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**Real Options?**

**Labour Contracts for an Uncertain World**

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Abstract

The standard labour contract is no more. Increasingly it is replaced by flexible and diverse alternative work arrangements that can often be characterized as real options. In this paper we examine optimal labour contracts from the perspective of a competitive firm facing uncertainty concerning both the cost of production and demand for its product or service. We initially restrict the firm to offering 'standard' contracts then add various alternative flexibility enhancing contracts. We discuss the circumstances under which these alternative contracts are real options, interpret the strike, compare them to employment contracts currently found in the labour market, and assess the benefits and costs.

Keywords: Standard labour contract, alternative work arrangements, real options

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## **Real Options?**

### **Labour Contracts for an Uncertain World**

#### 1. Introduction

How many workers does a firm need to operate profitably? When the “firm” was a manufacturer, say General Motors, the answer to that question may have been relatively straightforward once the decision to operate a production line at a particular speed was taken. This is not the case in retail. A “firm”, here more Starbucks than General Motors, can be open from 5:30 in the morning to midnight, but the number of workers it requires to operate profitably over the course of the day, from day to day and from store to store can vary hugely. Optimal staffing requires split shifts, short hours, and on call arrangements that vary over the course of the day, from day to day and from store to store. This staffing cannot be achieved via a “standard labour contract”<sup>1</sup>, the union negotiated contract that would have been offered to a GM worker, although not the waitress in the diner. While the institutional and legal legacy of the standard contract remains, the standard labour contract itself is more and more a thing of the past. The new standard contract may be the real option.

Today firms have expected lifespans of less than two decades. Even the GMs of the world must be nimble to survive. Were it ever, the standard contract is no longer fit for purpose. Now, non-standard employment relationships, the so called alternative work arrangements, are replacing standard ones (Katz & Krueger 2016).

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<sup>1</sup> The standard labour contract was a post WWII social and a labour contract providing continuity of employment in the employer’s place of business and under the employer’s supervision, with compensated overtime and benefits including health insurance and a company pension. It was institutionalized through collective bargaining, labour law and social welfare systems (Kalleberg 2000),

In contrast to standard contracts, alternative work arrangements are flexible and diverse, with supervision and employment relationships often divorced from the place of work and for whom the work is done. Alternative work arrangements, many of which can be characterized as real options since they give the manager the needed flexibility to make decisions about real labour assets (Sick 1995), include part-time contracts, temporary agency and contract company contracts, short-term contracts, contingent work, such as zero-hours or on-call contracts, and self-employment or independent contracting. Standard contracts, precisely because of the social contract under which they were established and the law and custom that supports them, provide job and income security to the worker, but are costly to the firm (Kalleberg 2003). Alternative work arrangements, in contrast, provide flexibility both for employers and employees alike, but may be insecure (Berg et al. 2014; Drache et al. 2015; Wilthagen & Tros 2004). They allow firms to control costs, to improve efficiency, and to match their just-in-time inventory systems or the peaks and troughs of retail foot traffic with just-in-time labour input (Kalleberg 2003). They have brought about changes in internal firm structures (Giudetti & Pedrini 2013; Lindbeck & Snower 1988; Piori 1986) and how work is organized (Broschak & Davis-Blake 2006; Davis-Blake, et al. 2003; Kalleberg 2003)..

In this paper we examine the optimal labour contracting decisions of a firm. Specifically, we are interested in deriving, in the abstract, labour contracts from the perspective of a firm facing uncertainty over demand for its product or service, which depends on consumer preference for the product or service and for the timing of consumption thereof, and its costs of production, which depends on the entry or exit of competitors, the introduction of new substitute or complementary products by

competitors, government regulations and macroeconomic conditions, among other things. To set the scene, we begin in section 2 by discussing a firm's decision, from the financial manager's perspective, to hire workers under standard and nonstandard contracts, determining when nonstandard contracts can be characterized as real options. In section 3 we characterize the firm's problem under a variety of assumptions on the uncertainty it faces and on the flexibility of the labour input, developing and solving the complete model and variations thereof in the Technical Appendix. Initially assuming cost certainty and demand uncertainty, we outline the firm's decision given an inflexible labour market. This provides a baseline for comparison. An employer's sole choice variable here is the number of workers, leading to production of a good or service. Because the labour input is fixed, output may not match demand, which is uncertain at the decision point. Both overproduction and underproduction lead to losses that the firm seeks to minimize.

Generalizing, while again restricting uncertainty to product or service demand, a degree of flexibility is introduced by assuming that firms can enter into standard as well as real options (contingent) contracts prior to the realization of demand and production taking place.. This degree of flexibility allows the employer to match more accurately production with demand. We then introduce cost as well as demand uncertainty. This allows firms to hire workers on 'standard' contracts, who can be thought of as insiders or core staff members, on cost-state contingent, fixed-term contracts, who can be thought of as outsiders or project-linked staff, and on cost and demand state-contingent contracts, who can be thought of as on call staff or providers of niche services, depending on the product/service being produced. Labour costs differ across the three types of workers, with insiders earning the standard wage, outsiders earning a cost

state contingent discount on the standard, and cost and demand state contingent workers earning either a premium or discount on the standard.

We determine when nonstandard contracts can be characterized as real options and interpret the strike condition from the financial manager's perspective. In section 4 we apply our analysis to case studies that mirror our contracting structures. In Section 5 we offer some concluding observations.

