Workload, Time Use and Efficiency

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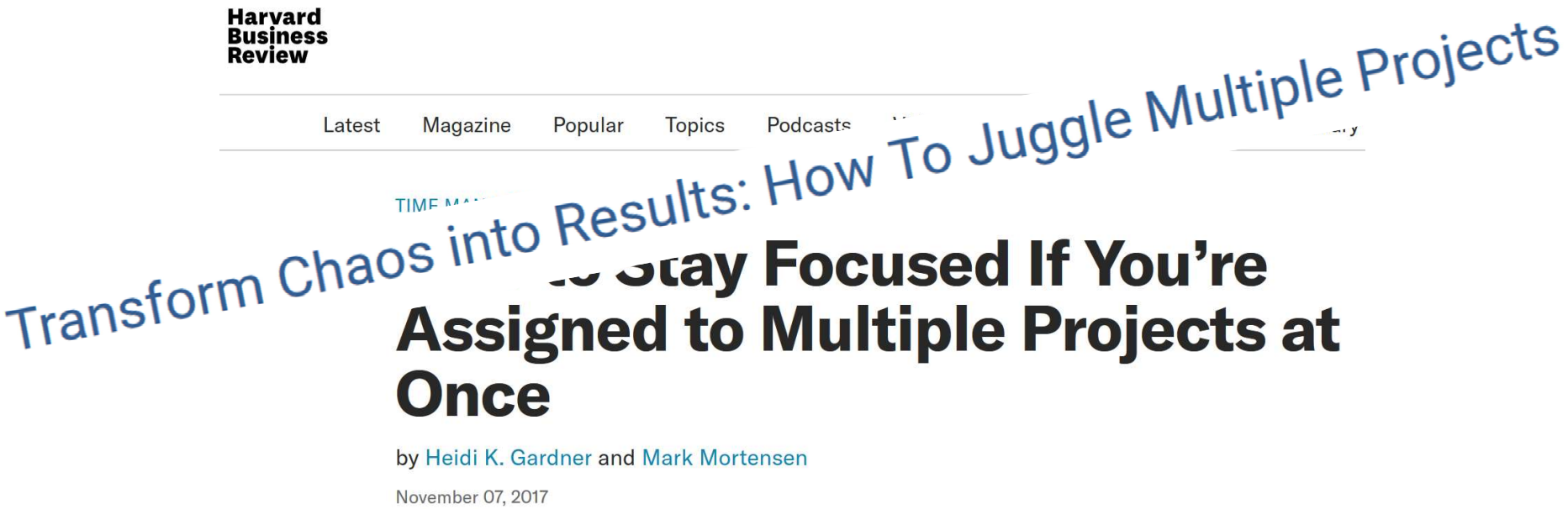
Motivation

Task juggling is a common occurrence:



Motivation

Task juggling is a problematic common occurrence:

Motivation

- Task juggling (parallel processing of projects) is a problematic common occurrence:
  - Coviello, Ichino and Persico (2014) find that judges who juggle multiple cases are slower to complete cases
  - Tan and Netessine (2014) find that service quality decreases in busy restaurants
- Fluctuations in workload often require task juggling (e.g. judges, scientists, accountants, doctors)
- Implicitly assumes that agents respond in same way to workload, or information of future workload
  - But response to workload may differ across production environments

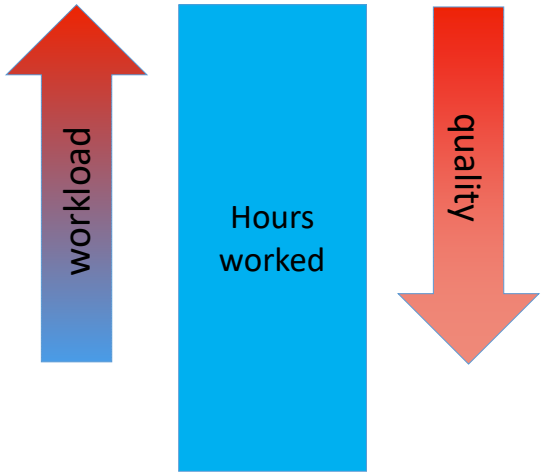
Contribution

1. We study how workload affects performance and work processes:
   - How does workload affect performance: output quantity, quality and timeliness?
   - How do workers adjust their labor input and organize their tasks in response to workload?
2. We present a theoretical model that shows that task juggling is sometimes optimal and empirical evidence to support this hypothesis:
   - When projects are homogeneous, there may be scale efficiencies from task juggling (working in batches)
   - When projects are heterogeneous, there are no scale efficiencies and sequential processing is optimal (no task juggling)

