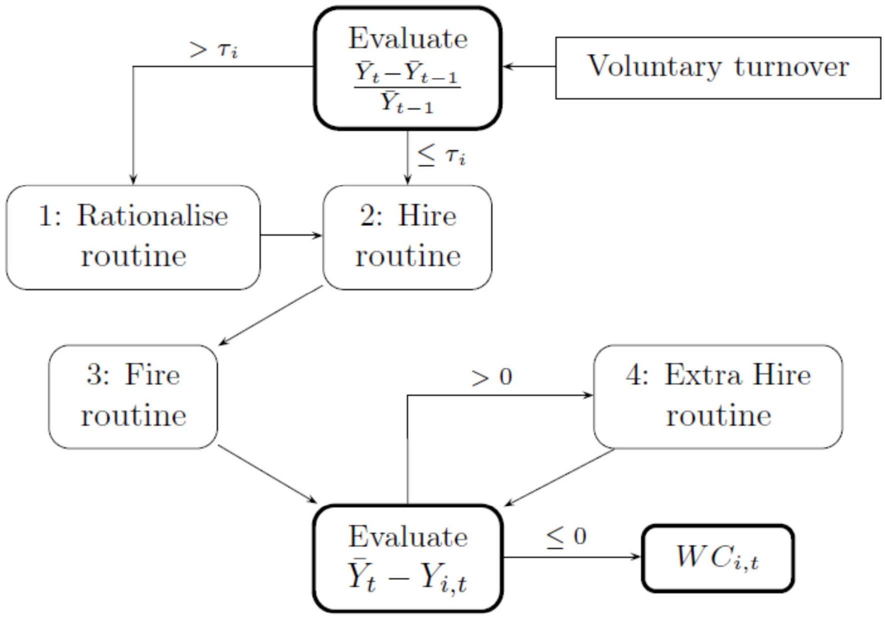


Figure 1: The sequence of firms' four routines

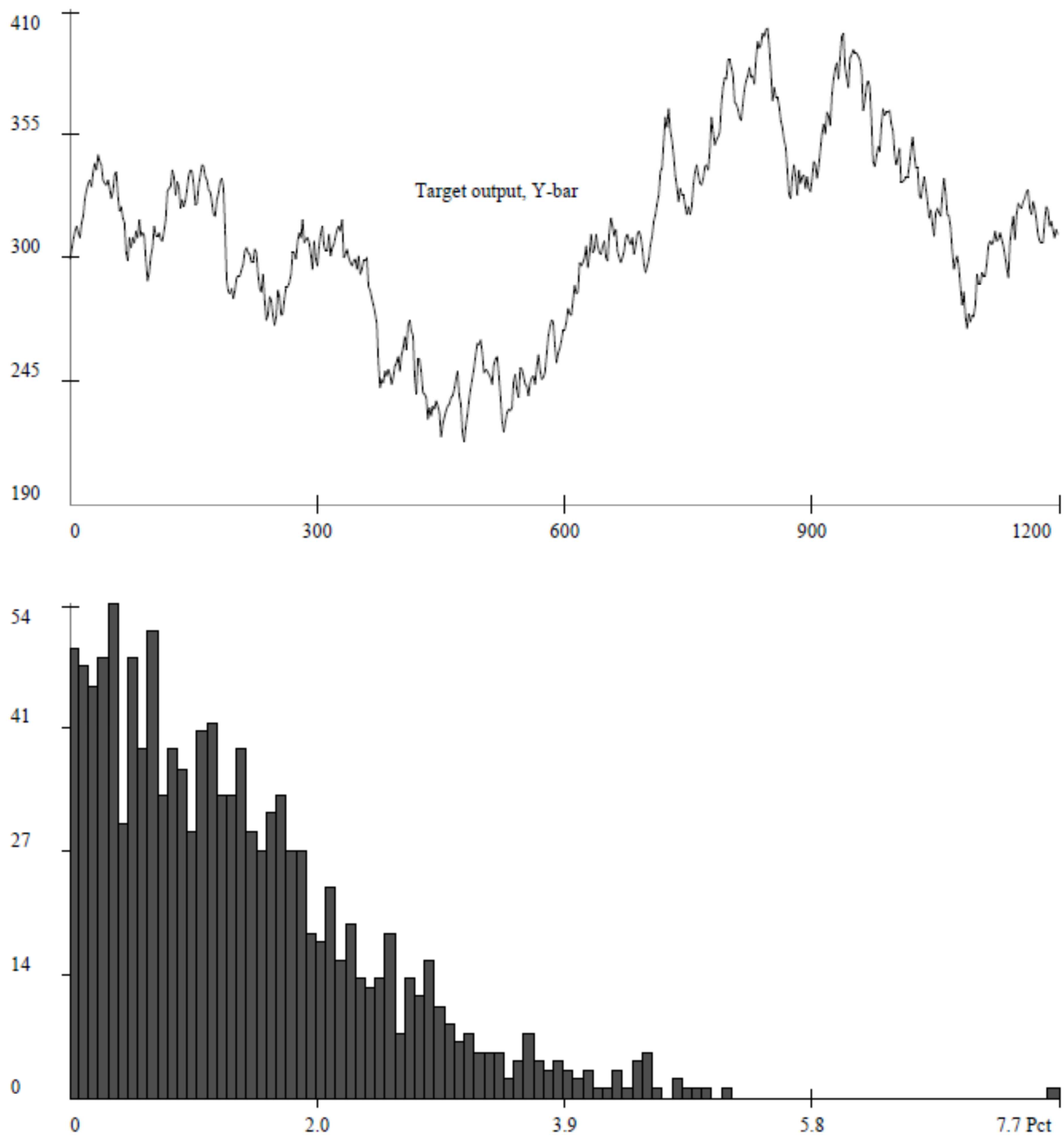