## 2. Standard Contracts and Real Options: Assessing the Firm's Employment Decision

Financial managers face three key decisions when managing a firm: the investing decision, the financing decision, and the working capital management decision. They must balance all three decisions to ensure the overall goal of the firm, to maximise shareholder wealth, is achieved. In terms of the investing decision, the firm identifies long-term investment opportunities in real assets that will generate future cash flows and add to the value of the firm. In order to identify as many profitable investment projects as possible, the firm must aim to maximise cash inflows generated by the asset and keep associated costs to a minimum. A key component of financial management relates to human capital investment.

Firms, having identified a need to hire workers, can do so by issuing many different types of employment contracts: standard or nonstandard. When firms choose to hire workers, the type of contract issued can have considerable managerial implications since different contracts have different cash flow effects that can make it difficult to establish a clear link between types of employment contracts and the overall position of the firm. The choice the firm faces depends on its expectation of the net benefits of each

type of contract. For example, the decision to issue standard employment contracts could be approached by the firm from a stakeholder-agency theory perspective (see Hill & Jones 1992) whereby management is acting to align the long-term goal of the workers with those of the firm, thus alleviating any perceived agency costs. The argument in this case is that individuals on standard contracts see their long-term future with the firm and develop skills and work more productively than individuals employed on nonstandard contracts that do not promise a long-term employment relationship. This efficiency gain, however, must be set against the higher implied costs in terms of training of and long-term benefits for employees, thus reducing the amount of free cash flow available for yet unforeseen alternative uses. Hiring workers on short-term contracts, because, for example, of the lack of commitment by the firm to its employees, may result in lower productivity (Wandera 2011; Foote & Folta 2002; Dolado et al. 2016). While lower productivity is a potential cost of hiring workers on non-standard contracts, there are potential benefits in terms of lower total labour costs and increased flexibility. Empirical evidence suggests that employing workers on non-standard contracts is often cheaper to the firm, even if they are less productive, as these workers are not entitled to as many long-term benefits as their counterparts on standard contracts (Osawa et al. 2013). It is the latter benefit of flexibility that is most important to our analysis as it is the flexibility of non-standard employment contracts that can transform them into valuable real options.

Originating in the finance discipline, the term “real option” was coined by Stewart Myers in 1977 and described by Sick (1995) as “the flexibility a manager has for making decisions about real assets”. One thing relatively certain when dealing with investing in fixed assets or long-term operations is that new information will reveal itself as time

evolves. When new information arrives, it might affect managerial decisions and a question of considerable importance is whether or not managers can exploit the new information to the firm's advantage.

Real options are everywhere and in reality managers have many options to adapt and revise their decisions in response to new and unexpected developments. One of the difficulties for researchers and practitioners alike is how to capture and quantify the value of such flexibility at the point of the initial investment decision. The real options approach in finance is becoming increasingly popular as it is widely recognized that incorporating flexibility into large capital investment decisions has real value and that such value should be integrated into the firm's decision making. Traditional analysis (such as discounted cash flow analysis) assumes a passive management strategy where the decision to undertake a project is based on forecasting future cash flows, discounting them back to today and comparing them with the cost of the project. While this type of analysis is widely used due to ease of calculation and understanding, there is no flexibility and no option for management to adjust strategies due to evolving market conditions. In essence, the value of flexibility is ignored or assumed away. Further, investments tend to be undervalued by NPV analysis due to the assumption that cash flows follow a constant pattern and can be accurately predicted. Real options offer an alternative insight regarding the impact of uncertainty on the value of project investment opportunities. Common types of real options include the option to delay an investment, the option to expand, the option to abandon, the option to stage an investment and production flexibility options. Projects that can be scaled up or down are worth more than similar projects that lack the flexibility to scale operations and the more uncertainty there is surrounding future cash flows that the projects will generate

the more value there is to the real option. For example, managers can often expand or contract production in response to changes in costs or demand, thus exploiting upside gains while limiting downside losses.

Real options analysis is commonly applied to the consideration of investing in long term capital projects and research and development where the up-front cost of capital is high. For example they are widely used when assessing renewable energy projects (Boomsma et al. 2012; Fernandes et al. 2011; Lee & Shih 2010), in the mining industry (Moel & Tufano 2002; Slade 2000), and strategic investment decisions (Krychowski & Quelin 2010). Some studies have also considered the value of real options in human capital (Bhattacharya & Wright 2005; Brady 2017; Foote & Folta 2002; Musselin 2005; Van Emmerik & Sanders 2004). We add to the existing body of literature that applies the concept of real options to labour contracts by assessing whether the inherent flexibility of non-standard employment contracts can be used by firms to respond to changes in its cost structure while aligning production and demand, thereby limiting the downside risk of long-term operations while exploiting any upside that such flexibility allows. With respect to traditional employment contracts, the cost to the firm of the workers is largely irreversible. If external market conditions are such that the firm's revenues fall sharply, terminating employment contracts given current demand conditions or maintaining employment in the hope that demand will revive might prove so costly that it pushes the firm towards financial distress. Non-standard employment contracts on the other hand provide flexibility to the firm that standard employment contracts do not. This is of strategic and financial importance to the firm given the empirical evidence showing such flexibility may add value to the firm. In effect, flexible employment contracts allow firms to scale employee numbers up or down quickly in



response to changing cost or demand conditions. Hence the firm can limit the cost of paying wages when demand is low and exploit strong market conditions by immediately increasing production when demand is high, thereby aligning production with market demand conditions (provided there are no production capacity issues), and it can replace permanent labour with contract labour to avoid legacy staffing issues when its cost environment changes. Conceptually, we can view the use of non-standard employment contracts as a variable cost of production as opposed to standard contracts which can be viewed as a fixed cost. One of the consequences of using such non-standard contracts could be to allow managers to adapt their production (output) decisions as market conditions change, thus contributing toward the goal of maximizing shareholder wealth. As such, any real options embedded in non-standard employment contracts can have value. Other reasons for hiring workers on non-standard contracts include lower cost and less compliance requirements in terms of employment legislation. Even if hiring workers on non-traditional employment contracts comes with a cost, the net benefit, the value of the real option, may still be positive. If so, the firm will avail of this instrument.