Literature

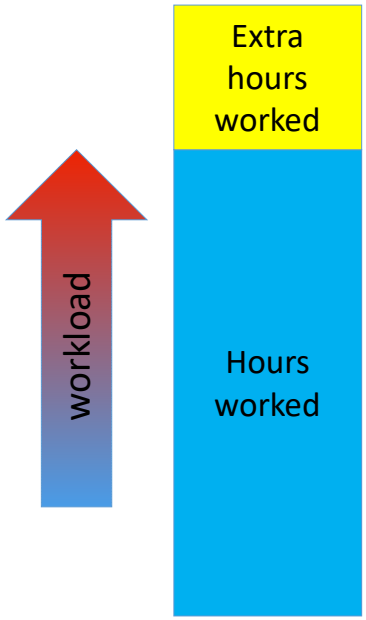
- Task juggling and multi-tasking:
  - Coviello et al. (2014, 2015), Holmstrom and Milgrom (1991)
- Workload and productivity:
  - Diwas et al. (2020), Kuntz et al. (2015), Tan and Netessine (2014), Warren et al. (2014), Terwiesch et al. (2009)
- Shirking/Loafing:
  - Corgnet et al. (2015), Eriksson et al. (2011), Dickinson (1999)
- Labor Hoarding and Slack:
  - Lazear et al. (2016), Burda et al. (2016), Hamermesh (1996), Bourgeois (1981)
- Productive efficiency:
  - Syverson (2011), Leibenstein (1966)

Intuition



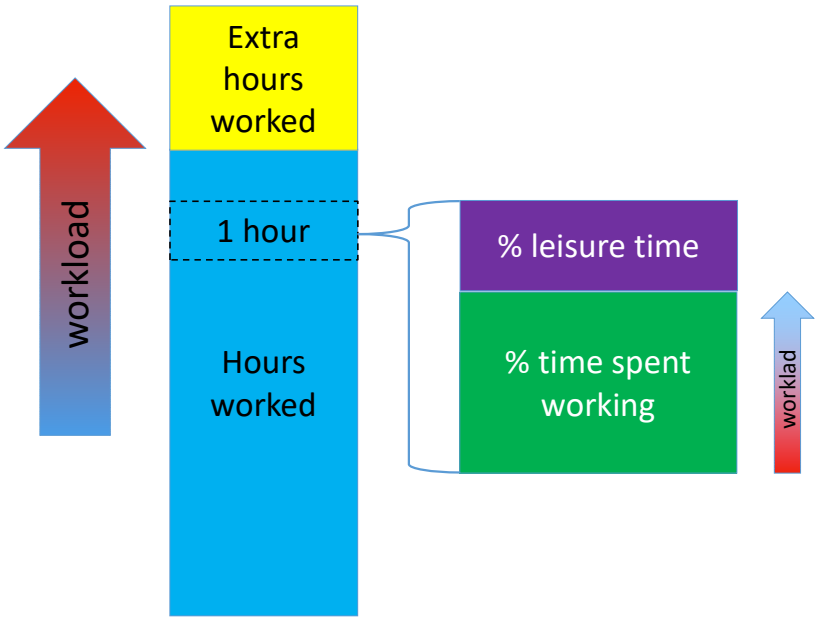
- If workload rises, output can be increased by:
  - Decreasing quality
    - No increase in labor input needed

Intuition



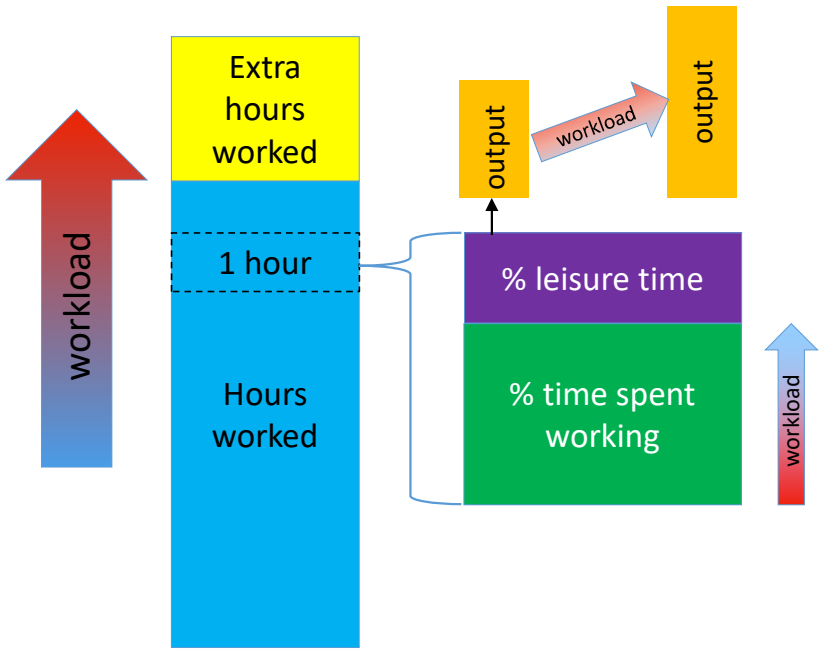
- If workload rises, output can be increased by:
  - Decreasing quality
  - Increasing total hours at work
    - Labor/leisure decision on extensive margin

Intuition



- If workload rises, output can be increased by:
  - Decreasing quality
  - Increasing total hours at work
  - Increasing hours spent working at work
    - Labor/leisure decision on intensive margin

