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JOB DESTRUCTION AND THE EXPERIENCES OF DISPLACED WORKERS

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# JOB DESTRUCTION AND THE EXPERIENCES OF DISPLACED WORKERS

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ABSTRACT. This paper evaluates a class of endogenous job destruction models based on how well they explain the observed experiences of displaced workers. We show that pure reallocation models in which relationship-specific productivity drifts downward over time are difficult to reconcile with the evidence on postdisplacement wages and displacement rates. Pure reallocation models with upward drift can explain the evidence, but implausibly large and persistent negative productivity shocks are required to generate displacements. Combining upward drift with outside benefits or moral hazard as additional motives for displacement makes it possible to explain the evidence with much smaller shocks. Propagation of aggregate shocks, welfare implications of displacement, upgrade of relationships in lieu of displacement, and learning effects are also discussed.

## 1. INTRODUCTION

Models of endogenous job destruction have generated much recent interest among macro-economists.<sup>1</sup> Along with the broad class of questions that have been addressed using these

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<sup>1</sup>Cole and Rogerson (1996), Den Haan, Ramey and Watson (1997), Gomes, Greenwood and Rebelo (1997), Mortensen and Pissarides (1994), Pries (1998) and Ramey and Watson (1997a), for example, have invoked

models, a wide variety of microeconomic mechanisms for generating endogenous job destruction have been employed. In view of the fact that different mechanisms can generate vastly different macroeconomic implications, it is important to ascertain which mechanisms are most strongly supported by the available data.

In this paper we appeal to the large body of evidence accumulated by labor economists on the experiences of displaced workers to assess the microeconomic foundations of endogenous job destruction. We consider a class of job destruction models built on the dynamic matching and contracting approaches of Mortensen and Pissarides (1994) and Ramey and Watson (1997a). Our benchmark specification is the *pure reallocation model*, in which job destruction is motivated solely by the desire to break up persistently unproductive employment relationships, thereby allowing the firm and worker to seek out more productive new relationships on the matching market. A key aspect of the pure reallocation model is the dynamic behavior of relationship-specific productivity. In the *downward drift case*, the productivity of particular relationships tends to decline over time, while in the *upward drift case* productivity tends to rise. We also consider an *outside benefits model*, in which relationships break up due to the availability of current-period benefits outside of the relationship, and a *moral hazard model*, where breakups are caused by the inability to sustain incentives for high effort.

Our analysis centers on two stylized facts about the experiences of displaced workers. First, among displaced workers, displacement rates at their subsequent jobs tend to be higher than displacement rates for the general population; we refer to this as the *subsequent displacement effect*. Second, hourly wages of displaced workers at their subsequent jobs tend to be lower than the wages of workers who had not experienced displacement; this is the

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endogenous job destruction to explain important features of aggregate data on job creation and destruction, as well as unemployment. Den Haan, Ramey and Watson (1997), Mortensen and Pissarides (1994) and Ramey and Watson (1997a) have appealed to endogeneous job destruction as a key channel of business cycle propagation, while Barlevy (1997,1998), Caballero and Hammour (1994,1996), Davis, Haltiwanger and Schuh (1996), Hall (1999) and Mortensen and Pissarides (1998) consider the role played by job destruction in reallocating labor resources toward more productive uses.

*postdisplacement wage effect.* Further, displaced workers having higher predisplacement tenure experience a larger drop in their own wages following displacement.

We first consider the pure reallocation model. We show that for steady-state equilibria of the downward drift case, displacement rates are lower in general for workers who have been recently displaced from other jobs, as downward drift means that productivity prospects are most favorable for recently-formed relationships. Thus, downward drift is inconsistent with the subsequent displacement effect. We show by example that downward drift can conform to the postdisplacement wage effect, but this occurs only for a very narrow range of parameters. The upward drift case, in contrast, will generally satisfy the subsequent displacement effect, and it is straightforward to generate an upward drift example giving a rough quantitative match to available evidence on the two effects, including the relationship between predisplacement tenure and postdisplacement wage drop. Thus, within the class of pure reallocation models, the evidence appears to be strongly supportive of upward drift.<sup>2</sup>

An important issue in the upward drift case, however, is that firms and workers will typically have weak incentives to break up their relationships: a negative productivity shock in the current period may be readily outweighed by prospects for improved productivity in future periods. In our upward drift example, positive displacements are induced in equilibrium only when extremely bad and highly persistent productivity shocks are specified. We show, however, that when outside benefits or moral hazard are combined with upward drift, it is possible to match the empirical evidence with specifications that posit much more reasonable values of the bad productivity shock. We conclude that the presence of upward drift in relationship-specific productivity, together with some combination of current-period outside benefits and moral hazard, is most strongly supported by the available evidence on experiences of displaced workers.

The presence of outside benefits or moral hazard is also important for the propagation of

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<sup>2</sup>See Cabrales and Hopenhayn (1998) for a related analysis of job destruction in the presence of productivity processes with upward drift. They establish that displacement rates decrease and average wages increase with job tenure.

aggregate shocks through variations in the job displacement rate.<sup>3</sup> In the pure reallocation case, displacements occur among very low-productivity matches, while high-productivity matches may be broken up in the presence of outside benefits or moral hazard. Further, to ensure that the steady-state displacement rate is maintained, a smaller cross-sectional variance of relationship-specific productivity is required when moral hazard or outside benefits are introduced. This implies that a shift in the breakup margin will affect a larger number of workers. As a consequence of these factors, the output effect of an aggregate shock may be greatly increased when displacements are driven by outside benefits or moral hazard. Quantitatively significant propagation effects can be present even when idiosyncratic productivity shocks are highly persistent.

The welfare consequences of displacement are also sensitive to the mechanism that generates displacement. To illustrate this point, we consider a policy experiment in which, starting in steady-state equilibrium, the policy authority bans all employment separations. Within a class of examples having identical initial steady states, the maximum welfare loss from the policy in the pure reallocation model is less than half of the maximum welfare gain in the moral hazard model. The key idea is that in the pure reallocation model, the need for very bad productivity shocks to induce displacements directly reflects the low social benefits of reallocation. In contrast, the fact that high-productivity relationships may break up under moral hazard indicates high social costs. The example suggests that imperfections in labor contracting may tend to have greater quantitative importance in welfare calculations than do impediments to reallocation.

Our results raise new questions concerning the idea that endogenous job destruction plays a role in facilitating the reallocation of productive resources toward more efficient uses. Models of such reallocation processes, including Caballero and Hammour (1994,1996) and Hall (1999), rely on downward drift specifications, wherein relationships become gradually less productive and must eventually be supplanted by new relationships. As we have emphasized,

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<sup>3</sup>Den Haan, Ramey and Watson (1997) address this issue in the context of an outside benefits model. That paper focusses on connections between capital and labor adjustment that are not considered here.

however, the downward drift specification is not supported by the microeconomic evidence on experiences of displaced workers, which favors specifications characterized by upward drift. In a world of upward drift, it is highly questionable whether displacements can be viewed as playing a useful reallocative role. Moreover, our welfare analysis indicates that the benefits of displacement-induced reallocation may be small when contrasted with potential costs.

Section 2 lays out the pure reallocation model, and Section 3 considers the experiences of displaced workers in the context of this model. The outside benefit and moral hazard models are introduced Section 4, propagation of aggregate shocks is considered in Section 5, and welfare implications are discussed in Section 6. In Section 7 we consider two extensions. First, we allow relationships to upgrade their relationship following a negative shock, giving them an alternative to displacement. In the pure reallocation model, no displacements occur in steady-state equilibrium if upgrade costs are less than or equal to initial setup costs, as seems plausible. This finding serves to further highlight the importance of outside benefits and moral hazard as explanatory factors for endogenous job destruction. The possibility of upgrade also mitigates further against the reallocative role of displacements. Second, we consider the possibility that firms and workers do not directly observe their relationship-specific productivity distributions, but instead learn them over time. We show by example that this kind of learning can lead to outcomes that are inconsistent with the subsequent displacement effect, contrary to the conclusion reached by Pries (1998). Section 8 concludes.

## 2. PURE REALLOCATION MODEL

**2.1. Basic Structure.** We begin by considering a model of employment relationships in which relationships may fall into persistent low-productivity episodes, relative to productivity levels obtainable in newly-formed relationships. Because of this, firms and workers may have an incentive to break up their relationships, in order to reallocate themselves to more productive relationships with new partners.<sup>4</sup>

The labor market is assumed to consist of a unit mass of atomistic firms, along with

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<sup>4</sup>In Section 7.1 we introduce the possibility that firms and workers can invest in upgrading their relationships, as an alternative to displacement.

a unit mass of atomistic workers. Employment relationships comprise one firm and one worker, who engage in production through discrete time until their relationship is severed. The output that can be produced by relationship  $i$  in period  $t$  is written  $z_{it}$ . At the start of each period, the firm and worker in an active relationship observe  $z_{it}$ , and then decide whether to continue the relationship or else break it up in period  $t$ . If they elect to continue, then they obtain a joint value of  $z_{it} + g_{it}$ , where  $g_{it}$  gives the expected current value of future joint payoffs obtained from continuing the relationship into the following period. If the firm and worker elect to break up, then they obtain the expected current value of future opportunities available outside of their relationship, written  $w_{it}$ .

If continue is chosen, then the firm and worker negotiate a contract that divides their joint surplus. The firm is assumed to directly appropriate  $z_{it}$ , and the contract entails a payment of  $p_{it}$  to the worker. The Nash bargaining solution determined  $p_{it}$ , where the bargaining weight of the worker is  $\pi^w$ , and the outside option is determined by breakup of the relationship. If breakup is chosen, then no payments are made and the agents simply receive their outside option values.

Relationships are formed on a matching market. For simplicity we assume that an unmatched firm or worker locates an unmatched counterpart in a given period with constant probability  $\lambda$ . Matching takes place at the same time as production in active relationships. Agents that are matched in a given period begin a new employment relationship in the following period. A firm and worker in a relationship that breaks up at the start of a period can seek to be rematched in the current period.

**2.2. Productivity Process.** Within a given continuing employment relationship,  $z_{it}$  follows a switching process. With probability  $\gamma$ ,  $z_{it}$  is drawn according to the probability distribution function  $\nu_k(z_{it})$ , where  $k$  gives the number of switches that have occurred since the relationship was first formed. With probability  $1 - \gamma$ , there is no switch, and  $z_{it} = z_{i,t-1}$ . Newly-formed relationships draw  $z_{it}$  from the distribution  $\nu_0(z_{it})$ . For each of the distributions  $\nu_k$ ,  $k \geq 0$ , we assume that  $z_{it} \geq 0$  with probability one, i.e. displacements are not driven by negative returns (we allow for positive current-period outside benefits, which



are equivalent to negative returns, in a later section).

Assume that there is an integer  $K > 0$  such that  $\nu_{k+1} = \nu_k$  for all  $k \geq K$ . Thus, after  $K$  switches, the distribution no longer changes on subsequent switches. For  $k < K$  we focus on two benchmark cases.

1. *Downward Drift.*  $\nu_{k+1}(z_{it}) > \nu_k(z_{it})$  for all  $z_{it} \geq 0$ .
2. *Upward Drift.*  $\nu_{k+1}(z_{it}) < \nu_k(z_{it})$  for all  $z_{it} \geq 0$ .

