THE ECONOMICS OF CROWDSOURCING: A THEORY OF DISAGGREGATED LABOR MARKETS

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Abstract What protects anonymous individuals from appropriation in disaggregated labor markets? A new kind of economic organization is emerging: the information-processing disaggregated labor market. In these online markets, which are organized by for-profit firms acting as labor market intermediaries, workers are freelancers who perform tasks for requesters for either hourly rates or piece rates, sometimes with incentives for quality or speed. Somewhat ironically, these very new labor markets most resemble the simplest models of labor markets. The sociological and psychological aspects of traditional work relationships are largely absent: work is proposed on take-it-or-leave-it terms, and workers accept or reject offers based only on the onerousness of the work and the pay. There are no compensating differentials or benefits, no unions, no career concerns, and so on. What kinds of contractual mechanisms prevent the hold-up problem that would otherwise cause the market to unravel? Does the fixed price vs. cost plus nature of transactions in different disaggregated labor markets explain the contractual mechanisms that are actually observed? This paper presents some descriptive facts and a simple model illustrating the role of market design for these disaggregated labor markets.

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1 Introduction

Tapping the collective experience and wisdom of a population to perform some task is not a new idea — the Oxford English Dictionary was composed from millions of submissions of word usage by volunteers — yet the internet has made proposing projects, attracting workers, easing collaboration and even compensating workers far easier. While the use of internet is a distinguishing feature of modern "crowd-sourcing," it is a necessary but not sufficient ingredient — we see many other kinds of labor relationships that are now possible with modern telecommunications yet are similar to existing relationships. For example, telecommuting programmers or back-office call centers in India are not fundamentally different from an on-site programmer or a call-center located across the street and we do not require new economic theories to explain these phenomena.

What distinguishes crowdsourcing is that the stakes of any particular contribution are so low that the normal mechanisms for easing exchange in the absence of complete, costless contracts and ready access to courts are missing or inappropriate. Reputations are hard to form or assess when the workforce is multitudes identifiable only by their IP address and chosen screen name. While many workers contribute more than once, it is hard to conceive of these interactions as repeated games. The fundamental problem is that the quanta of work performed is so small that the costs of writing a custom labor contract ex ante or negotiating ex post would be far greater than the costs of the work itself. Further, even if there was a contract, who would adjudicate a contract dispute over pennies?

For some of the most well-known open-source or crowdsourced projects, the payment issue and resulting hold-up problem is irrelevant because compensation is not monetary. The rewards are intellectual or career-concerns, not payment (Lerner and Tirole, 2002). However, there are organizations that have work they would like performed and that are ideal for crowdsourcing, yet are unlikely to attract volunteers. For example, very few people will perform data entry, tag images, classify webpages, validate search results etc. for the intellectual thrill of such tedium — they will want payment.

To illustrate the hold-up problem, consider a buyer (let's call him the boss) trying to procure a seller's (let's call him the worker) labor, say to transcribe a scanned image of text into text. If the boss has to pay the worker ex ante, then the worker could provide very poor quality work (with not doing the work at all, a particular low form of quality). Without any kind of third-party enforcement mechanism, even if most people still tried to act in good faith, dishonest types could destroy the market by taking on all advertised work and then not performing the work. The problem exists even if payment is made ex post: if the boss decides whether or not to pay only after inspecting the work, then the boss has an incentive to claim the work is unacceptable and refuse to pay, if the boss gets to keep the shoddy work. While keeping rejected work is not the norm in regular markets, it is almost unavoidable in micro-labor markets since the good or service is information and once you have it for inspection purposes, you cannot not have it.

One option is to let buyer's only see random selections from the work (like Google Books) or keep the work out of an easily expropriatable format. This does not appear to be the solution used by most of these disaggregated labor markets. There appears to be two distinct types of disaggregated labor markets, fixed price, where prices for projects are set ex ante and not renegotiated ex post,

and cost plus, where compensation is explicitly tied to reported time spent on project. Amazon's Mechanical Turk, one of the earliest disaggregated labor markets, is perhaps the best representation of the former while oDesk (now Upwork) may be the best representation of the latter. Most tasks posted on Mechanical Turk take only minutes or seconds to complete and pay pennies; common tasks include data entry and categorizing images. Workers are identified only by a unique string of letters and numbers, but Amazon is building tools to screen workers based on reputation, and Amazon has assigned decision rights in a way that encourages work quality. A somewhat more traditional market is oDesk. At oDesk, requesters can hire freelance programmers, clerical workers, graphic designers, and so on, for more substantive, longer-lasting projects. In this market, relationships tend to be longer term and contracts are usually hourly. With over $46 million in work delivered and explosive growth, both claiming over 100,000 users from over 100 countries, Amazon's Mechanical Turk and oDesk could represent how labor markets could be organized in the future.

