Age, morbidity, or something else?

A residual approach using microdata to measure the impact of technological progress on health care expenditure

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Objectives

1. To measure the increment of Health Care Expenditure (**HCE**) that is driven by Technological Progress

2. To decompose such an increment into the part that is due to the effect of **Delaying Time to Death** (**TTD**) and the part that is due to the effect of **Intensity of Resource use**

- **Why TTD?** Individuals surviving longer thanks to new technology and medical practice may contribute longer to the demand

- **Why Intensity?** The basket of health services becoming more expensive due to the cost of innovation

A Broad Definition of Tech Progress

- The term “**Technological Progress”** used here includes:
    - **Tangible new Technologies**
        - such as physical equipment, drugs and treatments

AND

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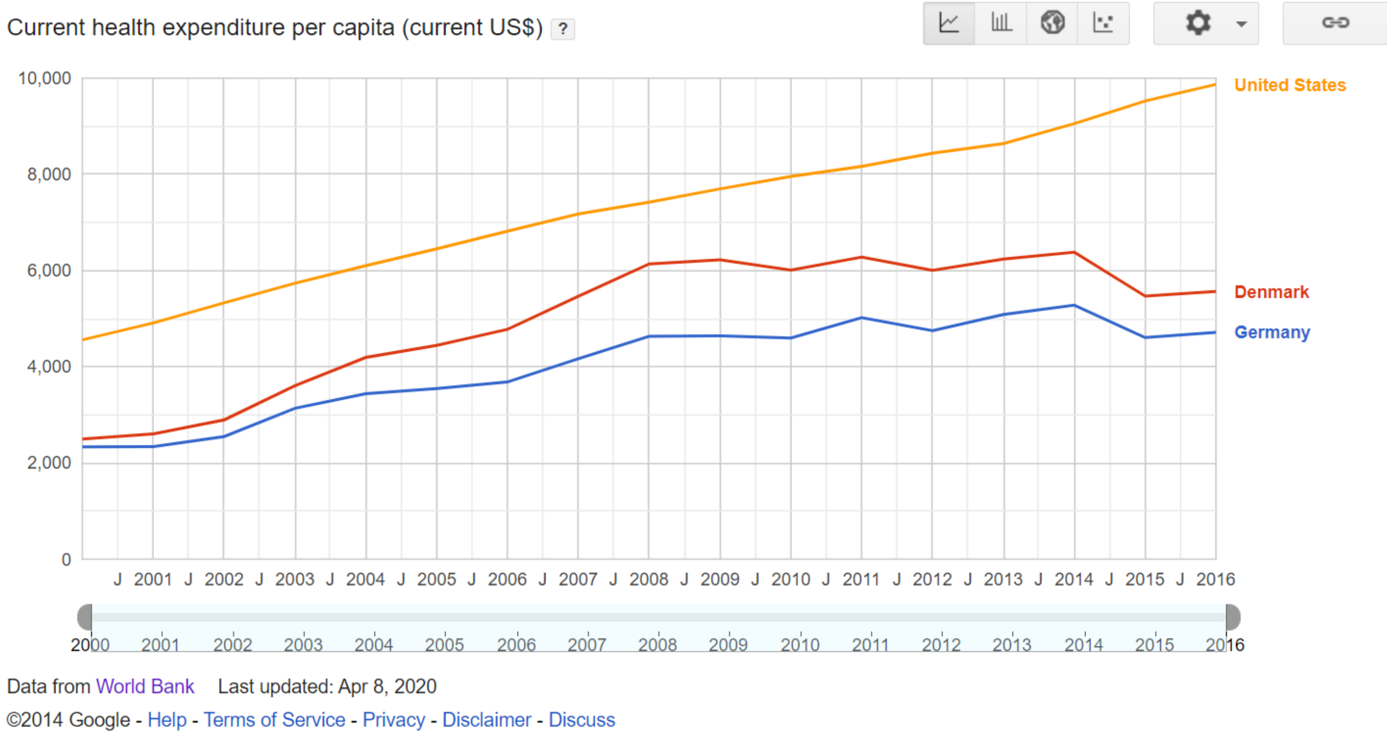
    - **Intangible new “Know How”**
        - such as **change in Medical Practice,** namely a change in the organization of existing services and utilization of existing equipment based on new knowledge and evidence