Figure 2: $\bar{Y}_t$ in 1200 time steps and distribution of percentage change

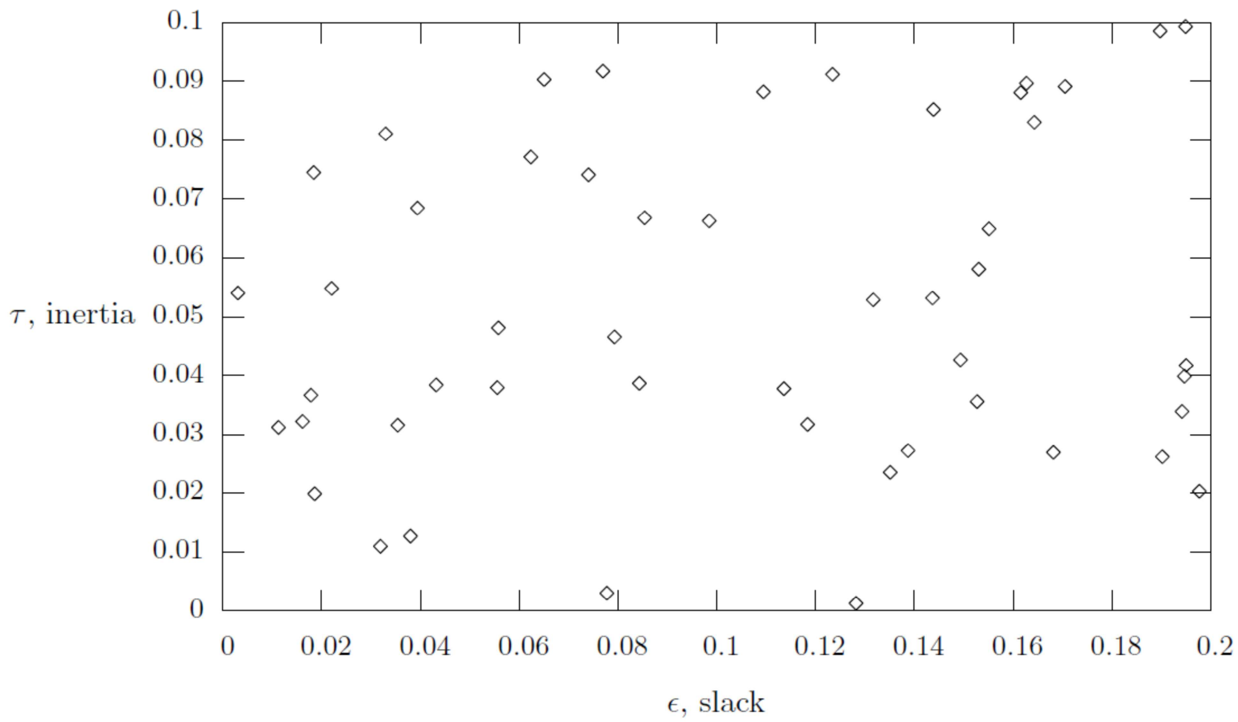