Intuition



- If workload rises, output can be increased by:
  - Decreasing quality
  - Increasing total hours at work
  - Increasing hours spent working at work
  - Increasing productive efficiency
    - Take advantage of efficiencies of scale by working in batches (task juggling)
    - Requires workload to be sufficiently high (returns to scale)

This Paper

- Dynamic multi-tasking model with labor-leisure and quality-quantity choice
  - Two environments: heterogeneous or homogenous projects
    - In homogeneous environment, batch processing is optimal
      - High workload increases not just quantity, but also performance (quality, timeliness)
    - In heterogeneous environment, sequential processing is optimal
      - High workload only increases quantity and may decrease performance (timeliness)
- Empirical test of predictions
  - Study insurance claims examiners that face hetero/homogeneous cases
  - Exogenous variation in workload, detailed work process and time use data
- Findings
  - Productivity increases in response to workload
  - Comes at cost of leisure if heterogeneous projects
  - Efficiency gains due to batch processing if homogenous projects
    - Quality and timeliness increases
    - Leisure does not decrease

Outline of Talk

- Model
  - Set-Up
  - Equilibrium
  - Comparative Statics
- Empirics
  - Institutional Setting
  - Productivity Responses to Workload
  - Time Use and Efficiency
- Discussion

Model – Set-Up

- In time t, a worker faces a workload of J_t projects, each comprising S steps, for a total workload of $J_t * S$ tasks
- In processing workload, the worker decides:
  - the number of tasks to complete
  - the ordering of the tasks
  - the time spent on each task
- We allow for set-up costs and learning benefits by assuming that:
  - Completing one step after another within the same project, the marginal time cost decreases (working sequentially)
  - Completing the same step across projects also decreases the marginal time costs (working in batches)
  - Without economies of scale, the time cost for completing task *i* with quality q_i is: $\tau_i(q_i) = q_i^2$

Illustration: Batch vs. Sequential Processing

- Batch processing:
  - Batch 1: task 1.1 and task 2.1
  - Batch 2: task 1.2 and task 2.2
- Sequential processing:
  - Project 1: task 1.1 and task 1.2
  - Project 2: task 2.1 and task 2.2

	Step 1	Step 2
Project 1	1.1	1.2
Project 2	2.1	2.2

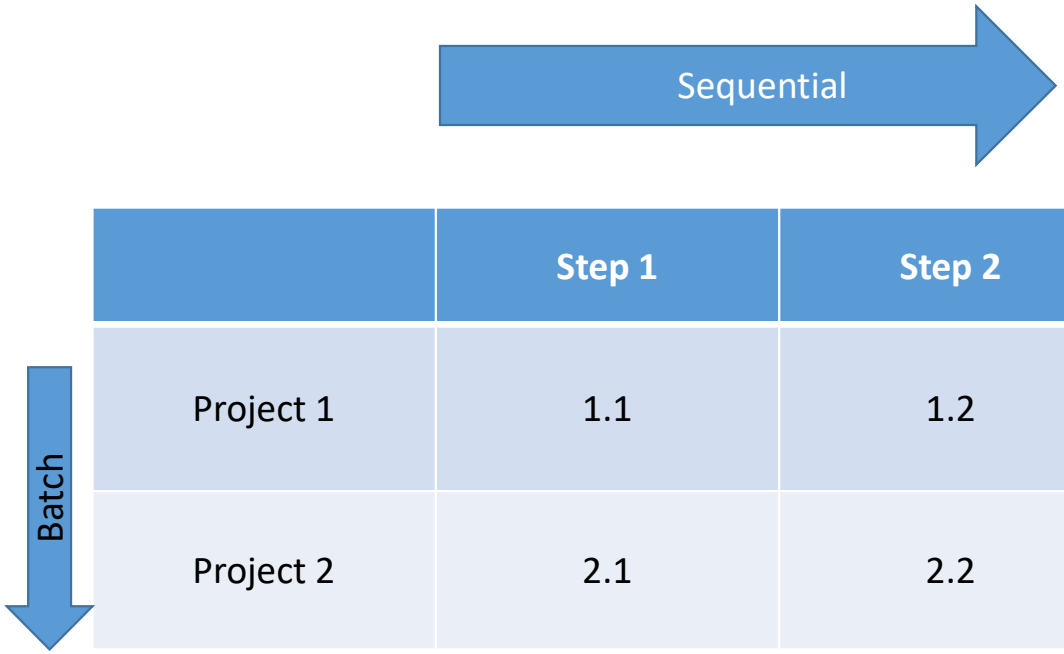
Illustration: Batch vs. Sequential Processing

Processing order and time cost per task:

- Batch processing: tasks are completed within steps, across projects
  - Time cost for batch with *J* tasks (projects):

    $\tau_i(q_i) = \frac{q_i^2}{J^{\kappa}}$, κ>0
- Sequential processing: tasks are completed across steps, within projects
  - Time cost for project with *S* tasks (steps):