Motivations

- High-income countries are experiencing a rapid growth of HCE
  - HCE growth outpacing demographic growth and aging of the population



Main Hypothesis

- A large body of literature investigates the contribution of **Aging** of the population, increment in **Morbidity** and proximity to death (**TTD**) on HCE
  - Evidence on aging population and morbidity are at odds with evidence of “healthy aging”
  - Individuals living longer shifting forward a constant number of years with disability
- **Hypothesis** investigated here:
  - HCE growth is driven by the **interaction** between Age Morbidity and Tech Progress
  - **HCE expenditure grows** not just because people are older or sicker, but also **because new and more expensive technologies are available to treat older and sicker people** over time

Challenges

1. Lack of agreement on a specific definition of Tech Progress

2. Lack of appropriate indicators to measure it over time
   - Number of patents?
   - Expenditure in R&D?

- Research traditionally led by **Macroeconomic studies** (Chernew and Newhouse, 2011)

  - Limitation 1: impact of tech depend on assumptions on **income elasticity** and health insurance markets

  - Limitation 2: no control for **Morbidity**

Methods 1
Measuring the impact of tech progress on HCE

- Combine **Residual Approach** with **Microdata**
- Repeated cross-sections of individuals experiencing an **Initial Health Shock** over a ten-year window
- Capture the impact of **unobservable Tech Progress** (and Medical Practice) to which they are exposed in the year of the health shock
- Controlling for differences in **Morbidity** and **Socioeconomic** status over time
- **Identification:**
  - Some degree of random assignment of individuals to their initial health shock over calendar years
  - A rich set of individual control indicators to adjust for potential bias in such assignment
    - Population become sicker or healthier over time

Study Population and Data

- We study people in **Denmark** age 50+ having an **initial health shock** between 2005 and 2014
  - Total population of about **1 million people**
  - People with an initial health shock in 2014 absorbed **23.5% of national HCE** for secondary care

- A **health shock** is defined as an **emergency admission** to the hospital with at least one day length of stay

- **Initial health shock**: we excluded patients having a health shock in the **past five years**
  - This mitigate **confounding effects** from tech they were exposed to in the past

- We extract data on utilisation of hospital **inpatient and outpatient care**. Primary diagnosis and comorbidities; socioeconomic status including income, migrant, living alone.

Research questions:

1. What is the increment in the HCE **per individual** exposed to a health shock over an 8-year time-window?

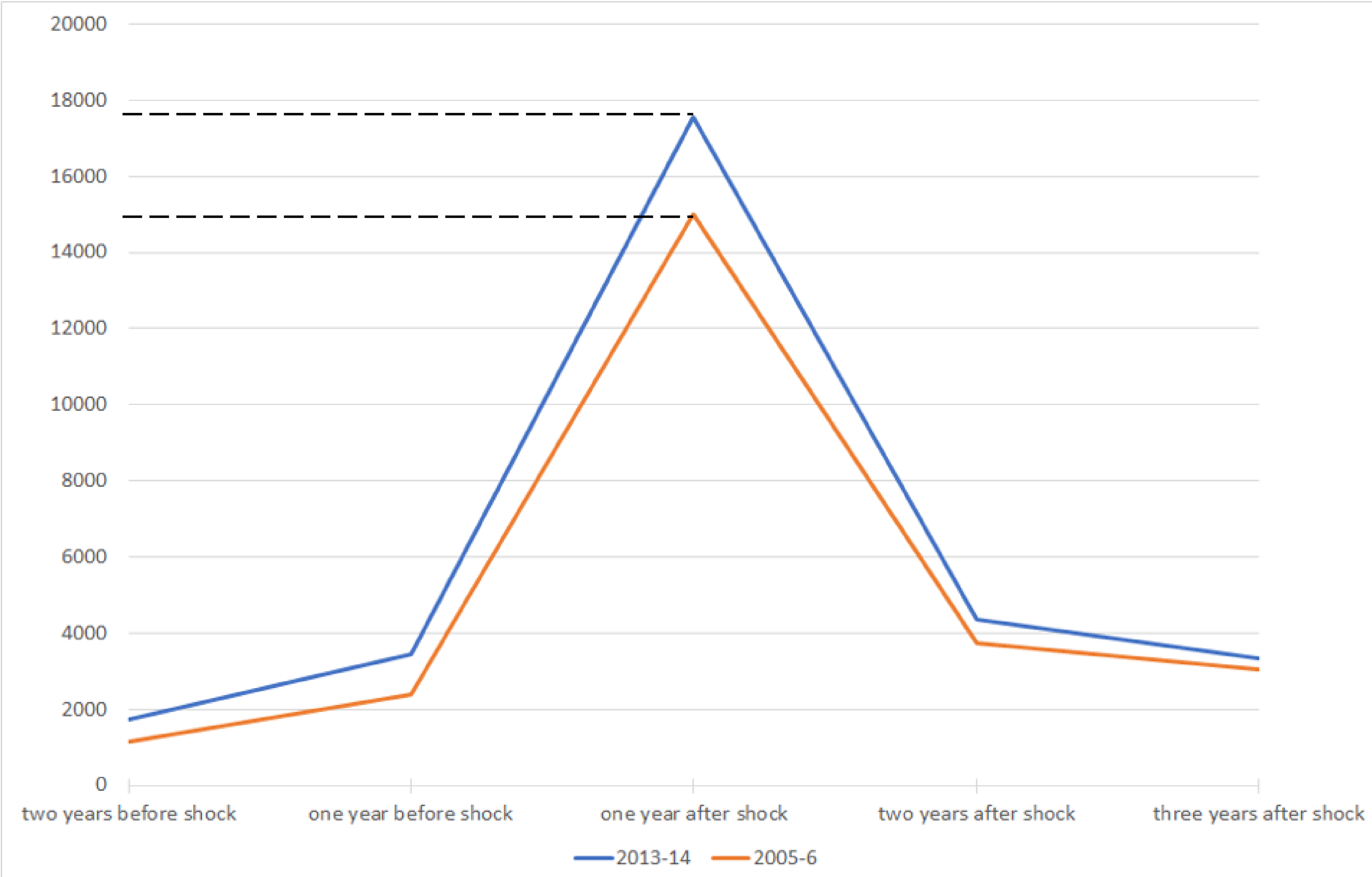
2. What is the increment due to **Age**? **Morbidity**?

3. What is the residual increment that can be attributed to **Tech progress**?

Table 1. Difference in the characteristics of individuals with a health shock in 2014-13 and 2005-6.

	Health shock 2013-14			Heath shock 2005-6			
	patients	mean	s.d.	patients	mean	s.d.	Difference
female	194,459	50.56%		188,275	51.90%		-1.34%
age	194,459	69.04	11.22	188,275	68.63	11.4322	0.41
total diagnoses	194,459	2.0385	1.3995	188,275	1.945	1.2338	0.0935
Charlson index	194,459	0.8578	1.4515	188,275	0.8005	1.3465	0.0573
AMI	194,459	4.60%		188,275	5.53%		-0.93%
congestive heart failure	194,459	3.73%		188,275	4.20%		-0.47%
peripheral vascular disease	194,459	2.99%		188,275	2.76%		0.23%
cerebrovascular disease	194,459	9.24%		188,275	10.06%		-0.82%
dementia	194,459	1.96%		188,275	2.12%		-0.16%
chronic obstructive pulmonary dis.	194,459	6.80%		188,275	6.41%		0.39%
rheumatoid disease	194,459	1.97%		188,275	1.86%		0.11%
peptic ulcer	194,459	1.36%		188,275	2.04%		-0.68%
liver disease (mild)	194,459	0.87%		188,275	0.83%		0.04%
liver disease (severe)	194,459	0.35%		188,275	0.31%		0.04%
diabetes	194,459	7.24%		188,275	6.45%		0.79%
diabetes complications	194,459	1.68%		188,275	1.67%		0.01%
renal disease	194,459	1.65%		188,275	1.09%		0.56%
cancer	194,459	11.95%		188,275	9.87%		2.08%
metastatic cancer	194,459	2.43%		188,275	2.13%		0.30%
living alone	194,459	41.65%		188,275	42.53%		-0.88%
migrant	194,459	5.51%		188,275	4.18%		1.33%
income (x1,000 Euros)	194,459	29.2736	38.3464	188,275	26.6662	38.4559	2.6074

Figure 1. HCE after an initial health shock in 2005-6 and 2013-14. Prices reported in Euros at 2017 level.