### 3. Demand for Labour when Demand and/or Costs are Uncertain

To analyse the firm's decision concerning the use of a variety of nonstandard in addition to standard labour contracts, we describe, in the spirit of Lazear & Shaw (2007), a simple model of cost minimization in the face of demand and cost uncertainty.<sup>2</sup> Under a series of assumptions concerning the contracts available to the firm, we define which

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<sup>2</sup> The formal model is developed and analyzed in the Technical Appendix.

of the alternative arrangements can be considered real options. We then interpret the strike condition and assess the value of the option to the firm.

Assume initially that all costs of production are certain but that demand is uncertain. Before uncertainty is resolved, decisions are taken which lead to output being produced. If output and demand differ, losses are incurred. We abstract from capital, and look at the employment decision.

In our initial setting, the choice variable is the number of workers which implies a fixed number of work hours.. The workers can be thought of as being on “standard contracts,” that is, full time, permanent and pensionable. Assume to produce any output some workers on standard contracts must be hired. These can be interpreted as the required managerial input, which could be in head office or at individual production locations, such as retail outlets. Thereafter the production function exhibits constant or diminishing returns to scale. Thus, given any labour input the firm knows precisely how much output it can produce.

Demand is random and depends on a myriad of market and non-market forces. Ideally the firm wants only to produce enough to meet demand. If the firm is in the retail trade it wants to have adequate employees on the floor to meet customer needs, neither too few so that customers do not get served in a reasonable amount of time nor too many so that some employees have nothing to do. If the firm is in manufacturing it wants to have enough workers to produce the amount of good demanded without building up or drawing down inventory unduly. Deviations of output, which can be real output or service potential, from demand are costly. For example, in the case of large ticket items, items with high storage costs or items that become obsolete quickly,

overproduction will be very costly. In contrast, underproduction leads to incurring the opportunity cost of disappointed customers.

The firm, restricted to hiring workers on standard contracts and producing to meet uncertain demand, has to take a middle path, always missing target demand, where the extent of the deviation depends on the cost of labour and on whether the expected loss of under or overproduction is higher. If demand is relatively certain and the expected loss of missing target demand is low, perhaps because goods demand can be smoothed by building up or drawing down inventories at a low cost, then the benefit in terms of good employee relations of relying on standard contracts alone may be worth the implied cost. However, when the firm is providing a service that cannot be inventoried rather than producing a good that can be, the firm would prefer, all else equal, a more flexible employment structure.

Now consider the same environment as above, but assume that the firm receives a verifiable signal of demand before production commences but after labour contracts have been negotiated. This allows the firm to adjust its labour input by, for example, requiring current workers to work overtime or by hiring additional contingent workers. Assume overtime hours for workers on standard contracts are paid a premium, that contingently contracted workers may but need not be paid a premium and that labour markets are segmented: wages and benefits for workers on standard contracts do not have to be offered to contingent workers. These contracts for contingent labour, which can be characterized as real options contracts, must be negotiated before the signal of demand has been received.<sup>3</sup> What is critical for firms in their decision to exercise their

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<sup>3</sup> The literature cited above suggests that hiring contingent labour can have either positive or negative external effects leading to workers being either more or less productive. These effects

option to hire contingent labour, that is, what defines the strike, is the difference in demand between high and low demand states relative to the cost of hiring contingent workers to meet demand peaks. For some firms, especially those in retail, these demand deviations occur on a daily or hourly basis leading firms to use predictive scheduling which optimizes labour usage. For other firms, demand deviations are project related causing them to increase or reduce their staff to meet fluctuations in project requirements. Contingent labour does not replace labour on standard contracts entirely, rather it offers a just-in-time labour input that anticipates demand.

The model can be generalized further to encompass both cost and demand fluctuations. In this framework real options contracts can be used to meet changes in the cost and/or the demand environment where these contracts are specific to the source of the fluctuation. Cost fluctuations can depend on the entry or exit of competitors, exchange rate fluctuations, the introduction of new substitute or complementary products or services, technological innovation, government regulations or other macroeconomic conditions. For example, entry of competitors, Costa opens an outlet across from Starbucks, or the introduction of new substitute or complementary products or services, Amazon buys Whole Foods and adds its products to its Amazon Fresh line challenging Walmart and Costco, could affect the costs of missing demand targets, while government regulation in the labour market governing the terms and conditions of permanent and temporary contracts, Macron's reforms reduce the cost of hiring and

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can be accommodated in the model by assuming that the firm hires effective units of labour for the effective price of that labour. So, if the external effects are positive the cost of hiring an effective unit of labour is lower, while if the external effects are negative, the cost of hiring an effective unit of labour is higher. The external effects on the permanent staff and the contingent staff do not need to be the same. Since the main results of the model are not affected by specifying these external effects, because cost considerations will remain at the root of firm decisions, we note but abstract from them in our analysis.

firing permanent workers, or labour market tightness could increase the wages of contingently hired workers, while changes in technology, such as accounting and legal search software, could change the need for workers on permanent contracts. In this more complex environment flexibility in labour contracting allows the firm to adjust to cost uncertainty, thereby saving on costly standard labour, and demand uncertainty, by hiring demand contingent labour. The strike for the cost contingent real options depends on the cost saving of hiring temporary relative to permanent workers, where any productivity differentials are subsumed in the wage discount, given the operational need for some employment continuity that permanent workers provide. The strike for the demand contingent real options contract depends on fluctuations in demand relative to the cost of hiring contingent workers to meet demand peaks.