    $\tau_i(q_i) = \frac{q_i^2}{S^{\omega}}$, ω>0



	Step 1	Step 2
Project 1	1.1	1.2
Project 2	2.1	2.2

Model – Set-Up

- A worker's per period utility from wages and leisure:

$$U_t = (1-\rho)^{-1}\,(w_t + l_t)^{1-\rho}$$

- A worker who completes *n* tasks with quality q_i earns a wage:

$$w_t = \sum_{i=1,..,n} q_i$$

- Leisure is the difference between time constraint τ_{max} and time spent working τ_{total}:

$$\tau_{total} = \sum_{i=1,..,n} \tau_i\,(q_i)$$

- Two period model with discount factor δ
- Simplest possible information environment: worker knows J_1 and J_2 at beginning of *t=1*

Model – Summary

- Worker's objective is to maximize life-time utility:

$$U = (1-\rho)^{-1}\,(w_1 + l_1)^{1-\rho} + \delta(1-\rho)^{-1}\,(w_2 + l_2)^{1-\rho}$$

subject to the following constraints:

$$w_t = \sum_{i \in N_t} q_i$$

$$\tau_{total,t} = \sum_{i \in N_t} \tau_i\,(q_i)$$

$$l_t \leq \tau_{max} - \tau_{total,t}$$

- The worker chooses:
  - Set of tasks to complete each period: N_t
  - Order in which the tasks are completed: batch, sequential, other
  - Quality with which to complete each task: q_i

Key Tradeoffs of Model

- Quantity – Quality
- Labor – Leisure
- Timeliness – Process Efficiency

- Efficiency gains from economies of scale affect all three tradeoffs:
  - Economies of scale may reduce time investment or increase level of performance (quality, timeliness) as well as quantity
  - Taking advantage of economies of scale may require shifting tasks across periods
    - Note: in one-period model, this latter channel is absent

Equilibrium

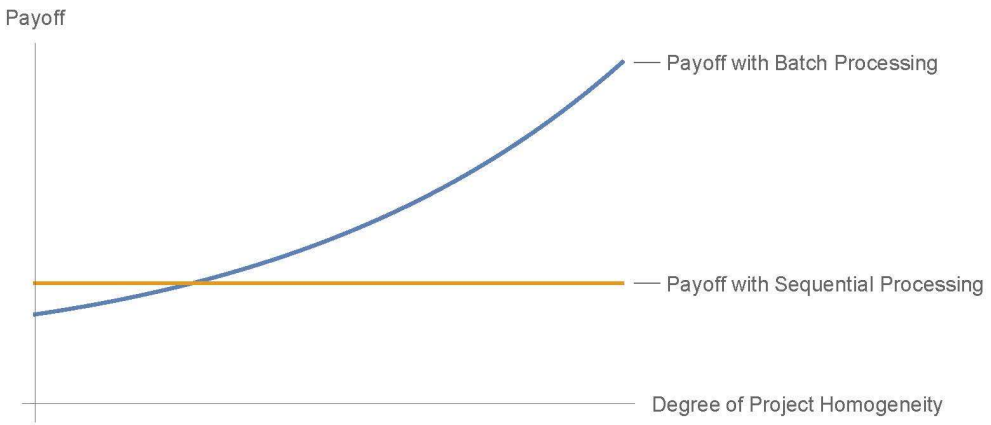
Optimal processing:

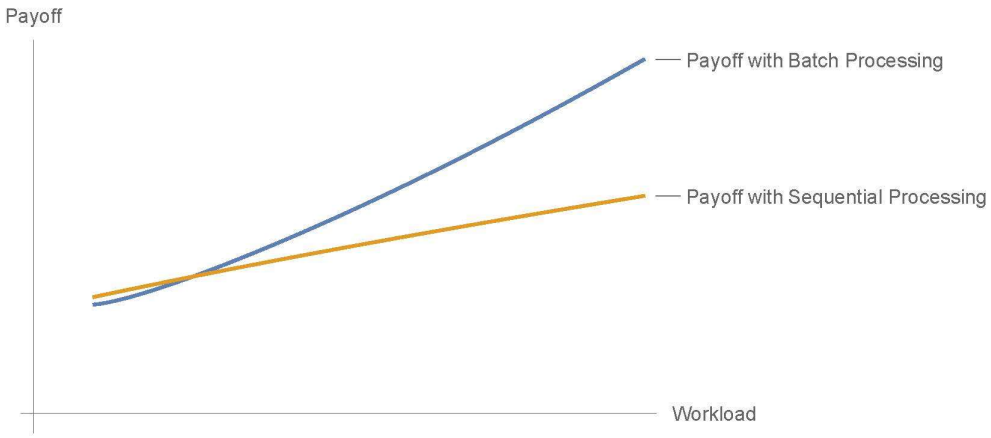
Batch processing is optimal:

- in homogeneous projects (κ large)
- when workload is sufficiently large

Sequential processing is optimal:

- in heterogeneous projects (κ small)
- when workload is low





Comparative Statics

- Performance:
  - Tasks completed
  - Quality
  - Tardiness
- Labor-leisure: time worked
- Efficiency (Batchwork vs Sequential)
  - Coefficient of variation (CoV)