Econometric Model 1 – details

- Simple GLM model with gamma distribution and log-link function:

$$HCE_i \sim Gamma(u, v)$$

$$E(HCE_i|X_i) = \exp(t + \beta X_i)$$

- $\boldsymbol{X_i}$ captures individual health and sociodemographic characteristics

- $\boldsymbol{t}$ captures the impact of **unobservable tech progress** as a **Residual Increment (RI)** of HCE over time

- Variation in average HCE per patient!

Results - Objective 1

Measuring the impact of tech progress on HCE

- Increment in HCE is **16.90** Percentage Points
- Age accounts for **7%** of HCE increment
  (1 -15.77/16.90 = 6.87; Model 2)
- Morbidity and Age account for **40%** of HCE increment
  (1 -10.19/16.90 = 39.70; Model 3)
- Including Socioeconomic indicators does not make a difference
  (Model 4 not displayed)
- **Residual increment of HCE that we can attribute to Tech Progress is 60%**

Table 2. Residual Increment in HCE in individuals with an initial health shock
Exponentiated coefficients from GLM regression.

	Model 1	Model 2	Model 3
shock 2005-6	baseline	baseline	baseline
shock 2007-8	0.9894**	0.9881***	0.9792***
	(0.0043)	(0.0042)	(0.0038)
shock 2009-10	1.0700***	1.0648***	1.0307***
	(0.0047)	(0.0047)	(0.0041)
shock 2011-12	1.1210***	1.1125***	1.0684***
	(0.0050)	(0.0049)	(0.0043)
shock 2013-14	1.1690***	1.1577***	1.1019***
	(0.0052)	(0.0051)	(0.0044)
female		0.8733***	0.9126***
		(0.0025)	(0.0025)
age		1.1274***	1.0849***
		(0.0017)	(0.0014)
age sq.		0.9991***	0.9994***
		(0.0000)	(0.0000)
total diagnoses			1.1190***
			(0.0012)
Charlson index			1.1769***
			(0.0136)
15 comorbidities indicators			yes
1005 primary diagnosis indicators			yes
Income, living alone, migrant			yes
HCE one and two year before the shock		yes	yes
Observations	962,794	962,794	962,794
BIC	-12203624	-12221661	-12457898

Robust SE in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Methods 2

Decomposing the impact of tech progress

- Follow up individuals 3 years after their initial health shock
- Model two dimensions of time: **Calendar Year** when individuals experience the shock and **Elapsed Time** after the shock
  - **Calendar Year:** to capture the effect of Tech on HCE
  - **Elapsed Time:** to examine cost accumulation over time
- Elapsed time is chopped into **discrete time** periods! So, we model **person-periods observations**

Econometric Model 2 – details

- Cost accumulation of individual *"i"* over a number of discrete time periods *j = 1 ..., K* can be described as (Basu and Manning, 2010):

$$\mu = \sum_{j=1}^{K} \Pr(V > a_{j-1}) * \{ \mu_{1j} * h(a_j) + \mu_{2j} * (1 - h(a_j)) \}$$

- Where μ is the expected cumulative HCE up to the time period j = 1,…, K;
- $\Pr(V > a_j)$ is a survival function with V indicating the time to death
- $h(a_j)$ is the hazard of death in the interval $(a_j, a_{j-1}]$ for individuals who survived until a_{j-1};
- μ_{1j} is the expected cost for individuals who die in $(a_j, a_{j-1}]$
- μ_{2j} is the expected cost for those who don't

- This model allows the rate of HCE accumulation to **differ** in **individuals who die** from **individuals who do not** in each period
  - This is a nice feature as they follow very different trajectories of HCE