#### 4. Case Studies

Cost and demand uncertainty, which drives the firm's demand for labour, depends on the competitive, regulatory and macroeconomic environment in which the firm produces as well as the firm's perceptions of the fickleness of consumer preferences. The wage premium and discount depend on labour market regulations governing full-time permanent and pensionable employment, full-time temporary employment, and part-time or contingent employment including non-wage benefits, here incorporated in the wage, costs of hiring and firing including redundancy payments, etc., union strength, labour market conditions (slackness or tightness), overall macroeconomic conditions and worker preferences. The firm's optimal decision depends both on product or service and labour market conditions.

While flexibility is valued in theory, it can be expensive. A firm will take out real options on contingent labour when deviations from the standard contract allow it to reduce its production costs while getting closer to its demand targets at an acceptable cost. Clearly, if the base wage or contingent wages are high and/or the benefit of contingent workers is low while the cost of missing target demand or demand variability is low, then the cost of flexibility exceeds the benefits thereof, and the firm eschews contingent labour. To address whether the theoretical conditions we have derived are met in practice, we examine a number of case studies.

#### *Case Study 1: Responding to Uncertain Demand*

Menlo Innovations, a software design company in Ann Arbor, Michigan, is well recognized for its flexible work practices and benefits for full-time, permanent staff. These practices have led it to be a repeat winner of the Alfred P. Sloan Award for Excellence in Workplace Effectiveness and Flexibility (Galinski & Jackson 2014). To meet increases in demand, contractors are hired. They fully share the work and are integrated into the design teams, but are paid less and are not eligible for the in or out of work benefits, such as sick, maternity and holiday pay, that full-time employees receive. As they are hired explicitly to meet fluctuations in demand, they are let go when demand returns to normal levels (Reynolds Lewis 2011). Menlo's behaviour appears consistent with that predicted given a market wage structure that allows contingent labour to be hired at a discount to the standard wage.<sup>4</sup>

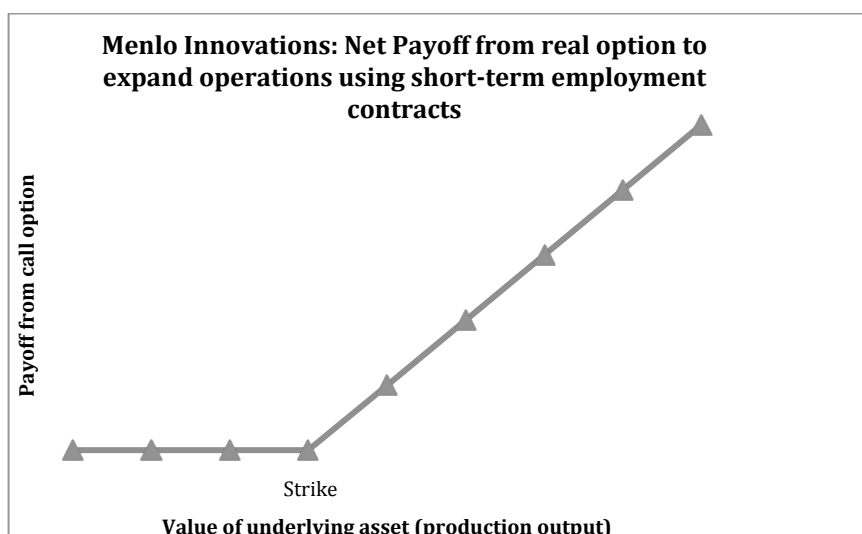
Menlo Innovations provide software design to the technology industry, a rapidly evolving market. They maintain a very lean organization to guard against costly over-

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<sup>4</sup> See Model 2 in the Technical Appendix.