"Who are these people who are willing to do such tedious tasks for a pittance?" is a common reaction to the Mechanical Turk phenomena. One popular hypothesis is that people enjoy doing the tasks and that the whole site is like a kind of video game in which the traditional points are replaced by pennies. However, even if subjects are playing a game, then the object of the game is something like "obtain the most amount of pennies for the least amount of effort," which seems like a reasonable characterization of the neoclassical conception of employment. In a survey of workers, time and money, were the most frequently used words to describe whythey participated in Mechanical Turk. Moreover, at least some workers do it out of need. A disabled former United States Army linguist, became a Turk Worker for various reasons and in nine months he made four thousand dollars (New York Times, March 25, 2007). And some are so successful that they drop out of college to pursue a full time career with these disaggregated labor markets (Web Worker Daily, October 16, 2008, Interview with oDesk CEO). This paper presents a simple model that captures key features of these disaggregated labor markets, exemplified by Mechanical Turk and oDesk and explores model implications under different contractual forms.

2 Stylized Facts

2.1 Bargaining Power In Mechanical Turk, bargaining power is tilted heavily in the employer's favor. Workers can only see the employer's ID, description, keywords, qualifications required, but nothing regarding the employer's reputation. Employers make take-it-or-leave-it offers. They decide how long workers can spend on each task, how long each task will be available and how many times they want a particular task to be completed. Workers, if they accept the task, must complete the task before it expires in order to receive payment. Even after completion, the employer has the option to reject the task or ask the worker to do additional work. If their work is rejected, workers receive no payment. A system of bonuses potentially allows for arbitrarily complex contracts but they are still set ex ante and not renegotiated ex post.

In oDesk, bargaining power is tilted in the worker's favor. Workers are automatically paid. oDesk provides a proprietary monitoring system that takes computer screen snapshots and work logs every ten minutes in order to ensure the worker is actually working during the time claimed. While reputations are only reported for the worker on Mechanical Turk, they are reported for both workers and employers on oDesk. These differences may reflect how the seller (worker) appropriates the

buyer's (employer's) surplus in a cost-plus setting but not in a fixed price setting. Indeed, while oDesk allows fixed price transactions, they are paid solely at the buyer's discretion, just as in Mechanical Turk. An important difference is that on oDesk, fixed price transactions that go unpaid do not show up on the seller's history but they do show up on the buyer's history, while on Mechanical Turk, they only appear on the seller's history. In cost plus transactions, buyers and sellers can end the assignment at any time.

2.2 Anonymity Both labor markets involve total anonymity. This presents the key conundrum to disaggregated labor markets on how to guarantee payment. On oDesk, there is a semblance of non-anonymity. People set up avatars, but fake identifications can be created. While employers are required to provide valid credit cards on oDesk, employees can deposit their earnings into any bank account or wire transfer. Mechanical Turk requires an escrow account. Buyers must pay for all potential jobs upfront even if they refuse the worker's product. This means that Amazon can force the buyer to pay if a valid complaint arises.

On Mechanical Turk, the worker starts working at the moment of acceptance. On oDesk, there are applicants, then workers are interviewed, before being hired. On Mechanical Turk, the buyer specifies qualifications for workers and make individual tests for each qualification, while oDesk has provided a battery of qualifications such as English, Java, Html, administrative skills, and some country specific criteria. A final difference is that Mechanical Turk is not designed for worker-to-worker interaction, while on oDesk, workers can easily manage other workers. The ratio of workers to employers is much higher on Mechanical Turk, where a task can literally be decomposed into thousands if not hundreds of thousands of similar pieces for a comparable number of workers to work on.