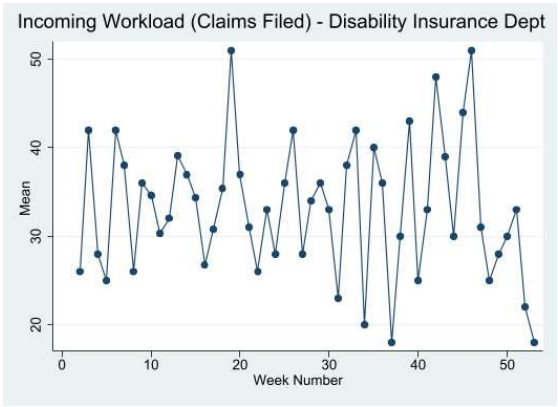
		Setting	
Outcomes	**wrt**	**Homogeneous**	**Heterogeneous**
Number of tasks completed	Current workload	+	+
	Future workload	-/+	+
Quality	Current workload	+	0
	Future workload	0	0
Tardiness (% of tasks completed past due)	Current workload	-	+
	Future workload	+/-	-
Hours worked	Current workload	+	+
	Future workload	-	+
CoV: # Unique tasks / Max # within tasks	Current workload	-	-
	Future workload	+	-
CoV - Alt: # Unique tasks / Total tasks completed	Current workload	-	-
	Future workload	0	-

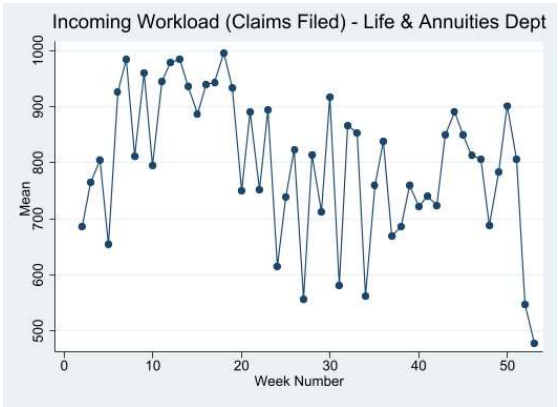
Empirics – Institutional Detail

- Data on claims examiners from large US insurance company
- Two insurance claims departments:
  - Life & Annuities (LA; 37 examiners)
  - Disability & Long Term Care (DI; 57 examiners)
- Insurance claim adjudication process:
  - Step 1: Notice of new claim
  - Step 2: Initial Review + Hold (Request additional information)
  - Step 3: Eligibility Review
  - Step 4: Determination of Compensation
- Compensation: bonuses and promotion evaluation based on quality-weighted productivity

Empirics – Institutional Detail

- Life & Annuities (LA; 37 examiners)
  - Linear production process
  - Homogeneous case files
- Disability & Long-term Care (DI; 57 examiners)
  - Hub-and-spokes process
  - Heterogeneous case files
- Plausibly exogenous variation in workload:
  - Large case load fluctuations throughout year
  - Capacity cannot be adjusted to short-term fluctuations due to training requirements
- Signal of future workload: new notices turn into claims ca. 5-6 weeks later





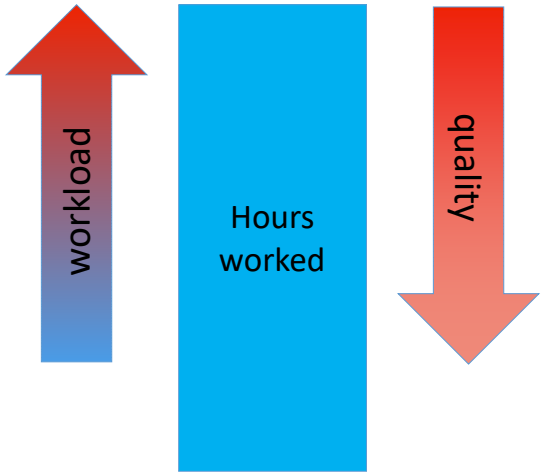
Empirics - Data

- Granular, individual-level data from several databases:
  - SAP: personal + organizational details
  - Workflow tracking system
    - Incoming workload
    - Productivity: tasks completed, timeliness
  - Quality audit scores
  - Systems use and internet use
- Matched on unique employee ID
- Daily data for 2015 (aggregated to weekly level)

Empirics – Summary Statistics

Variable	N	Mean	VAR	SD	Median	Min	Max
Panel A: Life and Annuity							
Current workload (Claims filed)	1593	27.06	21.84	4.67	26.55	18.67	41.67
Future workload (New notices)	1593	17.21	11.62	3.41	16.67	10.32	24.7
Total tasks completed	1594	106.93	3843.28	61.99	103.88	0	338.75
Tasts completed past due (%)	1566	28.82	297.01	17.23	26.09	0	100
QA Score (lagged)	686	98.55	12.76	3.57	100	81.48	100
Vacation hours	1594	3.36	70.57	8.4	0	0	40
Over time	1594	1.28	8.8	2.97	0	0	21.88
Panel B: Disability Insurance							
Current workload (Claims filed)	2424	0.74	0.02	0.16	0.71	0.43	1.09
Future workload (New notices)	2424	0.54	0.03	0.18	0.5	0.2	0.96
Total tasks completed	2425	28.42	730.6	27.03	21	0	212
Tasts completed past due (%)	2351	25.8	413.73	20.34	20.69	0	100
QA Score (lagged)	1203	95.66	53.32	7.3	100	50	100
Vacation hours	2425	3.18	61.51	7.84	0	0	40
Over time	2425	0.58	2.71	1.65	0	0	21

