UK intangible investment and national accounts industry productivity dataset

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This note describes the data and methods that underlie the UK intangible investment and national accounts industry productivity dataset published in The Productivity Institute 'Productivity Lab', which are data constructed for Goodridge & Haskel (2022). The source and details for each variable are described along with information on methods for constructed or derived variables.

1. Introduction

This note sets out details on the underlying data and the methods used in constructing each variable in the UK intangible investment and national accounts industry productivity dataset. The dataset includes information on 42 market sector industries for years 1998 to 2019.

The data include the latest ONS estimates of intangible investment (Fotopoulou, 2021), which are integrated with national accounts data consistent with Blue Book 2021 using the same framework and categorisation as that in Corrado, Hulten & Sichel (CHS, 2005). National accounts data in Blue Book 2021 incorporate double deflated gross value added for the first time and include industry data on: nominal and real gross value-added and the implied value-added price index; labour compensation which is compensation of employees plus a proportion of mixed income[1]; gross fixed capital formation (GFCF) and GFCF price indices

For a number of variables, where necessary, the dataset includes two sets of estimates for two different models. The first model is based on national accounts (na) definitions of output and capital and variables have the suffix "na". The second (including intangibles) capitalises all intangibles in the CHS framework; these variables are suffixed "ii".

2. Data

2.1. Industries

The dataset consists of information for 42 industries in the UK market sector. Industry labels and definitions are set out in Table 1.

[1] Mixed income is the income of the self-employed and so conceptually includes returns to both capital and labour. The share of mixed income assumed to represent compensation to labour is estimated based on the share of compensation of employees (CoE) in value-added (GVA) less mixed income (MI).

Table 1: Industry labels and definitions

No:	SIC	Description	SIC section
1	A1t3	Agriculture, Forestry and Fishing	A
2	B5t9	Mining and Quarrying	B
3	C10t12	Manufacture of food, beverages & tobacco	C: Manufacturing
4	C13t15	Manufacture of textiles, wearing apparel & leather products	
5	C16t18	Manufacture of wood & paper products; printing and reproduction of recorded media	
6	C19	Manufacture of coke and refined petroleum products	
7	C20	Manufacture of chemicals and chemical products	
8	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	
9	C22t23	Manufacture of rubber, plastic and non-metallic mineral products	
10	C24t25	Manufacture of basic & fabricated metals	
11	C26	Manufacture of computer, electronic and optical products	
12	C27	Manufacture of electrical equipment	
13	C28	Manufacture of machinery and equipment n.e.c.	
14	C29t30	Manufacture of transport equipment	
15	C31t33	Manufacture of furniture; other manufacturing; repair and installation	
16	D35	Electricity, Gas, Steam and Air Conditioning Supply	D
17	E36t39	Water Supply; Sewerage, Waste Management and Remediation Activities	E
18	F41t43	Construction	F
19	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	G: Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
20	G46	Wholesale trade, except of motor vehicles and motorcycles	
21	G47	Retail trade, except of motor vehicles and motorcycles	
22	H49	Land transport and transport via pipelines	H: Transportation and Storage
23	H50	Water transport	
24	H51	Air transport	
25	H52	Warehousing and support activities for transportation	
26	H53	Postal and courier activities	
27	I55t56	Accommodation and Food Service Activities	I
28	J58t60	Publishing; Motion picture, video and television, sound recording and music publishing; Programming and broadcasting	J: Information and Communication
29	J61	Telecommunications	
30	J62t63	Computer programming, consultancy and related activities; Information service activities	
31	K64t66	Financial and Insurance Activities	K
32	M69t70	Legal and accounting activities; Activities of head offices; management consultancy activities	M: Professional, Scientific and Technical Activities
33	M71	Architectural and engineering activities; technical testing and analysis	
34	M72	Scientific research and development	
35	M73	Advertising and market research	
36	M74t75	Other professional, scientific and technical activities	
37	N77	Rental and leasing activities	N: Administrative and Support Service Activities
38	N78	Employment activities	
39	N79	Travel agency, tour operator and other reservation service and related activities	
40	N80t82	Security and investigation; Services to buildings and landscape; Office administrative and other business support	
41	R90t93	Arts, Entertainment and Recreation	R
42	S94t96	Other Service Activities	S

Note to table: list of all 42 market sector industries in the dataset

2.2. Output: gross value added (GVA)

Data on nominal and real GVA are GDP(O) low level aggregates, from ONS, downloaded from: https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates.