Figure 3: Strategy space. 50 combinations of ϵ_i and τ_i

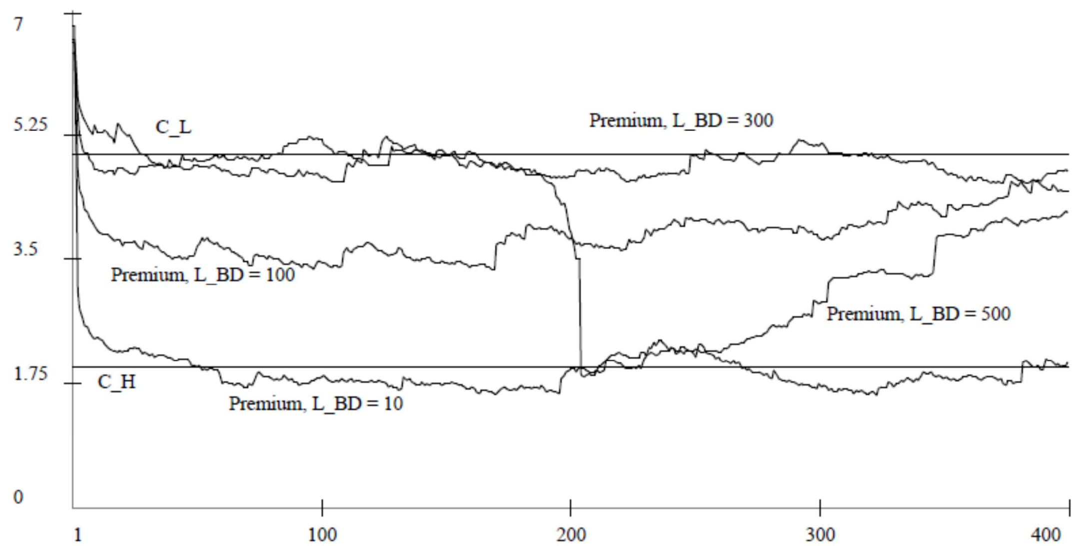