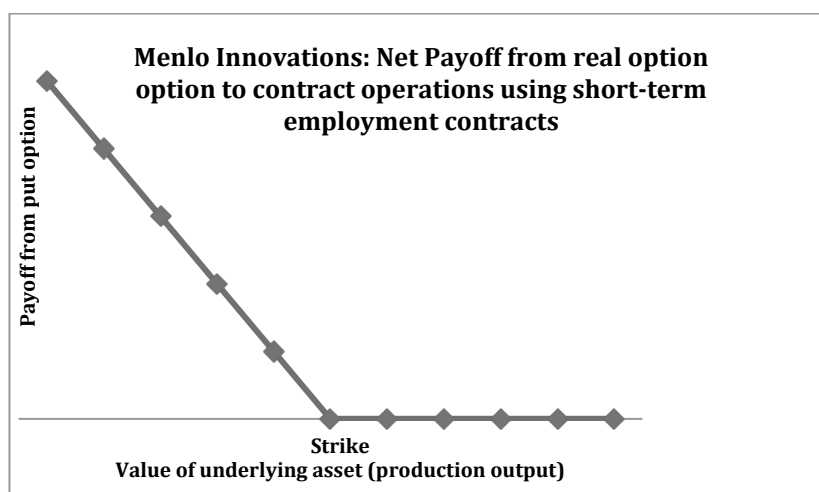
staffing, instead relying on short-term employment contracts that can be characterized as real options. Given that both overproduction and underproduction lead to losses, a concept contrary to the firm's goal of maximising shareholder wealth, Menlo Innovations takes advantage of the flexibility characteristic of the short-term contracts that allow them to respond immediately to increased demand by expanding production. Therefore the option can be viewed as an option to expand. The firm will choose to exercise the option in order to exploit the upside opportunities by increasing production to align it with demand. It is analogous to a call option. This is illustrated in Figure 1.1. When demand is as anticipated, the value of Menlo's output will be positive, there will be little if any over or underproduction and Menlo Innovations will continue operations using workers employed on standard employment contracts. When the level of demand increases and the value of output reaches the strike, they will issue short-term contracts to address the unanticipated increased levels of demand, thus becoming even more profitable. The higher the demand is, the more short-term contracts that will be issued until underproduction is eliminated.

Figure 1.1: Payoff to Menlo Innovations of real option to expand



Menlo Innovations' policy of issuing short-term employment contracts to address changing demand means that its operations actually contain a series of real options. Consider the case where the firm has exercised the option to hire additional workers to cope with increasing demand. Once time has passed, demand might drop to normal levels again and they will no longer require the additional contracted workers. Observing the fall in demand and given the flexibility inherent in the short-term employment contracts, management can now choose to cancel these contracts and limit the costs associated with overproduction, once again aligning production output with demand. In this case, the real option to contract operations is analogous to a put option. This is illustrated in Figure 1.2. Here, the value of the firm's operations is positive until the strike. Once the strike is reached, the firm will exercise the option to cancel the short-term employment contracts to avoid losses incurred as a result of overproduction until the point that production and demand are commensurate with each other. Hence, we have illustrated how the flexibility of the short-term employment contracts allows management to limit downside losses by exercising the real option to contract.

Figure 1.2: Payoff to Menlo Innovations of real option to contract





Menlo Innovations can continue to exercise these options to contract and expand operations through issuing short-term employment contracts, thus limiting the costs associated with under and over production that standard contracts cannot. The real option clearly has value to the firm. Each option can be valued as either a call option (to expand) or a put option (to contract).

An examination of job search web sites, such as Indeed.com, People2People.force.com.au, wallstreetservices.com or movemeon.com reveals that Menlo's strategy is shared by many firms the world over, often requiring very highly skilled staff, such as senior tax accountants, IT engineers or project managers, for short periods of time, often as little as two months. To get the right people at the right time firms are often willing and obliged to pay a premium.

#### *Case Study 2: Insider-Outsider/ Core-Periphery Workforce*

Because of the very different costs involved in hiring and firing workers granted permanent (CDI, *Contrat à durée indéterminée*) contracts in France, short-term (CDD, *Contrat à durée déterminée*) contracts, contracts that are limited in duration and can only be renewed once before the employee must either be offered a CDI position or let go, are often the preferred way to meet even stable demand (Le Barbanchon & Malherbert 2013) given cost uncertainty, creating an insider-outsider model of employment. In France in 2015, four out of five new hires were on CDD contracts, including that offered to Marine at a Paris cosmetics firm (Rose 2015), a position which required her to relocate to accept but did not provide the job security required to rent a flat. CDD contracts do not, for the most part, lead to CDI contracts. In 2010, for example, only 5.6% of workers on CDD contracts transitioned to CDI contracts (Le

Barbanchon & Malherbert 2013). The behaviour of firms issuing CDD contracts in France is consistent with firms facing both demand and cost uncertainty. CDD contracts are state contingent contracts, exercised after the cost state is realized if the strike is reached. When the firm increases (reduces) CDD contract hiring it is exercising a call (put) real option as shown in figure 1.1 (1.2), where flexibility here is of benefit not as a result of demand but cost uncertainty.<sup>5</sup>

In the UK some industries and public sector employers maintain a minimal core of permanent workers and utilize temporary (peripheral) workers to meet fluctuations in costs and/or demand. Some firms, such as gyms and leisure centres, build up a substantial pool of on call workers to meet these cost and demand fluctuations, others, such as child care centres, warehouses, such as Amazon (Cadwaller 2013) and SportsDirect (Business, Innovation and Skills Committee 2016), and schools, rely on agency staff who provide both the staff and the line supervision thereof. This core/periphery model is used to meet demand as closely as possible while minimizing labour costs (Metcalf & Dudwar 2010). These firms' behaviour can be interpreted in the context of both demand and cost uncertainty. The firm writes two types of real options contracts, those for temporary contract workers in the presence of cost fluctuations and those for contingent workers given fluctuations in demand. They can be characterized as call and put real options as in the above examples where firms exercise the options once the cost state and/or demand state is realized.