Real values are double deflated with a base year of 2019.

Table 2: Output variables

Variable	Description
PvV_na	Nominal value added, current prices, £bns, national accounts definition
PvV_ii	Nominal value added, current prices, £bns, adjusted for capitalisation of all CHS intangibles
V_na	Real value added, constant prices, £bns, equal to nominal value added in base year (2019), national accounts definition
V_ii	Real value added, constant prices, £bns, equal to nominal value added in base year (2019), adjusted for capitalisation of all CHS intangibles
Pv_na	Implied price of value added, base 2019=1, national accounts definition
Pv_ii	Implied price of value added, base 2019=1, adjusted for capitalisation of all CHS intangibles
DlnV_na	Annual growth in real value added, national accounts definition, change in the natural log
DlnV_ii	Annual growth in real value added, adjusted for capitalisation of all CHS intangibles, change in the natural log
DlnVH_na	Labour productivity growth, growth in real value added per hour worked, national accounts definition, change in the natural log
DlnVH_ii	Labour productivity growth, growth in real value added per hour worked, adjusted for capitalisation of all CHS intangibles, change in the natural log

Note to table: variable names and descriptions for all output variables in the dataset.

Variables suffixed "ii" are adjusted for the capitalisation of all CHS intangibles. Nominal variables are adjusted by addition, i.e.:

$$P^V V_j^{ii} = P^V V_j^{na} + P^N N_j^{CHS} \quad (1)$$

Where, for each industry j: $P^V V_j^{na}$is measured national accounts value added and $P^N N_j^{CHS}$ is nominal investment in CHS intangibles that are uncapitalised in national accounts. Aggregates of real variables are share-weighted superlative indices for changes, benchmarked in levels to 2019 nominal data, for each industry j, i.e.:

$$\Delta ln V_j^{ii} = \bar{s}_j^{V,na} \Delta ln V_j^{na} + \bar{s}_j^{N} \Delta ln N_j^{CHS} \quad (2)$$
$$where: s_j^{V,na} = P^V V_j^{na} / P^V V_j^{ii};\ s_j^{N} = P^N N_j^{CHS} / P^V V_j^{ii}$$
$$\bar{s}_j = (s_{j,t} + s_{j,t-1})/2$$

Where s terms are Tornqvist shares of adjusted value added and N_j^{CHS} is real other CHS (uncapitalised in national accounts) intangible investment. Real intangible investment is nominal investment deflated by the price index, for each asset. Intangible asset price indices are from: https://www.ons.gov.uk/economy/inflationandpriceindices/adhocs/13614deflatorsforintangibleassetsuk1997to2018. These price indices are to 2018. They are extended to 2019 using the average price change in previous years.

2.3. Capital input

Data on capital input include data on nominal and real investment (gross fixed capital formation, GFCF), asset price indices, real capital stocks, user costs, depreciation rates and estimates of growth in capital services and capital deepening (capital services per hour worked).

2.3.1. Tangible capital

Data on nominal GFCF in tangibles are from: https://www.ons.gov.uk/releases/annualgrossfixedcapitalformationbyindustryandasset1997to2020.

The ONS GFCF data also include real values. However, the values are rounded meaning that implied deflators derived from nominal and real estimates are volatile and imprecise. Therefore, instead, price indices are by asset (but not industry-asset, i.e. they are not industry-specific), downloaded from the ONS capital services dataset at: https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/capitalservicesestimates

For capital stocks, for tangibles we base our estimates on the EUKLEMS 2019 release (Stehrer et al., 2019), available at: https://euklems.eu/archive-history/download-archive/. Estimates of real capital stocks are published by ONS but the disaggregation in terms of industries and assets is not sufficiently detailed for our purposes.