In the downward drift case, each switch prior to the  $K$ th one leads productivity to be drawn from a less favorable distribution, according to first-order stochastic dominance, so that productivity tends to drift downward over time. Standard examples of downward drift models include the following.

1. *Mortensen and Pissarides (1994).* Here  $K = 1$ , the support of  $\nu_1$  is  $[z^l, z^u]$  with  $z^l < z^u$ , and  $\nu_0$  is degenerate at  $z^u$ . All newly-formed distributions begin at the highest productivity level, and subsequent switches are drawn from the common distribution  $\nu_1$ .
2. *Hall's Escalator (1999).* Each  $\nu_k$  is degenerate at  $z^k$ , with  $z^{k+1} < z^k$  for  $k < K$ . In this case, each switch leads productivity to shift downward.

In the upward drift case, in contrast, switches prior to the  $K$ th one are drawn from successively more favorable distributions, so that productivity tends to rise over time. An example of upward drift is given by *on-the-job learning*:  $\nu_k$  is degenerate at  $z^k$ , with  $z^{k+1} > z^k$  for  $k < K$ , and the worker learns each step with probability  $\gamma$ . The benefits of training are job-specific, in that new matches always start at the productivity level  $z^0$ . Cabrales and Hopenhayn (1998) incorporate a slightly different upward-drift specification into a version of the Mortensen-Pissarides matching setup.<sup>5</sup>

**2.3. Equilibrium.** We now define steady-state equilibria of the pure reallocation model. Since all employment relationships face common bargaining weights, matching probabilities and productivity processes, we may drop the  $i$  subscripts from the variables. Further, the

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<sup>5</sup>In Cabrales and Hopenhayn, relationship-specific productivity in period  $t$  is drawn from  $F(z_{it} | z_{i,t-1})$ , which is strictly decreasing in  $z_{i,t-1}$ . Ljungqvist and Sargent (1998) have utilized an upward-drift specification in a labor market model with exogenous displacements.

expected continuation values depend only on the preceding-period productivity level and the number of switches that have occurred since the relationship was first formed. Thus, the continuation value may be written  $g_k(z)$ , where  $k \geq 0$  is the number of switches and  $z$  indicates the preceding-period productivity level. In the steady-state, the value of outside opportunities is independent of  $t$ , and it may be written  $w$ .

In each period, as long as  $z + g_k(z) \geq w$ , an employment relationship having current productivity  $z$  and having experienced  $k$  switches will opt to continue their relationship, while  $z + g_k(z) < w$  implies that they prefer to break up. Since the value of a new draw is independent of the current  $z$ , it is obvious that  $g_k(z)$  is an increasing function of  $z$ . Thus, there is a *breakup margin*  $\underline{z}_k$  such that the relationship continues if and only if  $z \geq \underline{z}_k$ . The breakup margin is determined by

$$\underline{z}_k + g_k(\underline{z}_k) = w, \tag{1}$$

or else, if  $g_k(0) > w$ , we have  $\underline{z}_k = 0$ . Continuation values satisfy

$$g_k(z) = \beta\{(1 - \gamma)[z + g_k(z)] + \gamma\left[\int_{\underline{z}_{k+1}}^{\infty} (y + g_{k+1}(y))d\nu_{k+1}(y) + \int_0^{\underline{z}_{k+1}} w d\nu_{k+1}(y)\right]\}. \tag{2}$$

To define equilibrium wage payments, it is convenient to denote joint surplus for a match with current-period productivity  $z$ , and having undergone  $k$  switches, by

$$s_k(z) = z + g_k(z) - w. \tag{3}$$

Let  $w^w$  indicate the value of outside opportunities available to the worker. Under the Nash bargaining solution, the worker obtains his share of the surplus plus his outside option value, given by  $\pi^w s_k(z) + w^w$ , in the form of a current-period wage payment plus the present value of his share of the future surplus. Let the expected current value of future payoffs to the worker from continuing the relationship be given by

$$g_k^w(z) = \beta\{(1 - \gamma)[\pi^w s_k(z) + w^w] + \gamma[\int_{\underline{z}_{k+1}}^{\infty} \pi^w s_{k+1}(y) d\nu_{k+1}(y) + w^w]\}. \quad (4)$$

Then the wage payment, written  $p_k(z)$ , must satisfy

$$p_k(z) = \pi^w s_k(z) + w^w - g_k^w(z) \quad (5)$$

Finally, outside option values for the worker and firm, respectively, are determined by

$$w^w = \lambda\beta \int_{\underline{z}_0}^{\infty} \pi^w s_0(y) d\nu_0(y) + \beta w^w, \quad (6)$$

$$w^f = \lambda\beta \int_{\underline{z}_0}^{\infty} (1 - \pi^w) s_0(y) d\nu_0(y) + \beta w^f. \quad (7)$$

### 3. EFFECTS OF DISPLACEMENT

**3.1. Evidence.** A large body of evidence documents the experiences of displaced workers. Displacement has typically been defined in terms of involuntary job separation, including separations due to plant or business closing, layoff, or firing, but not separations associated with ending of temporary jobs. Displacements have also been distinguished from separations resulting from worker quits. With respect to the displacement/quit distinction, our model may be interpreted as capturing displacements to the extent that displacements are tied to changes in productivity on the job. The model could be extended to incorporate quits by allowing for fluctuations in workers' outside benefits, representing changes in personal circumstances that lead to quits. Alternatively, learning by workers about persistent worker-specific characteristics could induce quits tied to job shopping (Topel and Ward, 1992).<sup>6</sup>

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<sup>6</sup>These interpretations of displacements and quits can be motivated by the idea that a displacement occurs when the worker would have wished to continue the employment relationship at the previous-period wage level, while a quit occurs when the worker would not have wished to continue at the previous wage

In our view, quits are not of central importance for the cyclical behavior of employment. Quits make up only about a quarter of U.S. nonentrant employment inflows, and are mildly procyclical, while permanent and temporary layoffs are strongly countercyclical.<sup>7</sup> Further, Topel (1990) shows that displacements in the PSID data strongly track unemployment, as measured both in the PSID data and in the aggregate. Thus, in studying aggregate fluctuations, it seems best to focus on worker displacement.

We focus on two key facts about workers' postdisplacement experiences.

1. *Subsequent Displacement Effect.* Displaced workers experience higher displacement rates in subsequent jobs for years following displacement, relative to the general population.
2. *Postdisplacement Wage Effect.* Displaced workers on average obtain lower hourly wages in subsequent jobs for years following displacement, relative both to nondisplaced workers and to their predisplacement wage levels.

While these findings have been separately corroborated by numerous studies, we focus here on evidence drawn from the PSID, since these data allow the experiences of individual workers to be tracked for many years following displacement. Stevens (1997) calculates the probabilities that a worker experiences subsequent displacement in years following the first displacement; see Table 1. For comparison, the average displacement probability for the entire sample is 0.032 per year.<sup>8</sup> Thus, the probability of subsequent displacement is greatly increased following the initial displacement. Observe further that subsequent displacement probabilities tend to decline as the years since the first displacement increase. These observations regarding displaced workers are entirely in line with the large body of evidence showing that displacement probabilities decline with tenure; see, for example,

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level. More broadly, it should be recognized that the practical distinction between displacements and quits becomes blurred when, as in our model, the worker and firm negotiate to avoid or induce severance.

<sup>7</sup>See, for example, Davis, Haltiwanger and Schuh (1996, ch. 6). These authors conclude (p. 141), "...quits play little role in the sharply higher job destruction during cyclical downturns."

<sup>8</sup>Stevens' sample consists of heads of households who have reported no displacements in the ten years prior to 1969, and who report positive earnings in each year of the sample. The sample covers the years 1969-1986, and contains 1,606 workers, 441 experiencing at least one displacement over the sample period.

Farber (1993).

Stevens also estimates the effect of displacement on wages, relative to wages of workers who do not experience displacement. Column one of Table 2 presents average percent differences in hourly wages following a worker's first displacement, allowing for worker- and time-specific fixed effects. Observe that displacement leads to significantly lower wages for many years, even after controlling for worker characteristics and any effects associated with the year of displacement. Column two reports the estimated percent wage reductions for years since the *most recent* displacement. Wage reductions in the early years following the most recent displacement are roughly equal to those following the first displacement. After about seven years, however, reductions following the most recent displacement are substantially less, indicating that wage recovery becomes stronger for workers who can find and keep a new job. As stressed by Stevens, large longer-term wage reductions following the first displacement are tied to subsequent displacements.<sup>9</sup>

Using PSID data, Topel (1990) considers the percent change in postdisplacement wages, relative to the worker's predisplacement wage level; this serves to control for worker characteristics. Topel also divides the sample based on predisplacement tenure.<sup>10</sup> As reported in Table 3, reductions in own wages are small and short-lived for low-tenure displaced workers, while wage drops are much sharper and more long-lasting for high-tenure workers.<sup>11</sup>

**3.2. Downward Drift Case.** We now consider the extent to which the pure reallocation model with downward drift can account for the displacement effects discussed above. First consider the subsequent displacement effect. We begin with the following lemma.

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<sup>9</sup>A variety of studies have documented a positive relationship between wages and tenure; see Kletzer (1989) and Topel (1991). This effect is consistent with Stevens' finding that wage declines following the most recent displacement become smaller as time passes.

<sup>10</sup>The sample covers all displacements reported in the years 1968-1985, including 1,400 displacement events.

<sup>11</sup>Other studies finding postdisplacement declines in wages and earnings include Carrington (1993), Farber (1993,1997), Jacobson, LaLonde and Sullivan (1993a,b), Neal (1995), Ruhm (1991a,b) and Topel (1993). See also Hall (1995).

**Lemma 1.** *In the downward drift case,  $g_{k+1}(z) < g_k(z)$  for all  $z \geq 0$  and for all  $k < K - 1$ .*

The lemma establishes that continuation values must fall with each switch, as a consequence of downward drift. The proof of the lemma exploits backward induction together with the fact that each switch is associated with a less favorable distribution of productivity. Combining Lemma 1 with equation (1), we conclude that the breakup margin must rise with the number of switches.

**Proposition 1.** *In the downward drift case,  $\underline{z}_{k+1} \geq \underline{z}_k$  for all  $k < K - 1$ , with strict inequality when  $\underline{z}_{k+1} > 0$ .*

Implications of Proposition 1 for displacement rates are easy to derive. The probability of displacement at a given employment relationship, after it has experienced  $k$  switches, is  $\gamma\nu_{k+1}(\underline{z}_{k+1}-)$ :<sup>12</sup> displacement can occur only following a switch, which occurs with probability  $\gamma$ ; and the new productivity level must lie strictly below  $\underline{z}_{k+1}$ , which occurs with probability  $\nu_{k+1}(\underline{z}_{k+1}-)$ . Since both  $\underline{z}_{k+1} \geq \underline{z}_k$  and  $\nu_{k+1}(z) > \nu_k(z)$ , the displacement rate must rise with  $k$ , as long as  $k < K - 1$ . To summarize:

**Corollary 1.** *In the downward drift case, the probability of displacement for a given employment relationship rises with  $k$ , for  $k < K - 1$ .*

We conclude that the downward drift case is inconsistent with the subsequent displacement effect, since the population of recently displaced matched workers will have lower  $k$ , on average, than the general population. Thus, the model predicts that recently displaced workers would tend to have *lower* displacement probabilities. In cases with  $K = 1$ , such as the Mortensen and Pissarides example, displacement probabilities do not depend on  $k$ , so that subsequent displacement rates of recently displaced workers do not differ on average from those of the general population. This feature remains at odds with the observation of higher subsequent displacement rates. More broadly, the downward drift model implies a counterfactual positive relationship between displacement probabilities and tenure.