Performance



- If workload rises, output can be increased by:
  - Decreasing quality
    - No increase in labor input needed

Effect of Workload on Productivity (Total Number of Tasks Completed)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (normalized)	0.090***	0.085***	0.059***	0.024**	0.024**	0.020**
	(0.014)	(0.014)	(0.015)	(0.010)	(0.010)	(0.010)
Future Workload (normalized)	0.029	-0.001	-0.040	0.012	0.010	0.026*
	(0.028)	(0.023)	(0.025)	(0.011)	(0.010)	(0.014)
Age		-0.067	-0.037		0.016	-0.010
		(0.085)	(0.080)		(0.059)	(0.066)
Tenure		-0.068	0.480		-0.099	-0.080
		(0.149)	(0.570)		(0.127)	(0.411)
Pay level		-0.044**	-0.041**		-0.047*	-0.047*
		(0.022)	(0.020)		(0.026)	(0.025)
Net Dept Hours						
Number of obs.	1593	1593	1593	2424	2424	2424
Number of subjects	37	37	37	57	57	57
Log likelihood	-19749.495	-19544.886	-18953.767	-13990.714	-13789.049	-13677.052
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

Estimated as fixed effects Poisson quasi-maximum likelihood model. Robust SEs.

Effect of Workload on Tardiness (Percentage of Tasks Completed Past Due Date)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (above median)	-3.175***	-3.072***	-2.627***	-0.476	0.001	0.411
	(0.899)	(0.860)	(0.827)	(0.673)	(0.692)	(0.733)
Future Workload (above median)	-0.631	-0.249	-1.684	-0.440	-0.338	-0.959
	(0.974)	(0.955)	(1.103)	(0.662)	(0.660)	(0.798)
Age		2.942	3.476*		-2.943	-2.701
		(2.210)	(2.002)		(2.156)	(2.227)
Tenure		-2.536	-51.256		10.696***	13.175
		(3.316)	(46.963)		(3.567)	(13.595)
Pay level		0.904***	0.862***		0.242	0.146
		(0.275)	(0.235)		(0.452)	(0.434)
Net Dept Hours						
Number of obs.	1566	1566	1566	2351	2351	2351
Number of subjects	37	37	37	57	57	57
Log likelihood	0.01	0.011	0.121	0	0.016	0.037
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

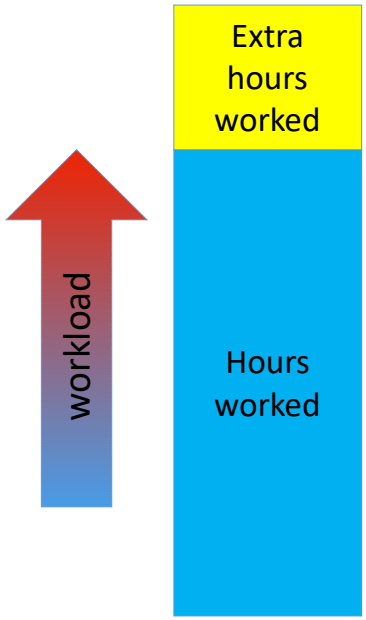
Estimated as panel fixed effects model. Robust SEs.

Effect of Workload on Quality (Average Quality Audit Score)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (above median)	-0.179	-0.244	0.021*	0.327	0.130	-0.028
	(0.310)	(0.253)	(0.010)	(0.369)	(0.368)	(0.075)
Future Workload (above median)	-0.114	0.020	0.034*	0.117	0.338	-0.021
	(0.311)	(0.332)	(0.017)	(0.433)	(0.488)	(0.051)
Age		0.651	0.781		-0.086	0.209
		(0.709)	(0.786)		(1.075)	(1.359)
Tenure		0.357	-2.747		-3.168	-8.312
		(1.786)	(6.312)		(2.551)	(11.466)
Pay level		-0.694***	-0.668***		-0.096***	-0.087
		(0.103)	(0.104)		(0.020)	(0.095)
Net Dept Hours						
Number of obs.	686	686	686	1203	1203	1203
Number of subjects	30	30	30	40	40	40
Log likelihood	-0.001	0.045	0.116	-0.001	0.013	0.096
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

Estimated as panel fixed effects model. Robust SEs.