### *Case Study 3: Retail and Food Service*

The retail and food service industries face fluctuating demand on an hourly, daily, and

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<sup>5</sup> See Model 3 in the Technical Appendix.

seasonal basis. Demand can spike for a day or a week as a result of a playoff birth for a local sports team, can plummet because of poor weather or temporary road closures as a result of repaving or other maintenance work. To respond to ever shifting demand, scheduling software programs (Goldin 2015) are often used to obtain optimal staffing levels, while managers are required to meet corporate profitability goals via their staffing decisions while staying within overall staffing limits (Lambert and Henley 2010). Once staffing decisions are made, work schedules to workers with an employment relationship, but possibly without specific guaranteed hours, that reflect demand variability are issued, sometimes less than three days prior to the beginning of the workweek where within week scheduling changes in response to unanticipated demand shifts are always possible (Kantor 2014). These employment contracts, which are more and more common and represent an ever increasing share of all labour contracts issued (Goldin 2015) can be considered as a collection of real time call and put real options. By allowing firms to minimize employment costs while providing high level service fulfilment, these real options provide value.

## 5. Conclusion

In this paper we have examined why firms may prefer to hire at least a portion of their labour on alternative work arrangements rather than on standard contracts. Even in the context of our very simple framework many real-world hiring practices are replicated. These practices can be interpreted as firms using a set of standard contracts and alternative work arrangements, which include but are not limited to real options. The real options take the form of contingent contracts for labour services agreed for a period, at a wage, that can be exercised or not depending on the realization of a production cost and/or a demand state. As in the real world, the preferred alternative

work arrangement from the perspective of the firm may not be low wage, temporary contracts but may, rather, be for high wage, critically important but temporary contracts. Indeed, it is highly likely that the real option value of non-standard employment contracts will differ greatly across firms, industries and across workers within an industry. But as non-standard employment continues to grow, so should the use of real options.

Firms' ability to avail of real options in the form of alternative work arrangements clearly benefits a firm when faced with significant cost and/or demand uncertainty. However, the benefit to the worker faced with unpredictable schedules and total work hours is open to question. It may be that firms through their use of real options are shifting economic costs onto workers rather than reducing them through efficiency gains. This question motivates our future research.

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## Technical Appendix

For analytical simplicity, we present a one period model. It can be easily generalized to multiple periods.

### Model One: The Inflexible Labour Market, Certain Costs, Uncertain Demand

Assume production takes time, and that, while costs are certain, demand is uncertain. Before demand uncertainty is resolved, decisions are taken which lead to output being produced. If output and demand differ, losses are incurred. We abstract from capital, and look at the employment decision.

In our initial model, the choice variable is the number of worker hours,  $N$ . These workers can be thought of as being on "standard contracts," that is, full time, permanent and pensionable. With capital fixed, output,  $q(N)$ , is determined by the choice of  $N$ , where  $q(\underline{N} - \epsilon) = 0$ ,  $\epsilon, \underline{N} \geq 0$ ,  $\epsilon$  small,  $q'(N) > 0$ ,  $q''(N) \leq 0$ ,  $N \geq \underline{N}$ , where  $\underline{N}$  is the total labour input. These assumptions on the production function suggest that firms require some workers on standard contracts to be able to produce. This is irrelevant for our initial model, but is critical for subsequent models.

Demand,  $y \in \{\underline{y}, \bar{y}\}$  is random. It takes on two values,  $\underline{y}$ , with subjective probability  $\pi$ , or  $\bar{y}$ , with probability  $(1 - \pi)$ . To ensure production takes place, assume  $\underline{y} > q(\underline{N})$ . We think of  $\underline{y}$  as the normal level of demand.

We define a loss, or disutility function, as  $L^o(q - \underline{y})$ ,  $L^{o'} > 0$ ,  $L^{o''} > 0$  if the firm overproduces and  $L^u(\bar{y} - q)$ ,  $L^{u'} > 0$ ,  $L^{u''} > 0$  if the firm under-produces. We assume that the producer is a price taker in both the product market and input market, where the unit price of labour for those on the standard contract is  $w$ . The producer's problem is to minimise loss by choice of  $N$ .

To be able to solve explicitly for  $N$  in various characterizations of the model, assume that output is linear in the labour input:  $q = N$ , and that the loss functions are quadratic so that

$$L^o(q - \underline{y}) = a(q - \underline{y})^2 \text{ and } L^u(\bar{y} - q) = b(\bar{y} - q)^2, a, b > 1.$$

Substituting  $N$  for  $q$ , the firm chooses  $N$  to minimise the cost of production given random demand, the cost of over- or under-production, and the minimum labour input required for production to take place.

$$\min \pi a(N - \underline{y})^2 + (1 - \pi)b(\bar{y} - N)^2 + wN - \mu(N - \underline{N})$$

The first-order conditions are

$$2\pi a(N - \underline{y}) - 2(1 - \pi)b(\bar{y} - N) + w - \mu = 0$$

$$N - \underline{N} \geq 0$$



Under the assumption that  $\underline{y} > \underline{N}$ , the nonnegativity constraint will not bind and  $\mu = 0$ . The second-order conditions for a minimum are satisfied since

$$a\pi + b(1 - \pi) > 0$$

Solving for  $N$  we find

$$N = \frac{a\pi\underline{y} + b(1 - \pi)\bar{y}}{a\pi + b(1 - \pi)} - \frac{w}{2[a\pi + b(1 - \pi)]}$$

where it is straightforward to show

$$\frac{dN}{dw} < 0$$

$$\frac{dN}{d\underline{y}}, \frac{dN}{d\bar{y}} > 0$$

$$\frac{dN}{da} < 0 \text{ if } \bar{y} - \underline{y} > \frac{w}{2(1-\pi)b}$$

$$\frac{dN}{db} > 0$$

$$\frac{dN}{d\pi} < 0 \text{ if } \frac{w(a-b)}{2ab} < (\bar{y} - \underline{y})$$

which is clearly true for  $a \leq b$ . In addition, for  $\frac{w}{2} < b(1 - \pi)(\bar{y} - \underline{y})$ ,  $\underline{y} < N < \bar{y}$ .