Instead, we first take estimates of nominal net tangible stocks from EUKLEMS in 1997. Our dataset has more industry detail than EUKLEMS since we include separate sub-industries within SIC sections M (Professional, Scientific and Technical Activities) and N (Administrative and Support Service Activities) (see Table 1). Therefore, for sub-industries within M and N, we impute initial nominal stocks in 1997 using a variation of the method in Appendix A of Guellec & de la Potterie (2004). Specifically, for industries within M and N, for each asset we impute the nominal stock in 1997 as:

$$P^I K_{k,i,1997} = \frac{P^I I_{k,i,1997}}{1-\lambda_{k,i}(1-\delta_{k,i})}; where: \lambda_{k,i} = \frac{1}{1+g_{k,i}} \quad (3)$$

Where for industries i=M or N, and for each tangible asset, k: g is the mean growth rate in nominal investment over the period 1997 to 2020; δ is a geometric rate of depreciation; $P^I I$ is nominal investment and $P^I K$ is the nominal stock. Depreciation rates for tangible capital are industry-asset-specific and from EUKLEMS (Stehrer et al., 2019).

Then, with estimates of the initial nominal stock for each industry within M or N, we estimate the share of the nominal stock for each industry in the aggregate for M or N:

$$s^{P^I K}_{k,i,1997} = \frac{P^I K_{k,i,1997}}{\sum P^I K_{k,i,1997}} \quad (4)$$

We then apply that share, $s^{P^I K}_{1997}$, to the nominal stock for M or N as published in EUKLEMS, to derive new estimates for nominal stocks within industries M and N, such that those nominal stocks in sub-industries sum to the aggregate nominal stocks for SIC sections M or N in EUKLEMS.

Once we have estimates of the nominal stock for all (tangible) assets in each industry in 1997, we deflate using the ONS price index giving real values (base year 2019) for the initial starting stock for each tangible asset in 1997. Real capital stocks for tangibles (K^{tan}) for years from 1998 are estimated using the perpetual inventory method, for each asset, k in each industry j:

$$K^{tan}_{kjt} = I^{tan}_{kjt} + (1-\delta_{kj})K^{tan}_{kjt-1} \quad (5)$$

Where I^{tan} is real investment and δ is an asset-industry specific geometric depreciation rate.

2.3.2. National accounts intangibles (intellectual property products, IPPs)

Data on nominal GFCF in national accounts intangibles (IPPs) are also from the ONS GFCF dataset. Nominal GFCF in national accounts intangibles (IPPs) include data for software and databases. We separate investment in software and databases into own-account and purchased components using the split published in the ONS intangible investment dataset, available at: https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/investmentinintangibleassetsintheukbyindustry. We do this rather than take estimates directly from the intangibles release as the software and database total differs between the two datasets in some years. We therefore take the total from the official GFCF data and use own-account and purchased shares of investment from the intangibles dataset to split the data, in order to maintain consistency with official GFCF and national accounts.

GFCF in IPPs are extended back to 1992 using growth rates observed from values in the ONS intangible investment dataset.

As with tangibles, due to the rounding of real GFCF, asset price indices are taken from the ONS capital services dataset.

For national accounts intangibles (IPPs), we impute real initial stocks (R^{na}_{1992}) in 1992 for each asset r in each industry j using the steady-state formula:

$$R^{na}_{r,j,1992} = \frac{N^{na}_{r,j,1998}(1+g_{j,r})}{g_{j,r}+\delta_r} \quad (6)$$

Where: g is mean growth in real investment over the period 1992 to 1996; δ is an asset-specific (but not industry-specific) geometric rate of depreciation; N is real investment and R is the real stock. Real capital stocks for national accounts intangibles (IPPs) for years from 1993 are estimated using the perpetual inventory method:

$$R^{na}_{r,j,t} = N^{na}_{r,j,t} + (1-\delta_r)R^{na}_{r,j,t-1} \quad (7)$$

Where: N^{na} is real investment in national accounts intangible assets of type r, R^{na} is the real stock for each asset and δ is an asset-(but not industry-)specific geometric rate of depreciation.: Depreciation rates for national accounts intangibles (IPPs) are from Goodridge et al. (2016) and earlier work.