We turn next to the postdisplacement wage effect. Analysis of equilibrium wages is

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<sup>12</sup> $\nu_{k+1}(\underline{z}_{k+1}-)$  denotes  $\lim_{z \uparrow \underline{z}_{k+1}} \nu_{k+1}(z)$ , i.e. the limit as  $z$  approaches  $\underline{z}_{k+1}$  from below.

facilitated by the following lemma.

**Lemma 2.** *The steady-state equilibrium value of  $p_k(z)$  may be written*

$$p_k(z) = \pi^w z. \tag{8}$$

Using Lemma 2, we may express the average wage of workers in employment relationships that have undergone  $k$  switches as

$$\bar{p}_k = \pi^w \int_{\underline{z}_k}^{\infty} y \frac{d\nu_k(y)}{1 - \nu_k(\underline{z}_k)}. \tag{9}$$

>From (9) it may be observed that a rise in  $k$  does not have clear implications for average wages: the increase in  $\underline{z}_k$ , implied by Proposition 1, will tend to raise  $\bar{p}_k$ ; and higher  $k$  has an unclear effect on the distribution of  $p_k(z)$  conditional on not breaking up. Results are obtainable for the standard examples given above, however. For the Mortensen and Pissarides example, we have:

$$\bar{p}_0 = \pi^w z^u > \pi^w \int_{\underline{z}_1}^{z^u} y \frac{d\nu_1(y)}{1 - \nu_1(\underline{z}_1)} = \bar{p}_1.$$

As for Hall’s escalator, the displacement probability is zero as long as  $z^k \geq \underline{z}_k$ , then jumps to unity once  $z^k < \underline{z}_k$ ; the latter occurs at some unique  $k'$ , since  $z^k$  falls and  $\underline{z}_k$  rises with  $k$ . Thus, using (9) we have that  $\bar{p}_k = \pi^w z^k$ , which strictly decreases in  $k$  as long as  $k < K$ . Thus, for either of the standard examples, recently-displaced workers will tend to have higher wages than nondisplaced workers, by virtue of their lower average values of  $k$ .

For other parameterizations of the downward drift model that we have studied, it is also typically the case that recently-displaced workers earn higher average wages. It is possible to construct examples with downward drift, however, in which the effect of higher  $\underline{z}_k$  as  $k$  rises dominates shifts in the distribution of  $z$ , leading to lower average wages for displaced workers. In particular, suppose  $K = 2$ , and let the distributions  $\nu_0, \nu_1$  and  $\nu_2$  have two-point supports, as indicated in Table 4; also  $\gamma = 0.1, \pi^w = 0.5, \lambda = 0.8$  and  $\beta = 0.96$ . In the steady-state equilibrium of this example, we have  $\underline{z}_0 < 1.67 < \underline{z}_1$ ; thus, the population of employed workers who have had no switches must necessarily earn lower average wages

compared to the population who have had one or more switches, since all employment relationships in the latter group operate only at the high productivity level. Average wages for workers experiencing a displacement at time zero, along with average wages for the remaining nondisplaced workers, are displayed in Figure 1, where the postdisplacement wage effect may be observed.<sup>13</sup> Note however that predisplacement wages of displaced workers lie above those of the nondisplacement workers, contrary to the evidence reported in Table 2.<sup>14</sup>

**3.3. Upward Drift Case.** We turn now to the upward drift case. Lemma 1 is easily extended to cover this case, where  $g_{k+1}(z) > g_k(z)$  for  $k < K - 1$  is implied. The following proposition, showing that the breakup margin declines with  $k$ , may then be obtained using (1)

**Proposition 2.** *In the upward drift case,  $\underline{z}_{k+1} \leq \underline{z}_k$  for all  $k < K - 1$ , with strict inequality when  $\underline{z}_k > 0$ .*

Before considering the subsequent displacement and wage effects, we first ask whether any displacements occur at all in steady-state equilibria of the upward drift case. This issue arises vividly in the on-the-job learning example. As long as any matches form,  $z^0 \geq \underline{z}_0$  must hold; then because  $z^{k+1} > z^k$  and  $\underline{z}_{k+1} \leq \underline{z}_k$ , displacements occur with probability zero for all  $k$ . Here the expectation of future productivity improvements undercuts the motive to reallocate, and displacements fail to occur in equilibrium.

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<sup>13</sup>It should be emphasized that the example produces the postdisplacement wage effect for a very slim range of parameters: moving the lower element of the support of  $z$  only slightly away from 1.67 in either direction produces steady-state equilibria in which either  $\underline{z}_0$  exceeds the lower element, or  $\underline{z}_1$  lies below it. A more robust way to generate the postdisplacement wage effect in a model with downward drift is to assume that the worker's bargaining weight increases with tenure.

<sup>14</sup>As a general matter, in any downward drift example with  $K = 2$  that exhibits the postdisplacement wage effect, displaced workers must earn *higher* predisplacement wages than nondisplaced workers. When the postdisplacement wage effect holds, workers who have had one or more switches have relatively higher average wages; since these workers also have higher displacement probabilities, they will predominate in the predisplacement population, leading to higher predisplacement wages. This is contrary to Stevens' findings, in which predisplacement wages of displaced workers are lower (see Table 2).



The on-the-job learning example is special in that productivity improvements are guaranteed following each switch. However, the most salient feature of the example is the anticipation of very high productivity at the last stage, following  $K$  switches. This point is made clear in the following proposition.

**Proposition 3.** *In the upward drift case, if the probability of displacement is zero after  $K$  switches, then no displacements occur in steady-state equilibrium.*

Intuitively, if productivity under the most favorable distribution is high enough to dissuade displacement, then there will be no flow of firms and workers out of the pool of relationships that have had  $K$  or more switches. The steady-state hypothesis then implies there can be no flow of relationships into this pool, which would have to come from the pool that had undergone  $K - 1$  switches; from this it can be deduced that the latter pool is empty. By induction it then follows that in the steady-state equilibrium, there are no active relationships that have undergone fewer than  $K$  switches, so there can be no displacements. The occurrence of displacements in equilibrium thus relies on the presence of some mechanism that can induce breakups of the most productive relationships.

Infrequency of switches is also an essential prerequisite to the occurrence of displacements in the upward drift case, as the following proposition demonstrates.

**Proposition 4.** *In the upward drift case, if  $\gamma = 1$ , then no displacements occur in steady-state equilibrium.*

If switches are guaranteed to occur each period, then drawing a low value of  $z$  is never sufficient inducement to break up in a given period, as the firm and worker anticipate a fresh productivity draw, from an improved distribution, in the following period. Combining Propositions 3 and 4, we conclude that for displacements to occur in the upward drift model, it is necessary that low productivity levels be possible under the most favorable productivity distribution, and for such levels to persist for sufficiently long episodes when they are drawn.

Consider now the subsequent displacement effect. Invoking Propositions 2 and the upward drift property, the following corollary is easily derived.

**Corollary 2.** *In the upward drift case, the probability of displacement for a given employ-*

ment relationship falls with  $k$ , and strictly so if the displacement probability is positive at  $k - 1$ .

>From Corollary 2 we may conclude that reallocation models exhibiting upward drift will produce the subsequent displacement effect, so long as  $K > 1$  and the highest-productivity relationships are subject to productivity shocks that are sufficiently deep and persistent to induce displacement.

As far as the postdisplacement wage effect, the upward drift case is subject to the same exception as observed in the downward drift case, wherein the reduction in  $\underline{z}_k$  as  $k$  rises will tend to reduce average wages, while shifts in the productivity distribution can lead to higher average wages. It is not difficult, however, to obtain an example satisfying upward drift that gives a rough quantitative match to the PSID evidence on the postdisplacement wage effect. In order to conserve on parameters, we modify the switching process as follows. Consider an employment relationship that has drawn its current  $z$  value from the distribution  $\nu_k$ . With probability  $\gamma$ , the relationship experiences a switch in which it draws a new  $z$  value from  $\nu_{k+1}$ , as usual. However, with probability  $\gamma'$ , there is a switch in which the relationship draws a new value of  $z$  from  $\nu_k$ . No switch occurs with probability  $1 - \gamma - \gamma'$ . With this alternative specification, we can maintain the tractable  $K = 2$  case, and still allow for the possibility of a large number of switches before a relationship reaches the most favorable distribution.

For this example, the productivity distributions have three-point supports, as shown in Table 5, and the parameters  $\pi^w$  and  $\beta$  are specified as before. We also set  $\lambda = 0.6$ ,  $\gamma = 0.05$  and  $\gamma' = 0.07$ . In equilibrium, the breakup margins are such that for every  $k$ , relationships break up if and only if the lowest productivity level is drawn (meaning that  $0.1 < \underline{z}_k \leq 2.0$  for each  $k$ ). Subsequent displacement probabilities in steady-state equilibrium are displayed in Figure 2, where results are roughly in line with the evidence presented earlier. Average wages for displaced and nondisplaced workers are reported in Figure 3.<sup>15</sup> Observe that

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<sup>15</sup>Here we measure average wages following any given displacement, in contrast to Stevens who considers the first displacement occurring after a long no-displacement interval. Average wages in period  $-t$  are

average postdisplacement wages of displaced workers lie below those of nondisplaced workers, and further, displaced workers experience a sharp drop in wages upon displacement. The key idea is that when displaced workers are rematched, their productivity is determined by the unfavorable distribution  $\nu_0$  for a number of periods, depressing their wages. Figure 3 also indicates that average wages following displacement recover more quickly if subsequent displacements are avoided, in line with the evidence.<sup>16</sup>

The link between postdisplacement wage drop and predisplacement tenure is displayed in Figure 4, where it may be seen that the model gives an excellent qualitative match with the evidence reported in Table 3. Displaced workers with high tenure are more likely to have predisplacement productivities drawn from the more favorable distributions, relative to workers with low predisplacement tenure. Thus, the high-tenure workers suffer a larger wage drop, given that new employment relationships start at the least favorable distribution.

Overall, the upward drift example gives a very good accounting of the evidence on displacement effects. An important caveat to these results, however, is that the example relies on an extremely large negative productivity shock to induce displacements among workers who have last drawn from  $\nu_2$ : note from Table 5 that the lowest productivity level is only one-half of one percent of the next highest productivity level. Moreover, the low productivity level cannot be raised to more than 1.15% of the next highest productivity level without inducing the zero displacement probabilities among relationships having the highest productivity distribution. This points to the difficulty of reconciling upward drift with the

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measured for the subpopulation of workers who have no displacements between periods  $-t$  and  $-1$ , and then are displaced in period 0.