Figure 4: Evolution of wage premium to taking education over 400 rounds

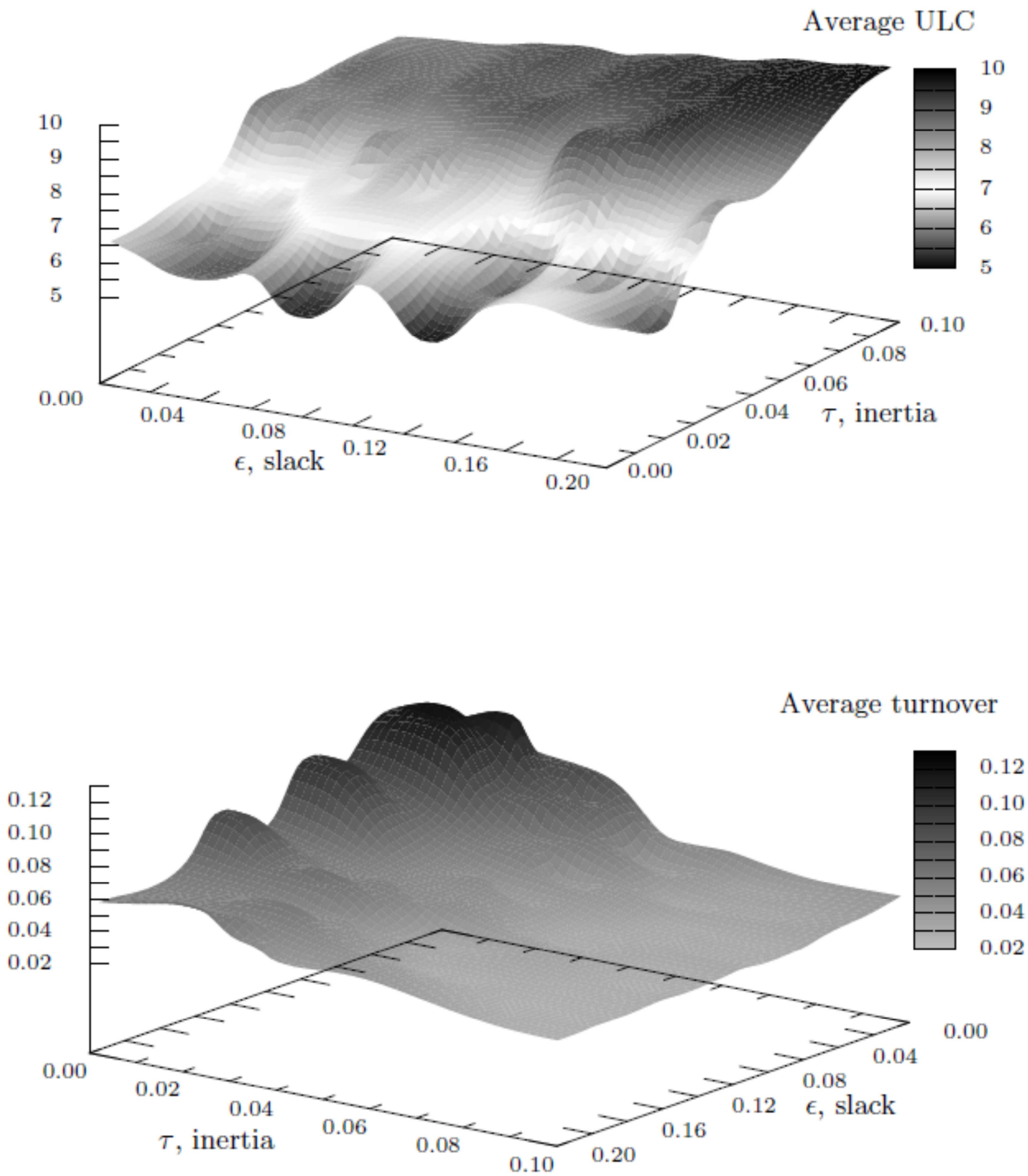