**Model 2: Overtime and/or Contingent Employment Contracts with Cost Certainty and Demand Uncertainty**

Consider the same environment as above, but now assume that the firm receives a perfect and verifiable signal of demand after production has commenced that allows the firm to adjust its labour input by requiring current workers to work overtime or by hiring additional workers. Assume overtime hours are paid a premium, that contingently contracted workers may but need not be paid a premium and that labour markets are segmented. These real options contracts must be negotiated prior to the commencement of production, that is, before the signal of demand has been received.

Since the firm would never hire contingent staff if the low demand state is signalled, contingent staffing is potentially feasible and optimal for high demand states. Thus, the firm chooses workers on standard contracts,  $N$ , and on overtime/contingent contracts,  $N'$ , to solve

$$\min \pi a(N - \underline{y})^2 + (1 - \pi)b(\bar{y} - (N + N'))^2 + wN + (1 - \pi)\omega wN' - \mu(N - \underline{N}) - \lambda N'$$

where  $\omega \neq 1$  denotes the percentage wage premium (or discount) and  $N'$  is the total contingent labour input required.<sup>6</sup> All else is as in Model 1.

The first-order conditions for  $N$  and  $N'$ , respectively, are

$$2\pi a(N - \underline{y}) - 2(1 - \pi)b(\bar{y} - (N + N')) + w - \mu = 0$$

$$-2(1 - \pi)b(\bar{y} - (N + N')) + (1 - \pi)\omega w - \lambda = 0$$

$$N - \underline{N} \geq 0$$

$$N' \geq 0$$

For an interior solution for which  $\underline{y} > \underline{N}$  and  $N' \geq 0$ , the nonnegativity constraints will not bind and  $\mu = \lambda = 0$ . Thus, under conditions derived below, the firm will rely on contingent labour, either in the form of overtime or contract staff, even if this labour is more expensive.

Solving for  $N$

$$N = \underline{y} + \frac{w}{2\pi a} [(1 - \pi)\omega - 1]$$

which depends only on the low demand outcome rather than both demand states. The bracketed right-hand side term, the expected change in labour cost when contingent workers are hired or overtime required, may, but need not, be positive if the overtime/contingent labour wage differential or the probability of the high demand state is adequately high. When this is the case, those on the standard labour contract,  $N$ , exceed the labour input required to meet demand in the low demand state, reducing the need for overtime/contingent labour when demand is high.

Solving for  $N'$ , the overtime or contingently contracted labour,

$$N' = \bar{y} - \underline{y} - \frac{w}{2} \left[ \frac{(1 - \pi)\omega - 1}{\pi a} + \frac{\omega}{b} \right]$$

which depends on the difference between high and low demand. If this difference is small, the cost of contingent labour outweighs the benefit, the non-negativity constraint on  $N'$  will bind, and the firm will operate under Model 1. Contingent labour demand/overtime depends on the cost differential between using only permanent staff and foregoing overtime or contingent labour as well as the relative cost of contingent labour to the cost of missing the high demand target.

The firm is just indifferent between hiring or not hiring contingent labour/mandating overtime when  $N' = 0$ . Then the difference between high and low demand,  $\bar{y} - \underline{y}$ , is

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<sup>6</sup> Premium payments for overtime are not required in all jurisdictions. Thus, while the United States (US Department of Labor 2016) and Canada (Ontario Ministry of Labour 2015), required time and a half for overtime work irrespective of the labour contract, standard or alternative work arrangement, this is not the case of the UK (Metcalf & Dudwar 2010).

just equal to the costs of hiring contingent labour/mandating overtime,  $\frac{w}{2} \left[ \frac{(1-\pi)\omega-1}{\pi a} + \frac{\omega}{b} \right]$ . This relationship can be interpreted in many ways. For example, if wage, probability and loss parameters are fixed it implies the minimum deviation in demand necessary before flexible labour contracting is beneficial to the firm. Or, if the demand deviation is fixed, as are the standard wage, probabilities and loss parameters, it implies the maximum wage premium (minimum discount) consistent with flexible labour contracting. This suggests that even if firms in the same industry face the same demand uncertainty, if the parameters of their loss functions differ, some firms may avail of labour flexibility via real options while others do not.

Differentiating the labour hired under a standard contract and labour hired under a contingent or overtime contract we find

$$\frac{dN}{dw} \geq 0 \text{ as } [(1-\pi)\omega - 1] \geq 0$$

$$\frac{dN'}{dw} \leq 0 \text{ as } \left[ \frac{(1-\pi)\omega - 1}{\pi a} + \frac{\omega}{b} \right] \geq 0$$

while

$$\frac{dN}{d\omega} > 0, \frac{dN'}{d\omega} < 0.$$

The firm balances its two forms of labour input to reduce its costs and to meet its demand targets. If the probability weight on the low demand outcome rises

$$\frac{dN}{d\pi} < 0, \frac{dN'}{d\pi} > 0$$

the firm reduces hours worked by those on standard contracts and increases hours worked by contingent workers should high demand be realized. If the loss suffered as a result of missing the low demand target increases

$$\frac{dN}{da} \leq 0 \text{ as } [(1-\pi)\omega - 1] \geq 0, \frac{dN'}{da} \geq 0 \text{ if } [(1-\pi)\omega - 1] \geq 0$$

given a positive (negative) contingent cost differential, the firm reduces (increases) hours worked by those on standard contracts while it increases (reduces) hours worked by contingent workers/overtime should high demand be realized. Finally, if the loss suffered as a result of missing the high demand target increases

$$\frac{dN}{db} = 0, \frac{dN'}{db} > 0$$

the firm leaves its core hours fixed and relies more heavily on overtime/contingent staffing.