<sup>16</sup>Interestingly, the example also displays the predisplacement wage reduction seen in Table 2. This is explained as follows. Displacement probabilities are higher among workers who have had last drawn from  $\nu_0$  or  $\nu_1$ , relative to workers who have last drawn from  $\nu_2$ . The former group also has relatively lower average wages. Since the population of workers displaced at time zero contains a disproportionate number of workers who have higher-than-average displacement probabilities, this population must also have lower-than-average wages. This effect becomes very slight in our example, however, if we restrict attention to workers who have experienced no displacements for a long interval prior to time zero.

occurrence of displacements.

**3.4. Zero Drift Case.** We briefly consider the case of  $K = 0$ , in which initial productivity levels, as well as the productivity levels following any switch, are drawn from the same distribution  $\nu_0(z)$ . In this *zero drift case*, productivity does not tend to exhibit any drift over time, and the persistence of productivity adjustments is tied solely to the frequency of switches. Based on the preceding analysis, the following proposition is immediate.

**Proposition 5.** *In the zero drift case, displacement probabilities and average wages are independent of  $k$ .*

We conclude that within this class of models, some sort of drift is needed in order to account for the wage and subsequent displacement effects.

#### 4. OUTSIDE BENEFIT AND MORAL HAZARD MODELS

Thus far we have considered the possibility that employment relationships break up as a consequence of incentives to reallocate firms and workers away from current relationships having persistently low productivity, toward future relationships having higher productivity. We now augment the reallocation model to consider two other reasons why displacements may occur. First, firms and workers may obtain positive *current-period outside benefits* when their relationship is broken up. For example, a firm may own capital that it can rent out if it ceases production, or a worker may obtain unemployment benefits. Second, production may be subject to *moral hazard* on the part of both the firm and worker, which may lead the relationship to break up if the agents have insufficient incentives to behave cooperatively. Either of these factors may cause displacement probabilities to be positive in cases where no displacements would occur in the pure reallocation model. In this section we consider an extension of the pure reallocation model that nests both outside benefits and moral hazard.

Assume that the firm and worker obtain current-period outside benefits of  $b^f$  and  $b^w$ , respectively, if they choose to break up their relationship at the start of a period. In addition to obtaining these outside benefits, the firm and worker enter the matching pool as usual. The outside benefits continue to be obtained as long as the firm and worker are unmatched.

In addition, as part of the process of production, the firm and worker make simultaneous effort choices. Effort levels can be high or low. If both agents choose high effort, then output is given by  $z$  as usual, and the relationship continues into the next period. If the firm chooses high effort, but the worker selects low effort, then output is zero, and instead the firm and worker obtain current-period private benefits of zero and  $x^w$ , respectively. Low effort by the firm and high effort by the worker lead to zero output and private benefits of  $x^f$  and zero for the firm and worker. Finally, low effort by both agents leads to zero output and zero private benefits. Assume that the agents do not obtain the outside benefits of  $b^f$  and  $b^w$  if they attempt production in a period. Moreover, if either agent selects low effort, then the relationship breaks up. For simplicity, assume that the firm and worker can enter the current-period matching pool following a breakup caused by low effort.

Define  $b = b^f + b^w$  and  $x = x^f + x^w$ , and assume  $x^f, x^w < b$  (this assures that the agents will never agree to choose low effort as part of their contract). Equilibrium conditions (1)-(7) are altered as follows. The joint continuation value, joint surplus, and outside option values become

$$g_k(z) = \beta\{(1 - \gamma)[z + g_k(z)]$$

$$+ \gamma[\int_{\underline{z}_{k+1}}^{\infty} (y + g_{k+1}(y))d\nu_{k+1}(y) + \int_0^{\underline{z}_{k+1}} (b + w)d\nu_{k+1}(y)]\}, \quad (10)$$

$$s_k(z) = z + g_k(z) - b - w, \quad (11)$$

$$w^w = \lambda\beta \int_{\underline{z}_0}^{\infty} \pi^w s_0(y)d\nu_0(y) + \beta(b^w + w^w), \quad (12)$$

$$w^f = \lambda\beta \int_{\underline{z}_0}^{\infty} (1 - \pi^w)s_0(y)d\nu_0(y) + \beta(b^f + w^f). \quad (13)$$

Bargaining determines the following wage payment for the worker:

$$p_k(z) = \pi^w s_k(z) + b^w + w^w - g_k^w(z), \quad (14)$$

where

$$g_k^w(z) = \beta\{(1 - \gamma)[\pi^w s_k(z) + b^w + w^w] + \gamma[\int_{z_{k+1}}^{\infty} \pi^w s_{k+1}(y) d\nu_{k+1}(y) + b^w + w^w]\}. \quad (15)$$

The firm and worker will agree to continue their relationship only if its joint value exceeds the values obtainable outside of the relationship, meaning  $z + g_k(z) \geq b + w$ . Further, the agents have incentives to choose high effort if and only if:

$$p_k(z) + g_k^w(z) \geq x^w + w^w, \quad (16)$$

$$z - p_k(z) + g_k^f(z) \geq x^f + w^f, \quad (17)$$

where  $g_k^w(z)$  is given in equation (4), while  $g_k^f(z)$  indicates the corresponding expected current value of future payoffs to the firm from continuing the relationship.<sup>17</sup> Combining equations (16) and (17), it follows that high effort by both agents is feasible if and only if  $z + g_k(z) \geq x + w$ . The outside benefit and moral hazard constraints together imply that the breakup margin must satisfy

$$z_k + g_k(z_k) = \max\{b, x\} + w \quad (18)$$

In summary, outside benefits and moral hazard change the pure reallocation model in two ways: (i) outside option values are increased by the value of current-period outside benefits; and (ii) incentives to choose low effort may place additional restrictions on the breakup margin. In particular, joint surplus will be strictly positive at the breakup margin when  $x > b$ ; in this case, there is a range of  $z$  values such that displacement is induced

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<sup>17</sup> $p_k(z)$  represents total compensation, which may consist of upfront payments and payments conditional on high effort. Employment contracts may also specify transfers conditional on severance. See Den Haan, Ramey and Watson (1999a) for further details on the nature of contracting in the presence of moral hazard.

as a consequence of moral hazard, even though the firm and worker would prefer that the relationship continue.<sup>18</sup>

We now consider the interaction between outside benefits, moral hazard and displacement. As shown above, there is no assurance that displacements occur in steady state equilibria of the pure reallocation model with upward drift. In such circumstances, however, outside benefits or moral hazard can assure positive displacement probabilities. To minimize complications, we consider this issue analytically in the context of the zero drift case, in which it is similarly possible that displacement probabilities may be zero (e.g., for  $\gamma = 1$ ).

**Proposition 6.** *In the zero drift case of the pure reallocation model, suppose  $\nu_0(z)$  is a non-degenerate distribution, and suppose that no displacements occur in steady-state equilibrium.*

*a. Holding the other parameters fixed, there exists  $b > 0$  such that in the outside benefits model, the probability of displacement must lie between zero and one.*

*b. Suppose in addition that  $\nu_0(z)$  has finite support. Holding the other parameters fixed, there exists  $x > 0$  such that in the moral hazard model, the probability of displacement must lie between zero and one.*

Thus, either outside benefits or moral hazard are sufficient to explain breakups for cases where productivity shocks are too small or too transient to account for displacements under the pure reallocation model.<sup>19</sup> This conclusion extends to the upward drift case, as long as  $\nu_0(z)$  and  $\nu_K(z)$  are sufficiently close together to ensure that newly-formed relationships can satisfy  $z \geq \underline{z}_0$  at values of  $b$  and  $x$  large enough to induce positive displacement probabilities after  $K$  switches.

With outside benefits or moral hazard, it is possible to account for observed subsequent

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<sup>18</sup>Ramey and Watson (1997a,b) have previously considered moral hazard as a source of joint-surplus-reducing breakups; see also Den Haan, Ramey and Watson (1999a,b). The present paper embeds the Ramey-Watson moral hazard framework into a model with a more general class of productivity processes, outside benefits and an option to upgrade.

<sup>19</sup>In the moral hazard model, feedbacks between the breakup margin and the continuation value leads to a possibly nonmonotonic relationship between  $x$  and  $\underline{z}_k$  when the support of  $\nu_k$  is connected, which undercuts the argument of the proof. These feedbacks are avoided under the finite support condition.

displacement and wage effects using productivity distributions that entail much smaller productivity shocks. This may be seen in the following upward drift example, which is the same as the example considered in Section 3.3, except that positive outside benefits are introduced. In particular, we set  $b^w = 2$  and  $b^f = 0$ , i.e. only the worker obtains outside benefits. The productivity distributions are given in Table 6; these are identical to those in Table 5, except that the lowest productivity level is now much higher. The remaining parameters are specified as before, and steady-state equilibria involve severance if and only if productivity is drawn at the lowest level.

By construction, subsequent displacement probabilities, given in Figure 2, are identical between the two examples. Average wages following displacement for this example are shown in Figure 5. Note the close similarity to Figure 3; wage levels for displaced workers are somewhat higher in the current example, reflecting workers' greater bargaining leverage, but the postdisplacement wage effect is still in evidence. Note however that in the present case, the negative productivity shock that induces displacement is much smaller: here the low productivity level amounts to 80 percent of the next highest level, and can be as high as 93.5%. A similar example can be constructed for the moral hazard model. The broad lesson is that a reasonable accounting of the experiences of displaced workers requires that the pure reallocation model be augmented with other factors that can help explain displacements.

## 5. PROPAGATION OF AGGREGATE SHOCKS

When job destruction is endogenous, aggregate shocks will lead to variations in the job destruction rate that can bring about larger and more persistent output responses. The importance of this propagation channel, however, depends on the particular mechanisms that generate job destruction. Propagation effects will tend to be small in the pure reallocation model, since separations occur only for the relationships having very low productivity, and there are relatively few of these under natural specifications of the productivity distribution. For the outside benefit and moral hazard models, in contrast, separations can occur among relationships having productivity close to the population mean. Under natural productivity specifications, fluctuations in the destruction rate can correspondingly lead to large changes



in output.<sup>20</sup>

To make this point transparent, we consider an example with zero drift, where productivity levels are drawn from a common uniform distribution. We model an aggregate productivity shock as follows. Starting in steady-state equilibrium, the productivity distribution for each relationship is shifted down by one percent in period zero. These lower productivity levels are maintained within individual relationships until the next switches occur, at which point productivities are drawn from the original distribution. Thus, the aggregate shock leads to a one-time increase in the displacement rate.<sup>21</sup> For the pure reallocation case, we specify a productivity distribution having support  $[1.065, 2.935]$ , implying a displacement rate of ten percent per period. This is contrasted with a moral hazard specification, in which  $x^w = x^f = 1.65$ . Importantly, in order to maintain the ten percent displacement rate, the support of the productivity distribution must be reduced to  $[1.95, 2.05]$ . The other parameters are  $\pi^w = 0.5$ ,  $\lambda = 0.6$ ,  $\beta = 0.96$ ,  $\gamma = 0.2$ .