Hours Worked – Extensive Margin



- If workload rises, output can be increased by:
  - Decreasing quality
  - Increasing total hours at work
    - Labor/leisure decision on extensive margin

Effect of Workload on Hours Worked (Overtime Hours)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (normalized)	0.014	0.038	0.187***	0.012	0.003	0.013
	(0.041)	(0.043)	(0.047)	(0.034)	(0.036)	(0.036)
Future Workload (normalized)	0.593***	-0.052	-0.450***	-0.027	0.013	0.017
	(0.080)	(0.102)	(0.096)	(0.033)	(0.034)	(0.035)
Age		-0.004	0.365*		0.621*	0.605**
		(0.211)	(0.201)		(0.338)	(0.291)
Tenure		-3.310***	-8.143***		-0.135	-2.644
		(0.897)	(1.576)		(0.713)	(3.408)
Pay level		-0.189**	-0.201***		-0.165***	-0.179**
		(0.093)	(0.076)		(0.061)	(0.074)
Net Dept Hours						
Number of obs.	1200	1200	1200	1280	1280	1280
Number of subjects	28	28	28	31	31	31
Log likelihood	-2486.33	-2195.64	-1971.21	-2014.95	-1966.14	-1791.6
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

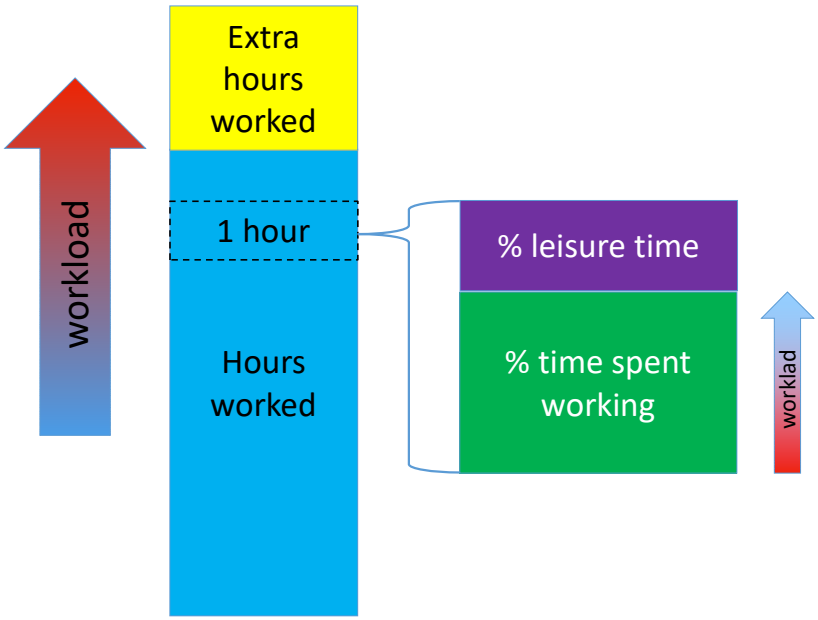
Estimated as fixed effects Poisson quasi-maximum likelihood model. Robust SEs.

Effect of Workload on Hours Worked (Scheduled Hours – Leave + Over Time)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (normalized)	1.069**	0.879**	1.261**	0.280*	0.255	0.277
	(0.421)	(0.432)	(0.570)	(0.164)	(0.162)	(0.183)
Future Workload (normalized)	1.115**	0.187	-0.712	0.712***	0.658***	0.637***
	(0.508)	(0.483)	(0.764)	(0.180)	(0.177)	(0.183)
Age		-1.820	-1.870		0.960	0.961
		(1.253)	(1.127)		(0.989)	(1.038)
Tenure		-3.588*	-8.101		-4.227***	-19.362**
		(1.873)	(14.153)		(1.452)	(8.058)
Pay level		-0.364	-0.391		-0.019	-0.034
		(0.476)	(0.471)		(0.081)	(0.079)
Net Dept Hours						
Number of obs.	1593	1593	1593	2424	2424	2424
Number of subjects	37	37	37	57	57	57
Log likelihood	0.038	0.053	0.064	0.008	0.016	0.026
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

Estimated as panel fixed effects model (Poisson QML does not converge). Robust SEs.

Hours worked – intensive margin



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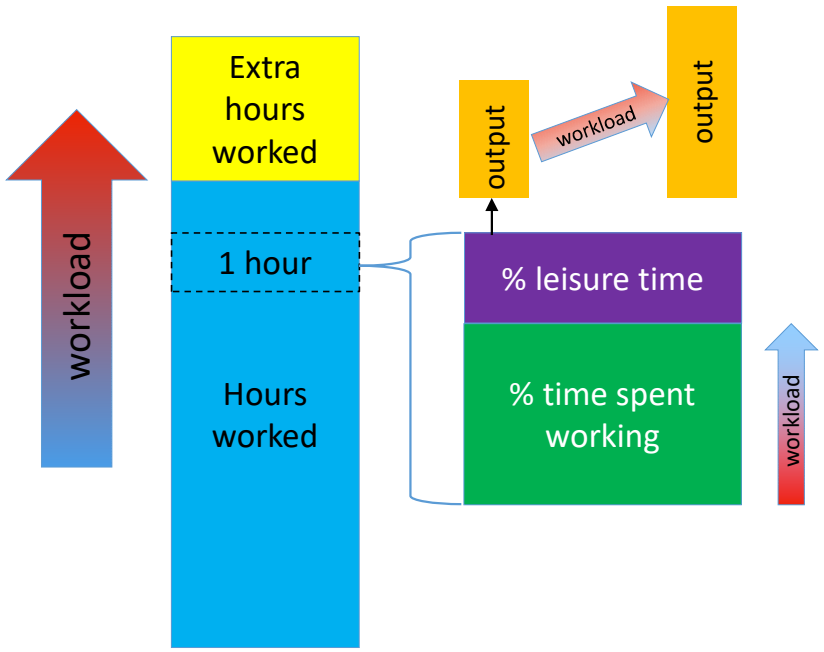
    - Labor/leisure decision on intensive margin