2.3 Other Markets Other examples of disaggregated labor markets include guru.com. Guru appears to be be more like Mechanical Turk except that people bid on projects rather than do take-it-or-leave-it offers. Upfront payments are placed in escrow accounts. People post profiles and the kind of work appears to be more varied and complex than the work on Mechanical Turk. The default seems to be bids for fixed price contracts since the bids include estimated total cost, time to completion, experience, and plan for completion. However, there is flexibility to propose an hourly rate, if requested by the employer. Markets like Manpower.com involve less anonymity and therefore seem to be like any other temp agency or labor market intermediary analyzed by Autor (2008).

3 Theory

The goal of this section is to develop a theoretical model of these new labor markets that captures their unique features. We need a model to understand why people participate both as employers and workers, why workers perform work and why employers do not reject all work (i.e., why the hold-up problem does not doom this market), especially in the case of fixed price transactions. One possible answer may be that it is because Amazon forces the employer to pay upfront for work, and the escrow account can potentially be distributed to workers if a complaint arises. Nevertheless, some of the key features of the market that will require special consideration are: 1) the small stakes make arbitration or formal methods of contract enforcement impractical, 2) for these informational goods, inspecting for quality control often allows expropriation, and 3) for quality control, employers often

have multiple workers perform the same task, yet this creates an opportunity for workers to use multiple online identifiers to perform the same task repeatedly.

Consider a buyer and a seller exchanging some good or service. The key features of this model are that a) the buyer can accept the work $a = 1$ or reject the work $a = 0$ if he would receive no utility at the realized level of quality q and contracted price y b) quality is stochastic, but depends on the seller's effort and c) effort e can be decomposed into the time spent on the project t and the intensity of effort i, or $e = it$. For simplicity, assume that there are two quality states: if $q = 1$, then the good is worth v to the buyer and if the quality is bad ($q = 0$), then the good is worth nothing to the buyer. The probability that the quality is high is given by

$$P(q = 1) = F(e)$$

where F is a concave, monotonically increasing function with range $[0, \infty)$. To keep from prematurely narrowing the options of the buyer, assume that the buyer repudiates the contract with probability p when it is rational to do so: $U_b < 0$. The buyer's expected utility is thus

$$U_b = a(vq - y)$$

where y is the payment made to the seller. The utility of the seller is

$$U_s = ay - e$$

Comment

Note that the seller must make his investment of e before realizing q. If the buyer always walks away from bad deals (i.e. $U_b < 0$ and $p = 1$), then the buyer can always obtain at least 0, but the seller is left with $-e$ when the buyer repudiates the contract. In non-anonymous settings under the rule of law, what normally prevents the buyer from always repudiating the contract is that he does not get to keep the good / service following a repudiation. I also do not allow y to change once the contract is signed — this restriction should be interpreted as the transaction costs of bargaining or renegotiation outweighing any gains from renegotiation.

4 Perfect Knowledge

4.1 Fixed-Price With a fixed-price contract and with $v > y$, then if $q = 1$, the buyer always accepts. The seller's problem is then:

$$\max_e \quad Pr(a = 1)(y - e) + Pr(a = 0)(-e)$$

or

$$\max_e \quad (y - e)(F(e)p - p + 1) - ep(1 - F(e))$$

The first-order condition is $pyF'(e) - 1 = 0$, or

$$F'(e) = \frac{1}{py}$$

Setting p

From the social planner's perspective, the optimal p causes the seller to choose the optimal level of effort. Total effort costs are e and total benefits are $F(e)v$, so the optimal effort e^{**} satisfies

$$1 = F'(e)v$$

which implies that

$$p = \frac{v}{y}$$

but since $v > y$, $p = 1$ and therefore

$$F'(e) = \frac{1}{y}$$

Define e^*_{FP} as the optimal effort level of the seller under a fixed-price contract.

Setting p

From the buyer's perspective, the optimal p causes the seller to choose the level of effort that maximizes $F(e)v$ while still meeting his individual rationality constraint. In order to do this, the buyer makes p as large as possible, which is 1. In other words, the buyer always repudiates when the realized worth of the good is less than the price, which in turn incentivizes the seller to maximize effort.