The effects of the aggregate shock on normalized output levels are shown in Figure 6. In the pure reallocation case, output effects are nearly identical to direct productivity effects: additional displacements occur only among low-productivity relationships, and there are relatively few of these under the assumed productivity distribution. In the moral hazard case, in contrast, the aggregate shock leads to a much larger number of displacements, and these relationships have significantly higher productivity. This causes the productivity shock to be magnified by over 10 times. Figure 7 shows that the aggregate shock also has a much greater effect on the unemployment rate in the moral hazard case, reflecting the greater

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<sup>20</sup>In this section we extend the findings of Den Haan, Ramey and Watson (1997) by showing that the output effects generated by shifts in the displacement rate can be large and persistent even when relationship-specific productivity shocks are not i.i.d.. That paper also shows that additional interactions between the labor and capital markets can lead to persistent increases in displacement rates following a contractionary shock. This effect greatly increases the persistence of output responses.

<sup>21</sup>We use a uniform distribution in this example, rather than distributions with finite support as in previous examples, in order to avoid lumpy changes in displacement rates that would occur in the finite-support case under the aggregate productivity shocks we consider.

number of relationships that are impacted by the aggregate shock. It should be noted that the example obtains large and persistent output effects for a case in which idiosyncratic productivity shocks are highly persistent.

Similar results are obtainable using outside benefits in place of moral hazard, although output magnification is reduced to the extent that outside benefits entail production activities. Overall, these results reflect the basic point that the pure reallocation model generates displacements only when productivity levels are very far below the mean, while the outside benefit and moral hazard models are consistent with displacements occurring for productivity levels close to the mean.

When upward drift is added to the model, there arises a second channel of propagation, whereby relationships formed in the wake of a negative aggregate shock have lower productivity and higher subsequent displacement rates. To illustrate this point, we return to the upward drift example of Section 3.3. For simplicity, we model the aggregate shock as an exogenous breakup of 25 percent of the employment relationships occurring at time zero. Results are shown in Figure 8, where it may be seen that the population average displacement probability rises following the aggregate shock, reflecting the less favorable productivity distributions of newly-formed relationships. This accords with empirical evidence, cited by Barlevy (1998), that jobs created during recessions are more likely to break up than jobs created during booms. Further, the higher displacement rates serve to add to the persistence of output effects following the shock.

## 6. WELFARE IMPLICATIONS OF DISPLACEMENT

The welfare consequences of displacement also depend on the particular mechanisms that generate displacement. Displacements tend to have favorable welfare effects in the pure reallocation model, in that workers and firms agree to sever their relationships in order to form more productive new relationships. In the moral hazard model, however, displacements can involve a loss of joint surplus and a decline in welfare. Further, breakups may occur among high-valued relationships in the moral hazard model, suggesting that the welfare losses from displacements may exceed potential benefits from reallocation.

To assess the trade-offs involved, we use the upward drift example of Section 3.3 to consider the following simple policy experiment. Beginning in a steady-state equilibrium, the policy authority implements a ban on breakups of employment relationships (including newly-formed relationships). This policy entails potential short-run costs, to the extent that persistently low-productivity relationships are not allowed to break up. Eventually all relationships reach the highest productivity distribution, however, leading to long run benefits. We consider a class of productivity distributions in which productivity levels and probabilities are the same as in Tables 5 and 6, except that the lowest productivity level, denoted by  $z^{low}$ , is varied parametrically. Attention is restricted to cases in which the initial steady state has  $z^{low} < \underline{z}_k \leq 2$  for each  $k$ , i.e. productivity is below the breakup margin if and only if the lowest productivity level is drawn. This assures that the situation prior to the policy change is identical across the different cases.

First consider the pure reallocation model. Since matching probabilities and bargaining weights are constant, firms and workers make socially optimal separation decisions, and the policy will necessarily lead to a welfare loss. This loss is greatest at  $z^{low} = 0$ , where the discounted value of lost output amounts to 1.3 percent of steady-state welfare. Higher values of  $z^{low}$  are associated with smaller welfare declines; at the highest allowable level  $z^{low} = 0.23$ , the policy reduces welfare by only 0.5 percent.<sup>22</sup> Here the low level of the breakup margin directly reflects the low social gains from reallocation.

In the moral hazard model, however, the policy can lead to substantial welfare gains, to the extent that moral hazard forces the severance of high-productivity relationships. Further, the welfare gain increases as  $z^{low}$  rises. At the highest allowable value of  $z^{low}$ , which is  $z^{low} = 1.2$ , the policy change implies a welfare increase of 2.94 percent, which is over twice the highest welfare loss associated with the pure reallocation model.<sup>23</sup> These findings

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<sup>22</sup>Note that  $z^{low}$  cannot be raised further without causing  $\underline{z}_2 \leq z^{low}$  in the initial steady state, in which case no displacements occur when productivity is drawn from the most favorable distribution. In view of Proposition 3, this would serve to eliminate all displacements even without the policy.

<sup>23</sup>For  $z^{low} = 1.2$ , the initial steady state is supported by the value  $x = 6.8$ . Higher values of  $z^{low}$  imply that  $2 < \underline{z}_0$  for any  $x$  that induces  $z^{low} < \underline{z}_2 \leq 2$ , meaning that the initial steady state cannot have the

suggest that imperfections in labor contracting may have substantially greater significance for welfare than impediments to reallocation.

## 7. EXTENSIONS

**7.1. Upgrades.** In the models considered above, it has been assumed that an employment relationship obtaining an adverse and persistent productivity shock has no recourse save for breaking up the relationship. We now investigate the possibility that such a relationship can invest in an *upgrade* that serves to re-initialize the productivity process. Allowing for upgrades places further constraints on the ability of the pure reallocation model to account for displacements.<sup>24</sup>

Let us return to the pure reallocation model, and extend it now by assuming that the firm and worker can elect to upgrade their relationship after observing  $z$  in any period. Choosing upgrade means that the firm and worker suspend production in the current period. In the following period, they pay an upgrade cost of  $k^U$ , and begin their productivity process as if the match were newly formed (i.e., in the following period,  $z$  is drawn from  $\nu_0(z)$ ; after  $k$  switches, if there have been no further upgrades,  $z$  is drawn from  $\nu_{k+1}(z)$  on the  $k + 1$ st switch; etc.). In addition, newly-formed relationships are assumed to pay a setup cost of  $k^S$  at the start of their first period of operation. Following a decision to upgrade, or in the period following their initial matching, the firm and worker negotiate a division of the joint surplus, net of upgrade or setup costs, in the usual manner, with the outside option determined by breakup of the relationship.

Let  $u$  denote the expected current value of future joint payoffs when the upgrade option is chosen in a period. With the addition of the upgrade option, equations (1) and (2) are modified to

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required form.

<sup>24</sup>Mortensen and Pissarides (1998) have studied upgrades versus breakups of employment relationships in the context of downward drift induced by technological progress. A key feature of their model is that relationships have permanent relationship-specific productivity factors that cannot be upgraded.

$$z_k + g_k(z_k) = \max\{u, w\}, \quad (19)$$

$$g_k(z) = \beta\{(1 - \gamma)[z + g_k(z)]$$

$$+ \gamma[\int_{z_{k+1}}^{\infty} (y + g_{k+1}(y))d\nu_{k+1}(y) + \int_0^{z_{k+1}} \max\{u, w\}d\nu_{k+1}(y)]\}. \quad (20)$$

Joint surplus at the point of upgrade or setup investment is given by

$$s^j = \int_{z_0}^{\infty} (y + g_0(y))d\nu_0(y) + \int_0^{z_0} \max\{u, w\}d\nu_0(y) - k^j - w, \quad j = U, S, \quad (21)$$

where  $s^U$  and  $s^S$  denote joint surplus at the point of upgrade and setup investment, respectively. The joint value of the upgrade option and the values of the agents' outside options may be written

$$u = \beta(s^U + w), \quad (22)$$

$$w^w = \lambda\beta\pi^w \max\{s^S, 0\} + \beta w^w, \quad (23)$$

$$w^f = \lambda\beta(1 - \pi^w) \max\{s^S, 0\} + \beta w^f. \quad (24)$$

Observe that equations (23) and (24) allow for the possibility that the setup cost is so high that  $s^S < 0$ ; in this case, no employment relationships are formed in equilibrium.

Given plausible restrictions on the upgrade and setup costs, the possibility of upgrade places stringent restrictions on the possible equilibria, as shown in the following proposition.

**Proposition 7.** *In the upgrade model, if  $k^U \leq k^S$ , then no displacements occur in steady-state equilibrium.*

The key idea is that an ongoing relationship can mimic any productive possibilities that are available to a newly-formed relationship by making a suitable upgrade investment.

Moreover, ongoing relationships will generally have advantages over new relationships; in particular, many aspects of relationship capital, such as specific training and familiarity, need not be reacquired. Thus, it is reasonable to assume that upgrade costs are no greater than setup costs. Moreover, by upgrading, ongoing relationships can avoid going through a time-consuming matching process. As a consequence of these factors, relationships will always find upgrade preferable to breakup in the upgrade model, and so there are no displacements.

As happens for the pure reallocation model, outside benefits or moral hazard may be added to the upgrade model to introduce displacements. To see this, we combine the upgrade and moral hazard models as follows (results are similar using the outside benefits model). If the firm and worker in an active relationship choose to produce in a period, then they make effort choices just as described in the earlier section. If upgrade is chosen, then they must also make effort choices in the current period, prior to the period in which the new productivity level is drawn. If both agents choose high effort, then upgrade proceeds normally, while if one or both select low effort, then payoffs are the same as in the earlier case, and the relationship is severed.

>From this it follows that, if the agents opt to upgrade, then they will have incentives to choose high effort if and only if

$$\beta(\pi^w s^U + w^w) \geq x^w + w^w, \quad (25)$$

$$\beta[(1 - \pi^w) s^U + w^f] \geq x^f + w^f. \quad (26)$$

Combining inequalities (25) and (26) gives  $u \geq x + w$ . Thus, as long as  $x > u - w$ , upgrade is incentive infeasible, and breakup again becomes the only recourse when productivity is low. Here the key advantage of newly-formed relationships is that they can avoid contracting problems in the period leading up to formation of the relationship.

**7.2. Learning.** Pries (1998) has recently argued that reallocation models with learning can account for the subsequent displacement effect. With learning, employment relationships

gain information through time about their productivity distribution. Thus, even though the unconditional distribution of productivity does not change, particular employment relationships may experience a form of upward drift as they acquire favorable information. Displacement probabilities fall over time for these relationships.

It is important to recognize, however, that learning itself does not imply any particular bias toward an upward drift effect. To see this, consider the following example, in which given employment relationships draw their productivity levels from an unchanging underlying distribution, but there is uncertainty about the distribution. There are two possible distributions. The “ordinary” distribution is given by  $\nu_0(z)$ , just as in the zero drift case considered above, with the added condition that its support is bounded. The “great” distribution, in contrast, yields the very high value  $z^*$  with probability  $\omega$  in each period, while with probability  $1 - \omega$  the realization of  $z$  is drawn from  $\nu_0(z)$ . To keep the example simple, we follow Pries and assume that exogenous separation is possible; such separations occur with probability  $\sigma$  in each period. The ex ante probability that a firm and worker have the great distribution is given by  $\xi$ .