- Hence, we can estimate the HCE accumulation function with a **three-part model**

- *Part-1* estimates the **predicted probability of survival** $\widehat{\boldsymbol{S}}_{\boldsymbol{j}}(\boldsymbol{X})$ until the start of the period *j* and the hazard function for death during the period $\widehat{h_j}(X)$ for all person-period observations
  - **Logit model**

- *Part-2* estimates **HCE** $\widehat{\boldsymbol{\mu}}_{\boldsymbol{1j}}(\boldsymbol{X})$ in the person-periods in which individuals die
  - **Two-part GLM**

- *Part-3* estimates **HCE** $\widehat{\boldsymbol{\mu}}_{\boldsymbol{2j}}(\boldsymbol{X})$ in the person-periods in which the individual survives
  - **Two-part GLM**

- Thus, the **estimated HCE function** for individual "*i* " in the interval ***j*** is:

$$\widehat{\mu_j}(X) = \widehat{S_j}(X) * \left[\widehat{h_j}(X) * \hat{\mu}_{1j}(X) + \left(1 - \widehat{h_j}(X)\right) * \hat{\mu}_{2j}(X)\right] \quad \text{and} \quad \hat{\mu}(X) = \sum_{j=1}^{K} \widehat{\mu_j}(X)$$

- We identify the effect of **Tech progress** on HCE by differentiating this Eq. by the **calendar year *"t"*** when individuals experience the health shock

- **Effect of Tech progress on HCE between 2014-2005** is measured as the difference in cost accumulation between an individual exposed to a health shock in 2014 **(treated)** and an individual exposed to the same shock in 2005 (**counterfactual**), after controlling for observable health and socioeconomic status

- Marginal effect of tech progress on HCE:

Tech effect on HCE due to **delaying TTD**

$$\frac{\Delta\mu}{\Delta t_c} = \sum_{j=1}^{K} \left\{ \frac{\Delta\widehat{S_j}}{\Delta t_c} \left[\widehat{h_j} * \hat{\mu}_{1j} + \left(1 - \widehat{h_j}\right) * \hat{\mu}_{2j} \right] + \widehat{S_j} \left[\frac{\Delta\widehat{h_j}}{\Delta t_c} * \left(\hat{\mu}_{1j} - \hat{\mu}_{2j} \right) \right] \right\} +$$

$$+ \left\{ \widehat{S_j} \left[\widehat{h_j} * \frac{\Delta\hat{\mu}_{1j}}{\Delta t_c} + \left(1 - \widehat{h_j}\right) * \frac{\Delta\hat{\mu}_{2j}}{\Delta t_c} \right] \right\}$$

Tech effect on HCE due to **increasing intensity of resource** use per unit of time j

Results - Objective 2

Decomposition of Tech Progress impact into DTT Effect and Intensity Effect

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Figure 2. Cumulative survival probability after a health shock in 2013-14 and 2005-6. Predictions from a logit model.