Lemma: The first-best level of quality e^{**} is greater than e^*_{FP}, the level of quality obtainable under a fixed-price contract so long as $v > y$; seller effort is increasing in price.

Proof. The social optimal level of effort is $F'(e^{**})v = 1$ and since $v > y$, $F'(e^{**}) \leq F'(e^*_{FP})$ which implies that $e^{**} > e^*_{FP}$ since F is concave. Since $F'(e) = \frac{1}{y}$, an increase in y implies an increase in e.

Comment 1

What drives the sub-optimal quality result is that quality shading offers a constant return of 1 yet there are diminishing returns from increased quality and since these quality gains are not fully internalized by the seller and the buyer cannot impose a punishment more severe than repudiation, lower-than-optimal quality results. One way of thinking about this result is that the limited liability of the seller prevents an efficient outcome.

Comment 2

In the fixed-price case, the shares of intensity i and time t are not separately determined — the optimal effort is obtained so long as $e^*_{FP} = it$. While the model allows intensity to approach infinity and time zero or vice versa with equal costs in both cases, we might imagine a more realistic cost function where the marginal product of greater intensity (measured in the time-savings it allows) equals the physical costs of that intensity.

Comment 3

Increasing the price y improves quality since it stimulates greater effort. The reason for this quality-increase is that the seller jeopardizes a greater surplus by shading on quality and thus increases quality, ceteris paribus, to prevent the realized quality being worthless to the buyer.

Setting y

From the buyer's perspective, the buyer faces a trade off between increasing y to increase seller's effort and paying the cost of that y to seller when value is realized.

Buyer wants to maximize p or y but since y enters negatively in utility, buyer sets y such that $\delta e/\delta y =$y/v< 1.

In summary, in the fixed price case, sub-optimal quality results because the employer is unable to punish the worker to an extent that results in optimal choice of effort by the worker.

4.2 Cost-Plus In the cost-plus contract, the compensation y is explicitly tied to the reported time spent on the project, t, and a reimbursement rate r per unit time. This would represent the oDesk environment, where workers are paid an hourly wage. As an hourly wage, the worker's outside opportunity costs are reimbursed. The most salient feature of oDesk is arguably the proprietary monitoring technology that allows employers to see what workers are doing every ten minutes. The model captures this by assuming the t time spent is verifiable.

The utilities for the two players are now:

$U_b = a(vq - rt)$

$U_s = a(rt) - it$

Lemma: In the cost-plus contract with reimbursement rates greater than the cost of effort, the seller chooses t that takes the entire buyer surplus, or $t^*_{CP} = \frac{v}{r}$.

Proof. Suppose $t' > \frac{v}{r}$, then buyer's utility is negative, so buyer will always reject. The buyer on oDesk can set a maximum time limit, however, and will thus set $\frac{v}{r}$ as the upper limit for the amount of time a worker can put in. Suppose $t' < \frac{v}{r}$. Let $p = 1$, that is, the buyer always rejects if his utility is negative. On oDesk, buyers can end an assignment at any time. Then, the seller's problem depends on the chosen reimbursement rate r. Intuitively, if r is low, then $t^*_{CP} = \frac{v}{r}$ and the seller extracts the entire buyer surplus. Worker will maximize time because the probability the work will be accepted increases faster than the reimbursement cost to the buyer. If r is high, then the worker sets his time so that the buyer gets zero utility in expectation with risk-neutral players.

For analytical convenience, consider the region where $\frac{v}{r} > \frac{i}{F'(it)}$ since the buyer is indifferent between choices over r.

Comment

Because the buyer rejects negative utility, this results in a downward sloping labor demand curve.

Lemma: Total time spent on a project is decreasing in the reimbursement rate, but work intensity is increasing in the reimbursement rate. The first-best level of effort is achieved under the cost-plus contract.

Proof. Since $t^*_{CP} = \frac{v}{r}$, increasing r decreases t^*_{CP}. Given the optimal time t, the seller must then set i, the work intensity. The seller's problem is the social planner's problem:

$$\max_i vF\left(i\frac{v}{r}\right) - i\frac{v}{r}$$

which gives a first-order condition of

$$\frac{v^2F'\left(i\frac{v}{r}\right)}{r} - \frac{v}{r} = 0$$

or

$$F'\left(i\frac{v}{r}\right) = \frac{1}{v}$$

Since $F'(e) = \frac{1}{v}$ is the first-best level of effort and $e = i\frac{v}{r}$, the cost-plus contract achieves the first-best level of output.