If a firm and worker draw  $z^*$  after a switch, then it is revealed that they have the great distribution. Assuming that  $\omega$  is close to unity,  $\sigma$  is close to zero and  $z^*$  is large enough to dissuade voluntary breakups, the joint value of such relationships is approximately equal to  $z^*/(1 - \beta)$ . Now consider relationships that have drawn  $z$  in the support of  $\nu_0$  initially and on their first switch. For these relationships, the continuation value satisfies

$$g_1(z) \cong \beta\{[1 - \gamma(1 - \sigma) - \sigma][z + g_1(z)] + \gamma(1 - \sigma)\left[\frac{\xi(1 - \omega)^2}{\xi(1 - \omega)^2 + 1 - \xi} \cdot \frac{z^*}{1 - \beta} + \frac{1 - \xi}{\xi(1 - \omega)^2 + 1 - \xi} \left(\int_{\underline{z}_2}^{\infty} (y + g_2(y)) d\nu_0(y) + \int_0^{\underline{z}_2} w d\nu_0(y)\right)\right] + \sigma w\}. \quad (27)$$

>From (27) it follows that  $g_1(z)$  may be made as large as desired by specifying sufficiently large  $z^*$ , while low values of  $w$  can be maintained by lowering  $\lambda$  accordingly. In particular, we can induce a value of  $\underline{z}_1$  that is low enough to yield a displacement probability of  $\sigma$  for these relationships. As  $k$  increases, however, the posterior probability of the great distribution

falls to zero for relationships having the ordinary distribution. This is tantamount to taking  $\xi \rightarrow 0$  in (27), and the displacement probability converges to the level associated with the zero drift case (augmented by exogenous separation). Since the latter probability may lie above  $\sigma$ , it follows that displacement probabilities for newly-displaced workers may lie below those of the general population. Thus, the subsequent displacement effect need not hold in a model with learning effects but zero drift of the unconditional productivity distribution.

The key feature of this example is that newly-formed relationships are willing to hold out for the prospect that their long-term productivity will be great. Some of these relationships obtain disappointing results, and their displacement probabilities rise to the usual zero-drift level. The example demonstrates that the latter kind of relationships can give rise to a situation where the subsequent displacement effect does not hold.

## 8. CONCLUSION

We have evaluated a class of models of endogenous job destruction from the perspective of their ability to account for the observed experiences of displaced workers. Pure reallocation models in which relationship-specific productivity is subject to downward drift fare poorly when confronted with the evidence. Models with upward drift are much closer in line with the evidence, but in the context of pure reallocation, unreasonably large negative productivity shocks are needed in order to induce displacements in equilibrium. Combining current-period outside benefits or moral hazard with the upward drift specification makes it possible to explain the data using reasonable values of negative productivity shocks. This conclusion is reinforced when the possibility of upgrades is added to the model: outside benefits or moral hazard then become essential ingredients to any explanation of endogenous job destruction.

In the pure reallocation model with upward drift, changes in the displacement rate do not contribute much to the propagation of aggregate shocks, and the welfare benefits of displacement-induced reallocation are small. Both of these results stem from the fact that negative productivity shocks must be very large to generate displacements. With outside benefits or moral hazard, in contrast, high-productivity relationships can be broken up, leading to important propagation effects and potentially high welfare costs of displacement.



Overall, our results show that the empirical plausibility of job destruction models, as well as the macroeconomic implications of endogenous job destruction, depend sensitively on the nature of the mechanisms that generate destruction. Future research should inquire more carefully into the sources of upward drift (firm vs. industry-specific human capital, adjustment costs to investment), outside benefits (home production, production in outside markets) and contracting imperfections (nonverifiability, illiquidity) that underlie the models considered here.

## APPENDIX

*Proof of Lemma 1.* Clearly,  $g_{K-1}(z) = g_K(z)$ , since in either case the next switch is drawn from  $\nu_K(z)$ . Note:

$$\begin{aligned}
 & \int_{\underline{z}_{K-1}}^{\infty} (y + g_{K-1}(y)) d\nu_{K-1}(y) + \int_0^{\underline{z}_{K-1}} w d\nu_{K-1}(y) \\
 & > \int_{\underline{z}_{K-1}}^{\infty} (y + g_{K-1}(y)) d\nu_K(y) + \int_0^{\underline{z}_{K-1}} w d\nu_K(y) \\
 & = \int_{\underline{z}_K}^{\infty} (y + g_K(y)) d\nu_K(y) + \int_0^{\underline{z}_K} w d\nu_K(y), \tag{28}
 \end{aligned}$$

where the inequality follows from  $\nu_K(z) > \nu_{K-1}(z)$  and the fact that the integrand is an increasing function of  $z$  (from (1) and (2)). Combining (2) and (28), we have  $g_{K-2}(z) > g_{K-1}(z)$  for all  $z \geq 0$ . Assuming  $g_k(z) > g_{k+1}(z)$  for all  $z \geq 0$ , for all  $k = k', \dots, K-1$ , (28) is easily modified to extend the result to  $k' - 1$ . Q.E.D.

*Proof of Lemma 2.* Substituting (3) into (5), adding and subtracting the following:

$$\beta\pi^w \gamma \int_0^{\underline{z}_{k+1}} w d\nu_{k+1}(y),$$

and then simplifying yields

$$p_k(z) = \pi^w(z - w) + w^w + \beta\pi^w w - \beta w^w. \tag{29}$$

Using (6), (7) and  $w = w^w + w^f$ , we have  $w^w = \pi^w w$ , whence (29) implies (8). Q.E.D.

*Proof of Proposition 3.* Let  $N_k$  denote the mass of matches that have undergone  $k$  switches,  $k = 0, 1, \dots, K - 1$ , and let  $N_K$  denote the mass of matches that have had  $K$  or more switches. In steady-state equilibrium, we have

$$N_K = (1 - \gamma\nu_K(\underline{z}_K-))N_K + \gamma(1 - \nu_K(\underline{z}_K-))N_{K-1}, \quad (30)$$

$$N_k = (1 - \gamma)N_k + \gamma(1 - \nu_k(\underline{z}_k-))N_{k-1}, \quad k = 1, \dots, K - 1, \quad (31)$$

$$N_0 = (1 - \gamma)N_0 + \lambda U(1 - \nu_0(\underline{z}_0-)), \quad (32)$$

where  $U$  gives the mass of unmatched workers. Now, if  $\nu_K(\underline{z}_K-) = 0$ , (30) implies  $N_{K-1} = 0$ , whence (31) implies  $N_{k-1} = 0$  as long as  $\nu_k(\underline{z}_k-) < 1$ . Note that  $\nu_0(\underline{z}_0-) < 1$  implies  $\nu_k(\underline{z}_k-) < 1$  for all  $k < K$ , as a consequence of Proposition 2 and  $\nu_{k+1}(z) < \nu_k(z)$ , whence  $N_k = 0$  for all  $k$ ; further, (32) implies  $U = 0$ , so we conclude  $N_K = 1$ . Thus, in steady-state equilibrium all workers are in matches that have had  $K$  or more switches, for which the displacement probability is zero.

The remaining possibility is  $\nu_0(\underline{z}_0-) = 1$ . In this case, (32) gives  $N_0 = 0$ , and (31) implies  $N_k = 0$  for  $k = 1, \dots, K - 1$ . Here workers are divided between the unmatched pool and matches that have had  $K$  or more switches, and again no displacements occur. Q.E.D.

*Proof of Proposition 4.* Combine (3), (6) and (7) to obtain

$$w = \lambda\beta \int_{\underline{z}_0}^{\infty} (y + g_0(y) - w)dg_0(y) + \beta w. \quad (33)$$

>From (2), using  $\gamma = 1$ :

$$g_k(z) = \beta \int_{\underline{z}_{k+1}}^{\infty} (y + g_{k+1}(y) - w)d\nu_{k+1}(y) + \beta w. \quad (34)$$

Using (33) and (34):

$$g_k(z) - w \geq \beta \left[ \int_{z_{k+1}}^{\infty} (y + g_{k+1}(y) - w) d\nu_{k+1}(y) - \int_{z_0}^{\infty} (y + g_0(y) - w) dg_0(y) \right] > 0,$$

using  $\lambda \leq 1$ ,  $g_{k+1}(z) > g_0(z)$  and the fact that the integrands are increasing functions of  $z$ . Equation (1) and  $z \geq 0$  then imply  $z_k = 0$ . Q.E.D.

*Proof of Proposition 6.* (11), (12) and (13) may be combined to obtain

$$w = \lambda \beta \int_{z_K}^{\infty} (y + g_0(y) - b - w) d\nu_0(y) + \beta(b + w). \tag{35}$$

Further, using (10) for  $k = 0$ :

$$g_0(z) = \beta[(1 - \gamma)(z + g_0(z)) + \gamma \int_{z_0}^{\infty} (y + g_0(y) - b - w) d\nu_0(y)] + \beta\gamma(b + w). \tag{36}$$

(35) and (36) may be combined to form an expression in terms of  $g_0(z) - w = \psi(z)$ :

$$\psi(z) = \beta(1 - \gamma)(z + \psi(z) - b) + \beta(\gamma - \lambda) \int_{z_0}^{\infty} (y + \psi(y) - b) d\nu_0(y). \tag{37}$$

Note from (37) that  $\psi(z)$  is a linear function of  $z$ , having slope  $\beta(1 - \gamma)/(1 - \beta(1 - \gamma))$ . Further, using (18) we have:

$$\psi(z_0) = \max\{b, x\} - z_0. \tag{38}$$

Using (37) and (38), we may solve for  $\psi(z)$ :

$$\psi(z) = \max\{b, x\} - z_0 + \frac{\beta(1 - \gamma)}{1 - \beta(1 - \gamma)}(z - z_0). \tag{39}$$

Finally, combining (37) and (39) at  $z = \underline{z}_0$ , and using (38):

$$\begin{aligned} \max\{b, x\} - \underline{z}_0 &= \beta(1 - \gamma)(\max\{b, x\} - b) \\ &+ \beta(\gamma - \lambda) \int_{\underline{z}_0}^{\infty} \left( \frac{y - \underline{z}_0}{1 - \beta(1 - \gamma)} + \max\{b, x\} - b \right) d\nu_0(y). \end{aligned} \quad (40)$$

For  $x = 0$ , (40) becomes

$$b = \underline{z}_0 + \frac{\beta(\gamma - \lambda)}{1 - \beta(1 - \gamma)} \int_{\underline{z}_0}^{\infty} (y - \underline{z}_0) d\nu_0(y). \quad (41)$$

>From (41) it follows that the equilibrium value of  $\underline{z}_0$  is an increasing function of  $b$ , and the derivative of  $\underline{z}_0$  with respect to  $b$  is bounded below by unity. If the displacement probability is zero for  $b = 0$ , then we have  $\nu_0(\underline{z}_0 -) = 0$ ; by raising  $b$ ,  $\underline{z}_0$  can be driven upward into the interior of the support of  $\nu_0(z)$ , where the displacement probability lies between zero and one.