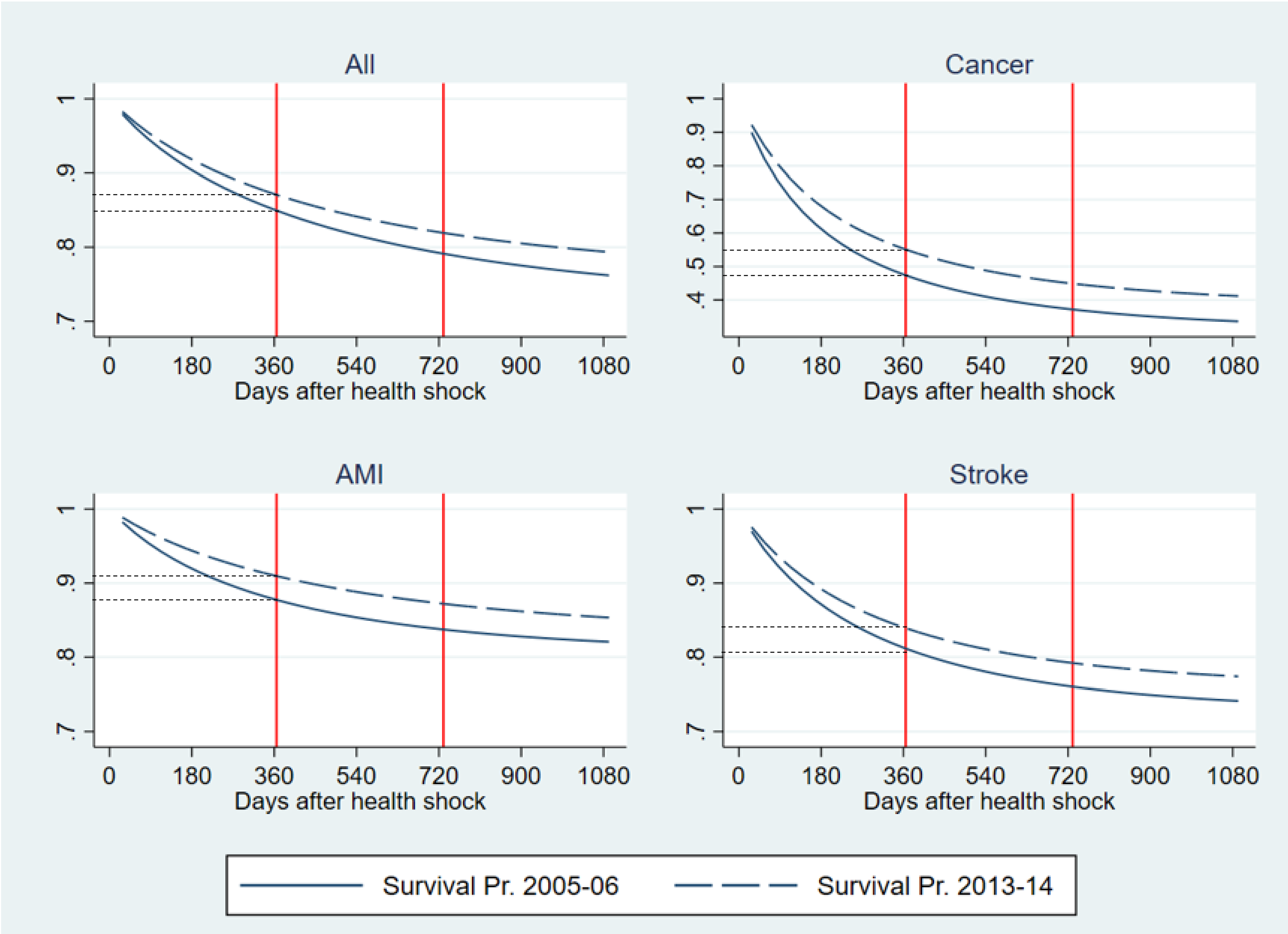
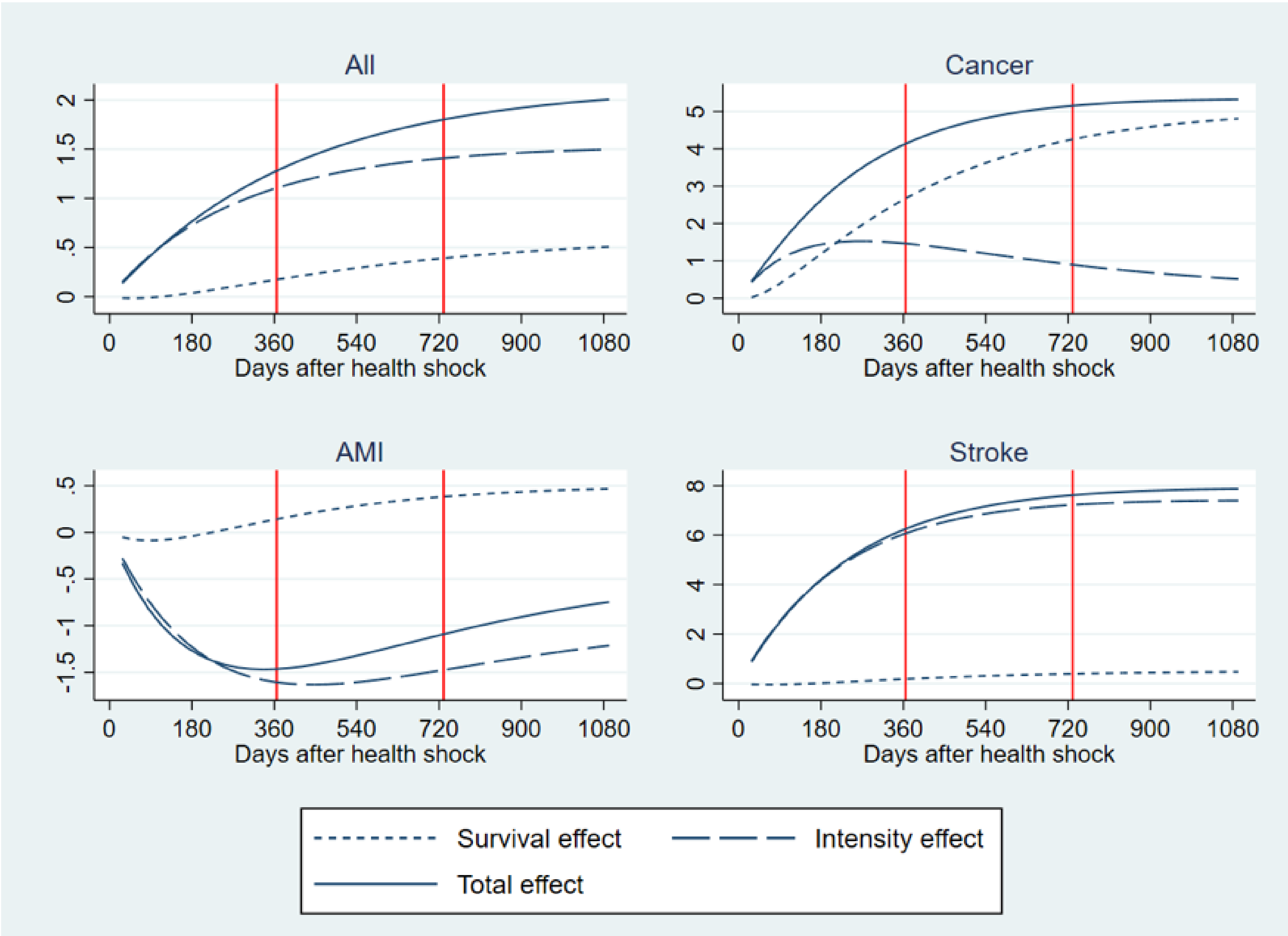