2.3.3. Other CHS intangibles

Capital input for other CHS intangibles (i.e. non-national accounts intangibles) is also from ONS. Details on ONS data and methods are in Goodridge (2022). Estimates of nominal investment (current prices) are for years 1992 to 2019 and are by asset-industry, published by ONS at: https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/investmentinintangibleassetsintheukbyindustry..

The exception is Training, where ONS data does not yet include estimates broken down by industry and are instead for the total market sector. We break down Training investment by industry using information from EUKLEMS 2021 (Lab of European Economics, 2021), which includes estimates of UK Training investment by industry. First we estimate industry shares of total investment in Training from the EUKLEMS data. Second, we apply those shares to the ONS market sector total to derive UK industry estimates consistent with the ONS aggregate. Third, as noted above, in EUKLEMS, industries M and N are two broad aggregate industries. We require estimates for sub-industries within M and N. Therefore, for industries M and N, we disaggregate further using the share of other nominal intangible investment (for all non-Training assets) within the nominal intangible investment (excluding Training) total for M and N, giving us estimates of nominal Training investment for all 42 industries in our dataset.

Estimates of real investment are derived using ONS Intangible asset price indices, published at: https://www.ons.gov.uk/economy/inflationandpriceindices/adhocs/13614deflatorsforintangibleassetsuk1997to2018. These only extend to 2018. They are extended to 2019 using the average change in the price index in 2016-18, for each asset.

For real capital stocks, for each asset r^{CHS} in each industry j, we impute real initial stocks in 1992 using the steady-state formula:

$$R^{CHS}_{r,j,1997} = \frac{N^{CHS}_{r,j,1998}(1+g_{r,j})}{g_{r,j}+\delta_r} \quad (8)$$

Where: g is the mean growth rate in real investment over the period 1992 to 1996; δ is a geometric rate of depreciation; N^{CHS} is real investment in other CHS intangibles and R^{CHS} is the real stock for other CHS intangible assets.

Real capital stocks in years from 1993 are estimated using the perpetual inventory method, for each asset, r^{CHS} in each industry j:

$$R^{CHS}_{r,j,t} = N^{CHS}_{r,j,t} + (1 - \delta_r)R^{CHS}_{r,j,t-1} \quad (9)$$

Depreciation rates are from Goodridge et al. (2016) and earlier work.

2.3.4. Capital services

Aggregations of capital services growth are for both models based on national accounts definitions (na) and including all CHS intangibles (ii), where estimated user costs (weights in the aggregation of capital services) differ in the two models.

Capital services includes both tangible (K^{tan}) and intangible (R) asset types. Intangible assets include those already capitalised in national accounts (naintan: R^{na}) and those currently uncapitalised in national accounts (othintan: R^{oth}). For each asset, we build a real capital stock via the perpetual inventory method whereby for any capital asset a, the stock of that asset in each industry j evolves according to:

$$K_{a,j,t} = I_{a,j,t} + (1 - \delta_a)K_{a,j,t-1} \qquad a \in K^{tan}, R^{na}, R^{oth} \quad (10)$$

Where I is real investment in that asset over the relevant period and δ the geometric rate of depreciation/deterioration. Real investment is nominal investment deflated by an investment price index. The investment price is converted into a rental price using the Hall-Jorgenson relation, with an industry-specific net rate of return estimated such that capital compensation is exhausted,[2] see for example Oulton & Wallis (2016) and Oulton & Srinivasan (2003).

$$P_{Ka,j} = P_{Ia,j}\left(r_j + \delta_{aj} - \pi_a\right)\tau_a \quad (11)$$

Where: $P_{Ka,j}$ is the rental price of each asset, a, in each industry, j; $P_{Ia,j}$ is the asset investment price; δ_{aj} is an asset-industry-specific depreciation rate; π_a is the capital gain term for each asset, derived from the price index; τ_a is the tax adjustment factor[3] for each asset; and r_j is an industry-specific net rate of return estimated such that industry gross operating surplus is exhausted.