For  $b = 0$ , (40) becomes

$$x = \frac{\underline{z}_0 + \frac{\beta(\gamma - \lambda)}{1 - \beta(1 - \gamma)} \int_{\underline{z}_0}^{\infty} (y - \underline{z}_0) d\nu_0(y)}{1 - \beta(1 - \gamma) - \beta(\gamma - \lambda)(1 - \nu_0(\underline{z}_0 -))} \quad (42)$$

Let  $z^l$  denote the minimum of the support of  $\nu_0(z)$ . Using (42), it can be shown that for  $\underline{z}_0 < z^l$ , the derivative of  $\underline{z}_0$  with respect to  $x$  is positive and bounded away from zero, and similarly for the left- and right-hand derivatives at  $\underline{z}_0 = z^l$ . Thus, if  $\underline{z}_0 \leq z^l$  for  $x = 0$ , then by raising  $x$ ,  $\underline{z}_0$  can be driven to a point just above  $z^l$ . Q.E.D.

*Proof of Proposition 7.* From (21) it is clear that  $k^U \leq k^S$  implies  $s^U \geq s^S$ . Combining (23) and (24), using  $w = w^w + w^f$ , gives

$$w = \lambda\beta \max\{s^S, 0\} + \beta w. \quad (43)$$

If  $s^S > 0$ , then  $u > w$  follows immediately from (22) and (43), since  $\lambda < 1$ . Otherwise,  $s^S \leq 0$ , and we have either  $u > w$  or  $\underline{z}_k = 0$  for all  $k$ . Thus, either upgrades are always selected in lieu of breakups, or else neither upgrades nor breakups are chosen. Q.E.D.

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Table 1  
Subsequent Displacement Effect

<u>Years after displacement</u>	<u>Probability of Subsequent Displacement</u>
1	0.099
2	0.117
3	0.077
4	0.064
5	0.086
6+	0.044

Source: Stevens (1997)



Table 2

Pre- and Postdisplacement Wage Effect

	Since First Displacement	Since Most Displacement
Years before/after displacement		
2 before	-0.012	-0.06
1 before	-0.081	-0.074
year of displacement	-0.131	-0.139
1 after	-0.116	-0.109
2 after	-0.074	-0.071
3 after	-0.092	-0.096
4 after	-0.106	-0.101
5 after	-0.065	-0.061
6 after	-0.060	-0.069
7 after	-0.084	-0.069
8 after	-0.113	-0.080
9 after	-0.213	-0.123
10 or more after	-0.070	-0.007

Source: Stevens (1997)

Table 3  
Percent Difference Between Post- and Predisplacement Wages

Years after displacement	Years of Predisplacement Tenure				
	0-1	1-3	3-6	6-10	10+
1 after	-0.12	-0.031	-0.145	-0.101	-0.198
2 after	-0.20	0.091	-0.114	-0.192	-0.229
3 after	0.138	0.15	-0.022	-0.131	-0.106
4 after	0.153	0.101	-0.022	-0.013	-0.031
5 after	0.174	0.222	0.048	-0.012	-0.43
6 or more after	0.327	0.215	0.072	0.059	-0.027

Source: Topel (1990)

Table 4  
Downward Drift Example

	Value of z	
	1.67	2.10
$v_0$	0.5	0.5
$v_1$	0.6	0.4
$v_2$	0.7	0.3

Table 5  
Upward Drift Example

	Value of z		
	0.1	2.00	2.40
$v_0$	0.65	0.35	0.0
$v_1$	0.10	0.40	0.50
$v_2$	0.05	0.45	0.50

Table 6  
Outside Benefit Example

	Value of z		
	1.60	2.00	2.40
$v_0$	0.65	0.35	0.0
$v_1$	0.10	0.40	0.50
$v_2$	0.05	0.45	0.50