Figure 3. Residual increment of HCE in 2013-14 vs 2005-6 (baseline). Total increment (continuous line) and decomposition into delaying time to death effect (dotted line) and intensity effect (dashed line). Cumulative distribution over the time elapsed from initial health shock. (Y = 1,000 Euros)



Quick Recap

- This study measure the overall effect of Tech Progress on HCE under a residual approach (Econometric Model 1)

- **Decomposing** tech effect into **TTD channel** and **intensity channel** is allowed by the specific cost function adopted (Econometric Model 2)

  - This cost function has been adopted in other studies, e.g. Federspiel et al., HSR 2013; White et al., HSR 2019; Williams et al., JAMA 2019

- The cost function provides a tool to apportion the contribution of **TTD channel** and **intensity channel consistently** and examine their impact over time **separately**.

  - The above holds for many other type of decomposition exercise – they are descriptive in nature and based on assumptions!

Discussion

- Our estimates of the impact of Tech Progress are consistent with **Macroeconomic studies** (Smith et al., 2009 HA; Peden and Freeland, 1998 HE; Newhouse, 1992 JEP**;** Willemé and Dumont, 2015 HE; Okunade and Murthy, 2002 JHE)
  - Evidence of tech impact range between 40% and 70%
- Using **Microdata** gives us an edge
  1. Control for morbidity
  2. No assumption on Income Elasticity influencing predictions of macroeconomic models
  3. Decomposing the impact that is channeled by survival and by intensity

Thanks for your attention!

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