Figure 5: Results from initial parametrisation

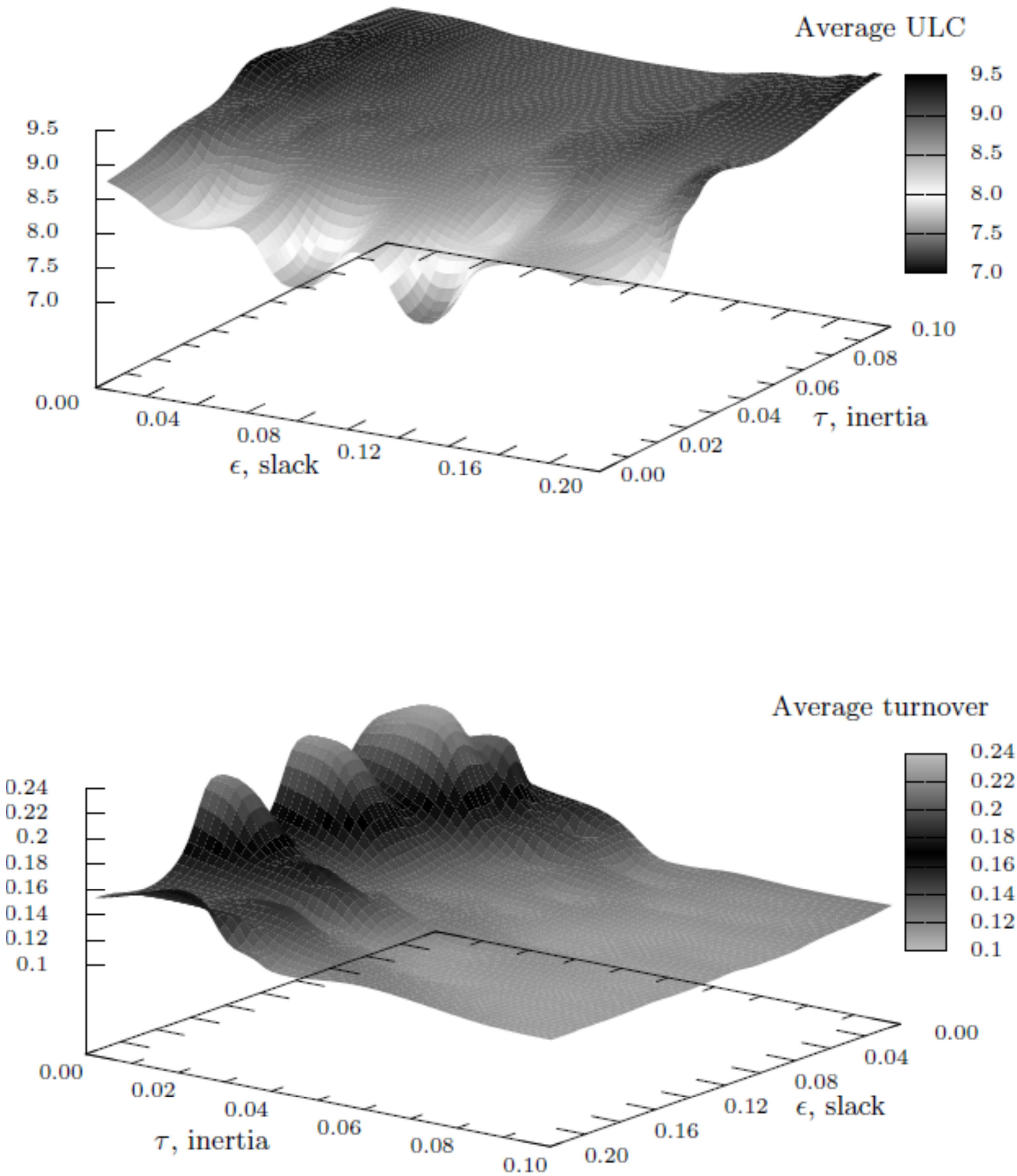
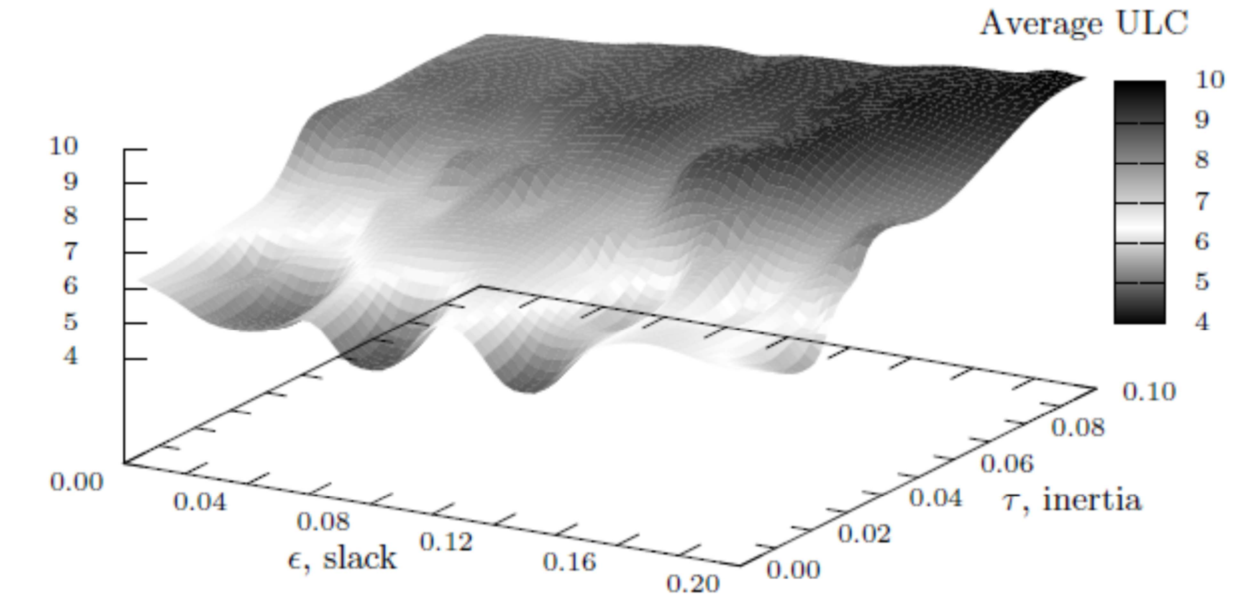