Comment 1

Since the seller is expropriating the buyer's entire surplus, the buyer and seller's incentives are completely aligned by the cost-plus contract and the seller chooses the optimal combination of intensity and time. Notice that the standard trade-off between time and intensity does not arise because intensity factors into increasing the probability the resultant quality is accepted by the buyer.

In summary, the first best level of effort is attained in the cost plus setting but the buyer is left with zero surplus, perhaps explaining why oDesk appears to be a "higher quality" disaggregated labor market.

5 Discussion

This work is quite preliminary. Many features of disaggregated labor markets do appear to be explicable by the fixed price vs. cost plus nature of the transactions offered in the different markets. For instance, differences between Mechanical Turk, a fixed price setting, and oDesk, a cost plus setting, are consistent with buyer surplus being expropriated by the seller in a cost plus setting but not in a fixed price setting. Reputations are reported only for the worker in Mechanical Turk but reported for both workers and employers in oDesk. oDesk employers are required to provide valid credit card information and workers are automatically paid, while in Mechanical Turk, employers pay upfront in escrow accounts to Amazon and workers are not automatically paid. Consistent with the higher quality of work available on oDesk, various qualification tests are ready-made and worker-to-worker interactions are facilitated.

Mechanical Turk and oDesk are, of course, real, with hundreds of thousands, if not millions, of dollars of funds transferred to workers in exchange for useful work—but it is also a far cry from the kinds of labor markets in which the vast majority of people participate. Despite this lack of realism, Mechanical Turk and oDesk still preserve many of the essential features of a real labor relationship (and in fact may be closer to the neoclassical ideal without behavioral considerations than real labor markets): workers are paid for tasks that they would not otherwise perform under terms reached in a competitive spot market.[1] With rising energy prices and ever-cheaper bandwidth, these disaggregated labor markets (paid crowdsourcing) may prove to be not an oddity but rather the ragged edge of the future labor market.[2]

Throughout history, the constraints of physical distance have limited the size of labor markets. Generally speaking, potential workers must live within a short distance of the capital they use for production, with "short" being an evolving standard determined by the dominant mode of transportation. Of course, firms can and do re-locate their capital to more favorable locations, but wherever they choose to set-up, workers must still live nearby. This basic fact profoundly affected (and affects) human geography, trade and economic growth.

[1]For example, Chen and Horton (2014) examines the behavioral response to wage cuts and finds that workers quickly form wage reference points and react negatively to proposed wage cuts by quitting. Shaw et al. (2011) finds that workers asked to prospectively think about responses of their peers — when combined with financial incentives — produced more accurate performance.

[2]It has already proven useful for experimental social scientists interested in running experiments outside the lab (Chen et al., 2014).

Appendix: Annotated Listing of On-Line LMI-created Markets

Major Sites

- Elance is probably the largest, most well-known generalist site. The main work categories are Web & Programming, Design & Multimedia, Writing & Translation, Administration Support, Sales & Marketing, Finance & Management, Legal and Engineering & Manufacturing. As of January 2009, 137,597 users have registered with the site; since 2005, they have collectively earned $141,767,674.
- Guru allows buyers to post jobs and solicit bids from providers. The site seems to be more popular with "firms," which, at least on first inspection appear to be loose conglomerations of freelancers. The exact nature of these firms is probably worth investigating since it might be relevant to the 'boundaries of the firm" research question.
- oDesk is a rapidly growing site that encourages buyers to offer work on hourly terms. oDesk is probably the most successful of the LMI markets and has attracted the most investment.[3] One clear strength of oDesk is that it offers very robust monitoring tools: workers download software that tracks the time they spend working on projects. The software also logs all keystrokes and even periodically takes shots of the worker's screen. This monitoring allows buyers to see precisely what they are paying for and as such, it allows oDesk to guarantee providers that they will be paid for hourly work (since buyers have not option of disputing charges given the ease of monitoring).
- rentAcoder.com focuses on computer programming. Programmers work on a strictly fixed-price basis. After a project is awarded to a bidder, the buyer places the agreed upon amount in an escrow account. Payment is not released until the buyer approves the work. If there are disputes, the company provides arbitrators.
- GetAFreelancer.com is a Swedish generalist that has operated since 2004 and uses the fixed-price / escrow method. As of January 718,222 users (this figure includes buyers and sellers) have exchanged $30,477,400 on 343,233 projects.
- iFreelance is a generalist site with the same basic model as Guru, oDesk and Elance. Very little data is available without registering with the site.
- Amazon's Mechanical Turk is quite different from the other sites: it allows workers to perform simple, piece-rate work for money or store credit. The tasks are generally the kinds of simple tasks that computers are generally incapable of performing. Common tasks include writing captions for photographs, extracting information from scanned documents and transcribing audio clips. Unlike other sites, workers can begin work on a task as soon as it is posted and, remarkably, *all* decision-rights on payment are reserved by the buyer.