Model 3: Insider-Outsider Model with Overtime, Flexible Rostering or Contingent Contracts, Demand and Cost Uncertainty

Consider an environment similar to that in Model 2, again assuming segmented labour markets but now assume that there are  $s \in S$  distinct and verifiable cost states. In each cost state  $s$  demand can be high,  $\bar{y}_s$ , or low,  $\underline{y}_s$ . The firm can hire three types of workers: “insiders” on standard contracts (permanent, pensionable, etc.), outsiders on a lower wage, contract (neither permanent nor pensionable) contingent on the cost state, and labour on a wage contingent both on the cost and demand states. Assume insider/standard contract workers are required for production to take place. Most model parameters, except the standard wage, including the probability of low or high demand, the loss parameters, and the discount on the standard wage depend on the cost state. Further, as before, assume that the wage paid for demand contingent labour be either a premium over or a discount on the standard wage, where, if a discount, the discount is less than that for outside workers.

The firm chooses  $N$  insider workers on standard contracts,  $N_s''$  outsider workers in state  $s$  and  $N_s'$  workers contingent on realization of high demand in state  $s$  to solve

$$\min \pi_s a_s (N + N_s'' - \underline{y}_s)^2 + (1 - \pi_s) b_s (\bar{y}_s - (N + N_s' + N_s''))^2 + wN + (1 - \pi_s) \omega_s w N_s' + \theta_s w N_s'' - \mu_s (N - \underline{N}) - \lambda_s N_s' - \gamma_s N_s''$$

where  $0 < \theta_s < 1$  is the discount applied to the wage paid to the  $N_s''$  outsider workers and  $\omega_s < \theta_s$  if  $\omega_s < 1$ .

The first-order conditions for  $N$ ,  $N_s'$  and  $N_s''$ , respectively, for all  $s$  are

$$2 \pi_s a_s (N + N_s'' - \underline{y}_s) - 2(1 - \pi_s) b_s (\bar{y}_s - (N + N_s' + N_s'')) + w - \mu_s = 0$$

$$-2(1 - \pi_s) b_s (\bar{y}_s - (N + N_s' + N_s'')) + (1 - \pi_s) \omega_s w - \lambda_s = 0$$

$$2 \pi_s a_s (N + N_s'' - \underline{y}_s) - 2(1 - \pi_s) b_s (\bar{y}_s - (N + N_s' + N_s'')) + \theta_s w - \gamma_s = 0$$

$$N - \underline{N} \geq 0$$

$$N_s' \geq 0$$

$$N_s'' > 0$$

By  $\theta_s < 1$ ,  $\mu_s > 0$  for all  $s$ ,  $N$ , insider labour, will be at the minimum necessary for production to take place in all states  $s$ . Solving for state-contingent, outsider labour and cost and demand state contingent labour we have

$$N_s'' = \underline{y}_s - \underline{N} + w \left( \frac{(1 - \pi_s) \omega_s - \theta_s}{2 \pi_s a_s} \right)$$

$$N_s' = \bar{y}_s - \underline{y}_s - w \left( \frac{(1 - \pi_s) \omega_s - \theta_s}{2 \pi_s a_s} + \frac{\omega_s}{2 b_s} \right)$$

Since insider labour is state independent, the firm solves  $S$  separate labour demand exercises leading to up to  $2S$  real options contracts agreed prior to the realization of the either the cost state or demand in that cost state. In this model outsiders, whose contracts are ratified when costs are revealed, provide flexibility with respect to cost

fluctuations and contingent/overtime labour provides flexibility with respect to demand fluctuations.

Dropping the state subscript for notational simplicity, and noting that, as in Model 2, the firm is just indifferent between hiring demand contingent labour/mandating overtime when  $N' = 0$ . This defines the “strike” for the demand contingent real options contract. At this point the difference between high and low demand,  $\bar{y} - \underline{y}$ , is just equal to the

increase in costs of hiring contingent labour/mandating overtime,  $\frac{w}{2} \left[ \frac{(1-\pi)\omega-\theta}{\pi a} + \frac{\omega}{b} \right]$ .

This relationship has the same interpretations as in Model 2 given that once the product market state is realized the firm’s decision is essentially identical to that in Model 2.

The firm is indifferent between hiring outsider/cost state contingent labour when  $N'' = 0$ . This defines the “strike” for the cost contingent real options contract. At this point the difference between low demand and output produced with mandated labour,  $\underline{y} - \underline{N}$ , is just equal to the cost saving of hiring outsiders, where any productivity

differentials are subsumed in the wage discount,  $-\frac{w}{2} \left[ \frac{(1-\pi)\omega-\theta}{\pi a} \right]$ . Again the strike will

define, for example, given the standard wage, the demand probabilities, cost of overproducing in the low demand state and the overtime/demand state contingent wage differential the maximum feasible discount consistent with hiring outsider labour.