Figure 1

A Downward Drift Example with Postdisplacement Wage Effect

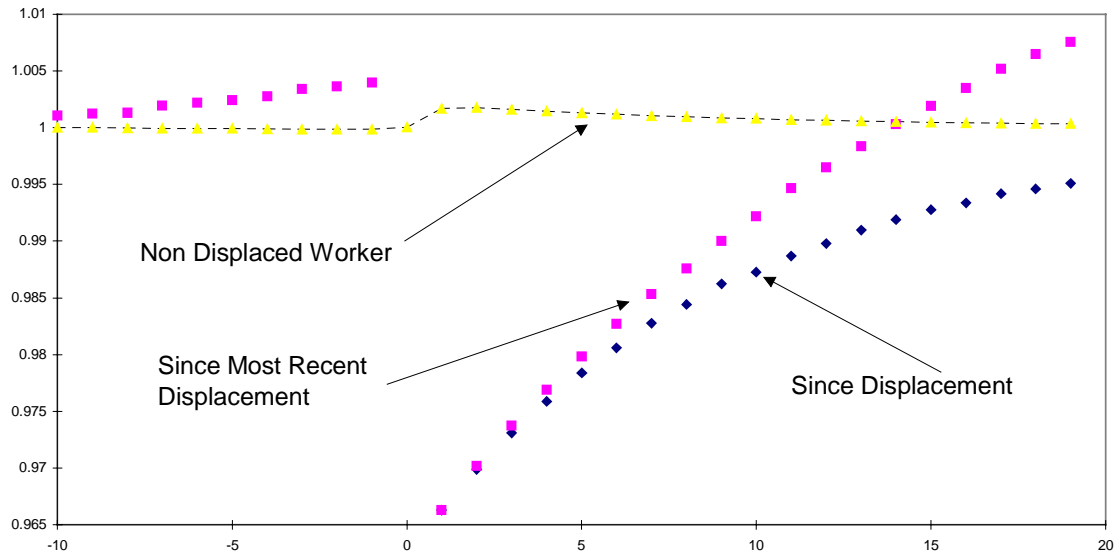


Figure 2

Subsequent Displacement Probability with Upward Drift

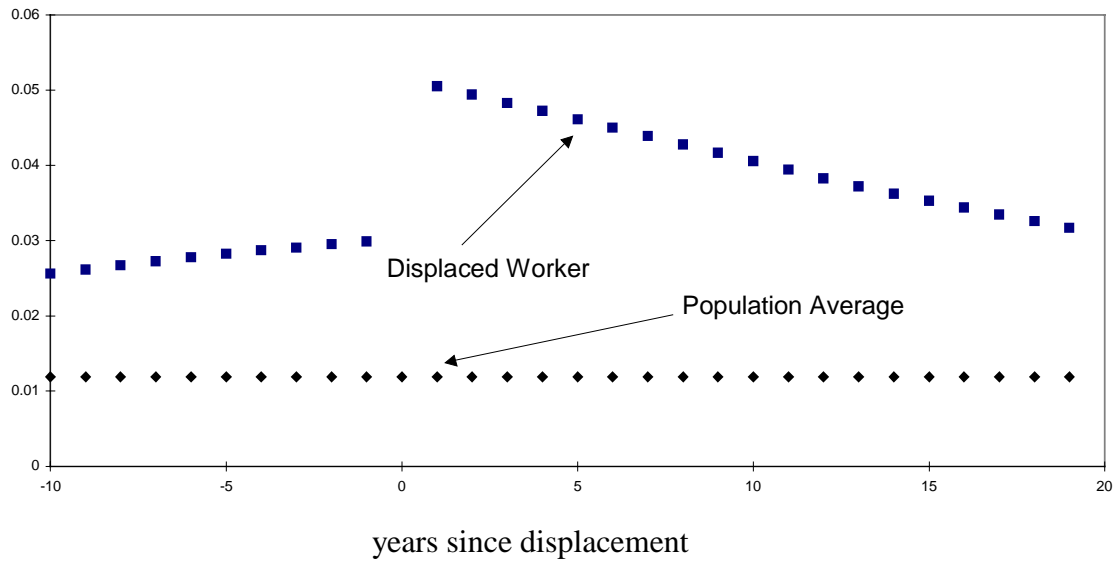


Figure 3  
Average Wages in Upward Drift Model

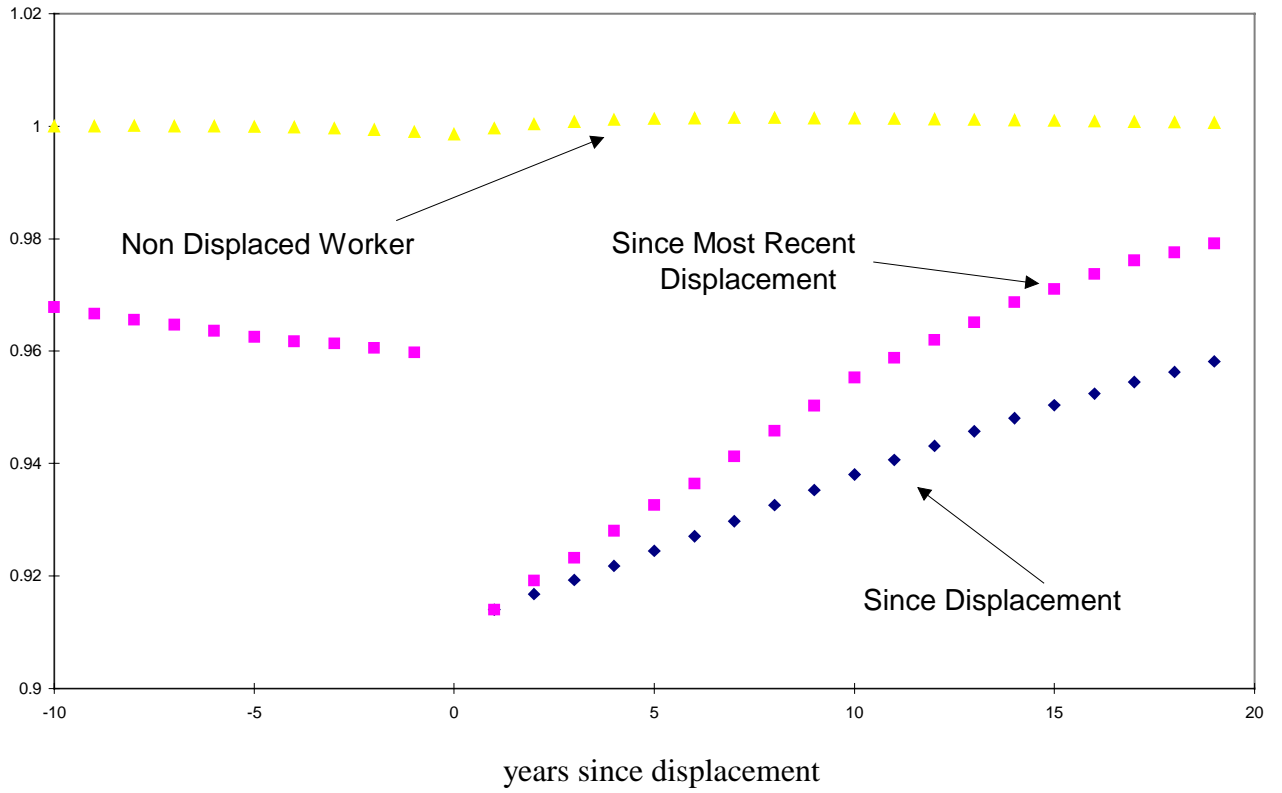


Figure 4  
Change in Wages of Displaced Worker

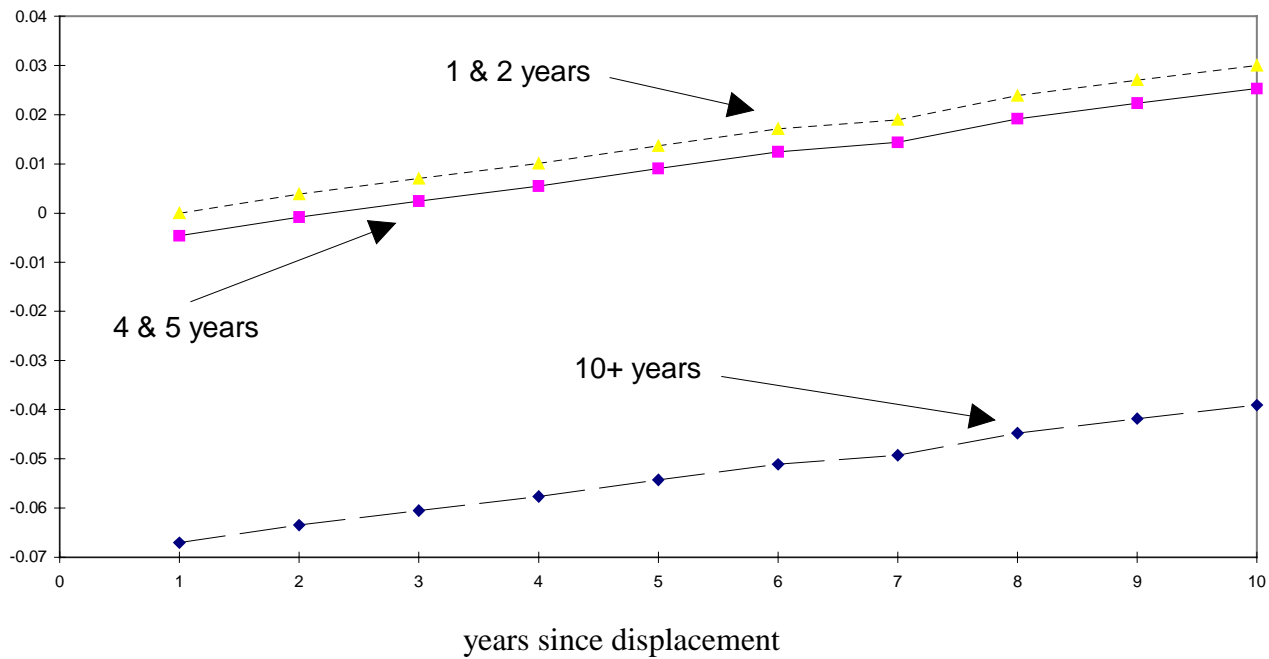


Figure 5

Average Wages in Outside Benefit Model

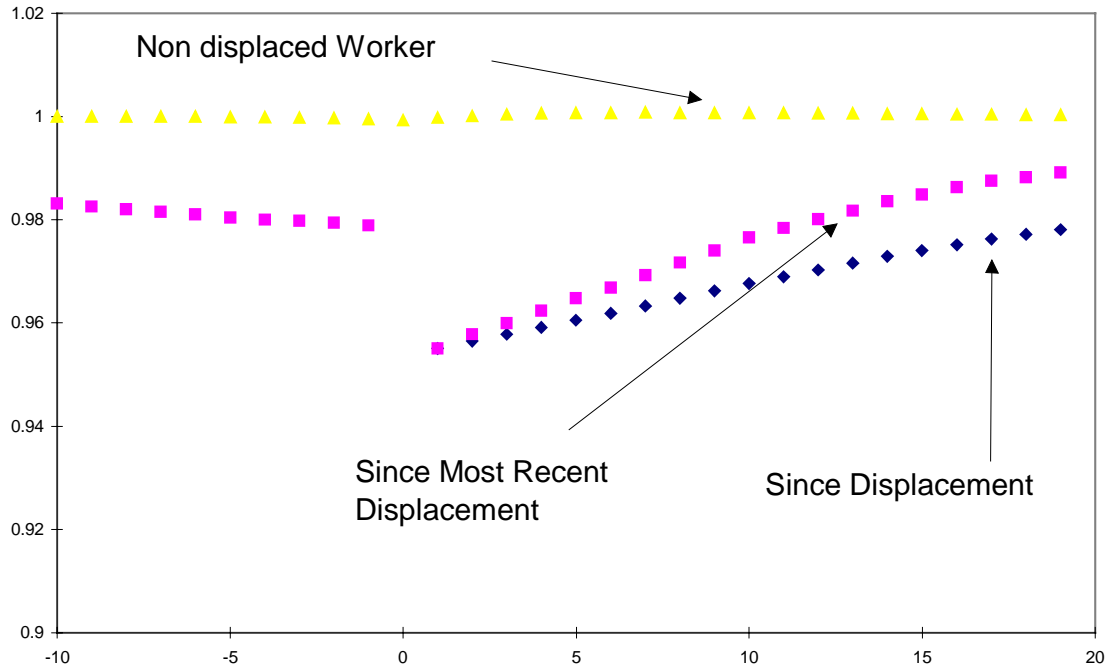
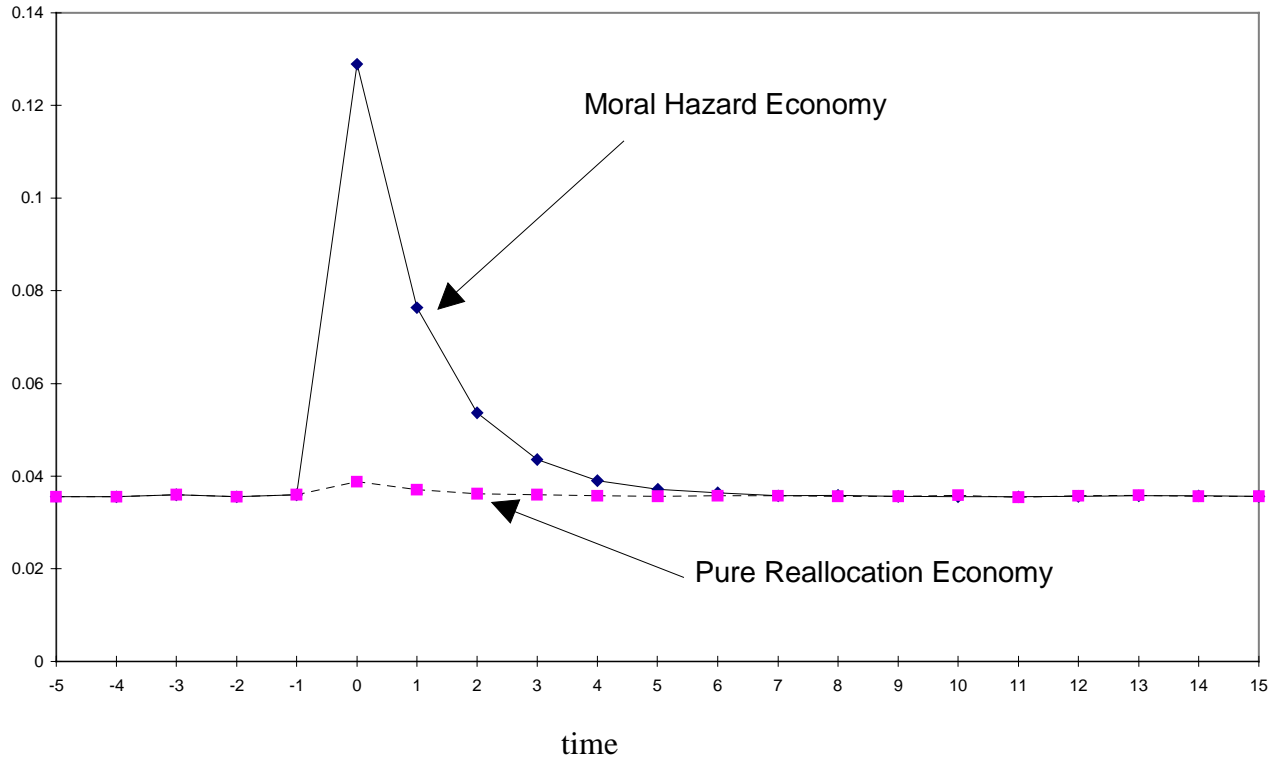




Figure 6  
Magnification & Persistence

A: Unemployment Rate



B: Per Capita Output

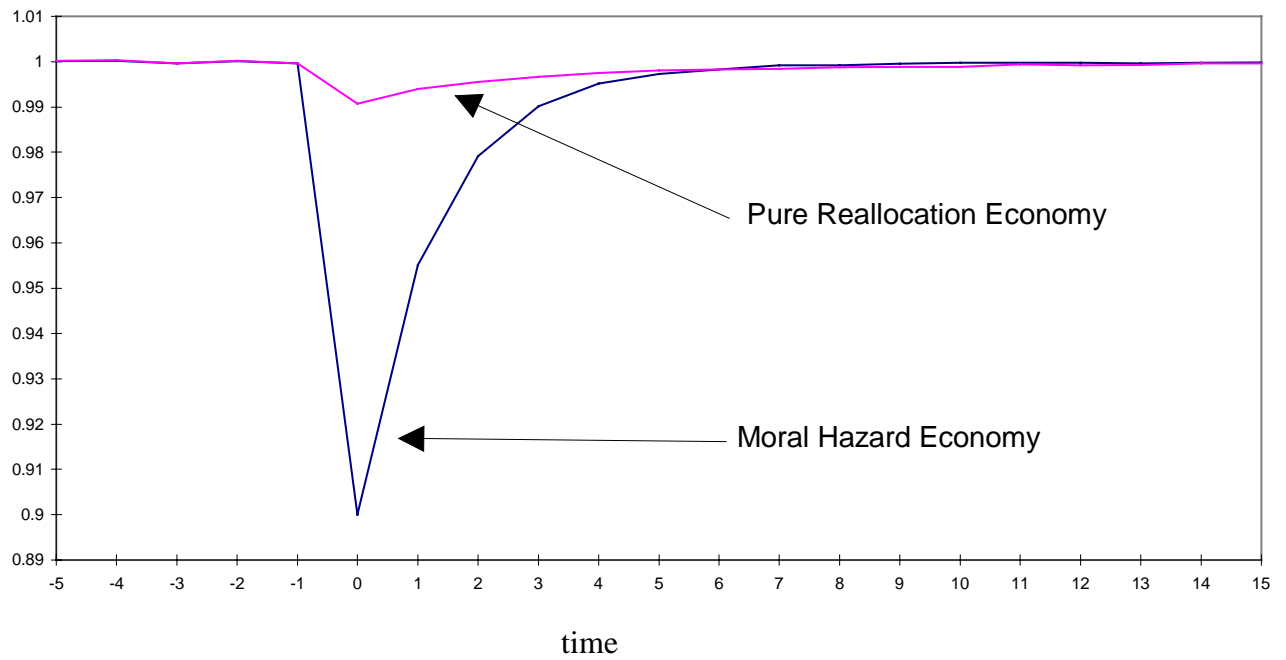


Figure 7

Displacement Probability in Response to Aggregate Shock