Effect of Workload on Hours Worked (first-last event online)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (normalized)	-0.050	0.015	0.003	0.032***	0.023***	0.026***
	(0.030)	(0.029)	(0.029)	(0.009)	(0.008)	(0.010)
Future Workload (normalized)	0.112**	-0.001	0.011	0.007	0.027***	0.007
	(0.044)	(0.036)	(0.038)	(0.009)	(0.010)	(0.009)
Age		0.011	-0.042		0.039	0.049
		(0.111)	(0.114)		(0.098)	(0.096)
Tenure		0.942***	2.166		0.656***	-0.181
		(0.185)	(4.794)		(0.195)	(3.473)
Pay level		-0.004	0.011*		0.019	0.012
		(0.009)	(0.007)		(0.031)	(0.036)
Number of obs.	971	971	971	1442	1442	1442
Number of subjects	33	33	33	55	55	55
Log likelihood	-8647.68	-8005.47	-7796.87	-13694.3	-13150.1	-13028.1
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

Estimated as fixed effects Poisson quasi-maximum likelihood model. Robust SEs.

Efficiency: Batch vs. Sequential



- If workload rises, output can be increased by increasing:
  - Total hours at work
  - Hours spent working at work
  - Output per hour spent working (productive efficiency)

Effect of Workload on Coefficient of Variation (Number of unique steps divided by max number of times a task is completed)

	Panel A: Life and Annuity			Panel B: Disability Insurance		
	1	**2**	**3**	**1**	**2**	**3**
Current Workload (above median)	-0.063**	-0.050**	0.009	-0.102**	-0.097**	-0.102*
	(0.024)	(0.023)	(0.028)	(0.042)	(0.043)	(0.053)
Future Workload (above median)	0.054**	0.096***	0.107***	0.061	0.085	0.078
	(0.025)	(0.020)	(0.030)	(0.050)	(0.051)	(0.052)
Age		-0.044	-0.023		0.238	0.332
		(0.079)	(0.083)		(0.234)	(0.237)
Tenure		0.315**	0.344		0.577	2.946
		(0.151)	(0.843)		(0.353)	(1.937)
Pay level		0.046**	0.039*		0.033	0.040
		(0.020)	(0.020)		(0.065)	(0.059)
Net Dept Hours						
Number of obs.	1565	1565	1565	2348	2348	2348
Number of subjects	37	37	37	57	57	57
Log likelihood	0.005	0.019	0.045	0.001	0.012	0.025
Individual FE	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y

Estimated as panel fixed effects model. Robust SEs.

Effect of Workload on Coefficient of Variation – Alt. (Number of unique steps divided by number tasks completed)

	Panel A: Life and Annuity			Panel B: Disability Insurance			
	1	**2**	**3**	**1**	**2**	**3**	**4**
Current Workload (normalized)	-0.080***	-0.070***	-0.000	-0.016*	-0.016*	-0.033***	-0.000
	(0.025)	(0.022)	(0.035)	(0.009)	(0.009)	(0.008)	(0.009)
Future Workload (normalized)	0.048	0.090***	0.057	-0.005	-0.005	-0.008	-0.001
	(0.029)	(0.028)	(0.043)	(0.007)	(0.008)	(0.009)	(0.008)
Age		0.090	0.109		-0.000	0.009	0.010
		(0.106)	(0.107)		(0.051)	(0.048)	(0.048)
Tenure		0.151	-2.342**		0.004	3.746***	2.257**
		(0.184)	(1.128)		(0.071)	(1.090)	(0.949)
Pay level		0.041	0.035		0.014	0.014	0.014
		(0.028)	(0.033)		(0.010)	(0.011)	(0.011)
Number of obs.	1565	1565	1565	2350	2350	2350	2350
Number of subjects	37	37	37	57	57	57	57
Log likelihood	-524.467	-523.937	-521.811	-1709.06	-1708.74	-1702.49	-1693.27
Individual FE	Y	Y	Y	Y	Y	Y	Y
Month FE	N	N	Y	N	N	Y	Y

Estimated as fixed effects Poisson quasi-maximum likelihood model.
Robust SEs.

Discussion

- People in different production environments may respond differently to changes in workload
  - In a homogenous environment, an increase in workload could lead to an increase in performance because batch processing (task juggling) can improve efficiency
  - In a heterogeneous environment, an increase in workload does not improve performance (other than increase quantity) because there are no efficiency gains
- Implications for organization of work: there are potential advantages to homogenizing work processes and task juggling
- Next steps:
  - Information provision about future high workload
- Any questions? Comments?
  - Please e-mail me: eytsma@andrew.cmu.edu

Thank you!