Figure 6: Change: $\chi = 0.1$



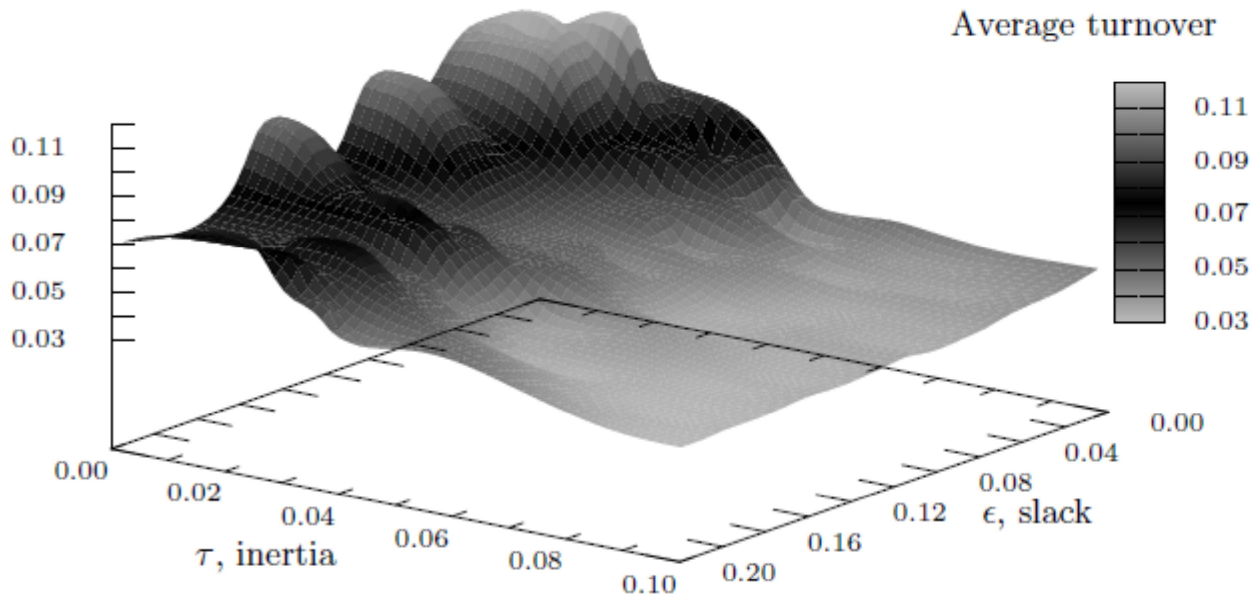


Figure 7: Change: $L_{BD} = 100$