Graphics & Design

- iStockPhoto is a royalty-free photo exchange allowing photographers to upload images and sell them to buyers. Over 50,000 photographers have contributed over 4 million photos. Unlike other sites, workers are not responding to explicit demands for labor but rather are more like individual merchants trying to determine buyer needs.

[3]They also seem the most ambitious—their corporate motto is "Changing how the world works"

- 99 Designs lets buyers propose design needs, which are usually logos for small businesses or specialty events. The buyer also states a price they will pay for the winning design and a date when they will choose the winner. Providers then submit designs as small, thumbnail images which the whole community can view (and vote upon). One interesting feature of this market it is probably one of the few real-life examples of non-political all-pay auctions. As of January 2009, the community has 25,100 registered designers who have submitted 1,152,786 designs for 15,993 contests. Buyers have awarded $3,465,314 in prizes.

Software Testing

- uTest provides software testing using a pool of workers that are paid for the bugs that they find.[4] Buyers (software companies) ask for testers with certain demographic characteristics, including their software sophistication and the platforms they use. uTest selects matches from their pool of registered testers. The testers report bugs and make suggestions; they are paid for verified bugs or helpful reviews.

Consulting & Advice

- BitWine is a network of advisors that charge clients a per-minute rate for consultations. Advisors are ostensible experts in some field, such as nutrition, travel, coaching, technology etc. Consultations occur using the voice-over-IP (VoIP) technology Skype and payments are made through PayPal. BitWine takes a percentage of all transactions.

Patent Validation / Invalidation

- Article One Partners is private firm that assists its corporate clients in invalidating patents. A network of "AOP Associates" who have registered with the site can earn up to $50,000 for providing evidence of patent-invalidating "prior art."
- Peer-to-Peer Patent Project is similar to Article One Partners in that the goal of the project is patent assessment, but it is not a true contest or market. The project is sponsored by the US Technology and Patent Office and NYU Law School and patent reviewers are not paid. This crowdsourcing site is now defunct.

Finance

- LendingClub facilitates unsecured lending by individuals to other individuals. The site uses a proprietary matching algorithm to match lenders and borrowers to lower credit risks. This peer-to-peer lending has a labor component in that LendingClub is partially outsourcing risk-assessment and default-prevention work to the community, who are compensated with loan interest.
- Kiva is a non-profit peer-to-peer lending service that allows lenders to make loans to credit-worthy individuals and entrepreneurs in developing countries(Flannery, 2007). While lenders have motives other than profit, they are still "working" for the pro-social benefit they seek by

[4]This is not, however, a new idea: Stanford Computer Scientist Donald Knuth has used this method since the 1970's to find errors in his books and programs.

reviewing loan applicants. As of January 2009, $19,050,735 have been loaned; the default rate for ended loans is 2.8%.

- Prosper.com is another for-profit peer-to-peer lending site similar to LendingClub. As of January 2009, the site claims 830,000 members and $178,000,000 of loans.

Enabling Technologies

- Payoneer uses MasterCard prepaid cards to allow firms to pay people worldwide. The primary user of the service seem to be web-based businesses such as the freelance marketplaces.
- Brainbench.com is a testing and certification business for both on-line and traditional workers. It is used by oDesk in particular to verify IT skills.

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