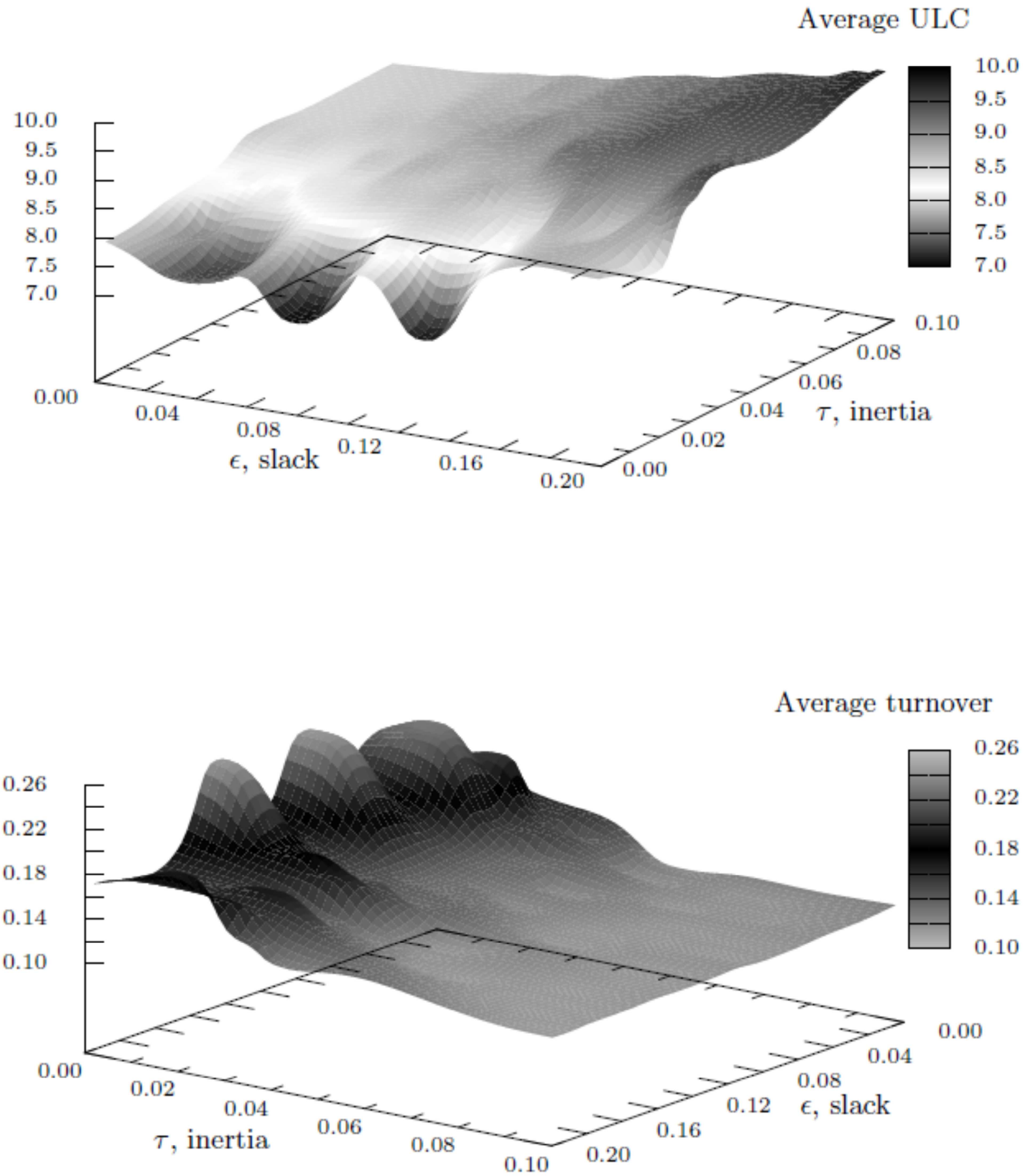


Figure 8: Change: $\chi = 0.1$ and $L_{BD} = 100$