In constructing composition-adjusted capital services, we aggregate across different types of tangible and intangible assets, all by industry. Denoting capital types a we construct capital services for each industry j:

[2] In calculating rental prices we set the capital gain terms for buildings to zero to avoid generating negative user costs for buildings, as described in Statistics New Zealand (2010). Some rental prices remain negative for a small number of industry-year observations in industries C26, C28 and H. We therefore replace the negative value with a value of 0.0000001 to effectively make user costs zero in that particular asset-industry-year. Capital compensation is then estimated as the sum of user costs in each industry-year and the labour share estimated as one minus the capital share to enforce constant returns to scale in each industry. To maintain consistency we re-estimate labour compensation using the labour income share and estimates of nominal value-added.

[3] Constructed from corporate tax data in Hanappi (2018) and OECD (2021). We thank Tibor Hanappi of OECD for giving us access to these data.

$$\Delta \ln K_j = \sum_a \overline{s}_{a,j} \Delta \ln K_{a,j} \qquad a \in K^{tan}, R^{na}, R^{oth} \qquad (12)$$

$$where: s_{a,j} = \frac{P_{Ka,j}K_{a,j}}{\sum_a P_{Ka,j}K_{a,j}}, \overline{s} = 0.5 * (s_t + s_{t-1})$$

Estimates of capital deepening (growth in capital services per hour worked are simply:

$$\Delta \ln(K/H)_{a,j,t} = \Delta \ln K_{a,j,t} - \Delta \ln H_{j,t} \qquad (13)$$

2.3.5. Summary of variables

Table 3 sets out variable names and description for each of the capital input variables in the dataset. Each variable is created for each asset. Some variables also include an industry aggregate not suffixed by an asset name. Asset types are set out in Table 4. Aggregations of capital services growth are for both models based on national accounts definitions (na) and including all CHS intangibles (ii), where estimated user costs (weights in the aggregation of capital services) differ in the two models (because gross operating surplus changes when intangibles are capitalised).

Table 3: Capital input variables: Tangible capital and intangibles (IPPs) capitalised in national accounts

Variable	Description
PiI_asset	Nominal investment, current prices, £ billions, by asset
I_asset	Real investment, constant prices, £ billions, equal to nominal investment in base year (2019), by asset
Pi_asset	Asset price index, base 2019=1
K_asset	Real net capital stock, £bns, constant prices (base year=2019), by asset
dpr_asset	Geometric depreciation rate, by industry-asset
PkK_na	Industry gross operating surplus (capital compensation), nominal, national accounts definition, current prices, £bns
PkK_ii	Industry gross operating surplus (capital compensation), nominal, adjusted for capitalisation of all CHS intangibles, current prices, £bns
PkK_na_asset	Capital rental payments (user costs), by asset, nominal, national accounts definition, current prices, £bns
PkK_ii_asset	Capital rental payments (user costs), by asset, nominal, adjusted for capitalisation of all CHS intangibles, current prices, £bns
DlnK_na_asset	Growth in capital services, by asset, national accounts definition, change in the natural log
DlnK_ii_asset	Growth in capital services, by asset, adjusted for capitalisation of all CHS intangibles, change in the natural log
DlnKH_na_asset	Growth in capital deepening (capital services per hour worked), by asset, national accounts definition, change in the natural log
DlnKH_ii_asset	Growth in capital deepening (capital services per hour worked), by asset, adjusted for capitalisation of all CHS intangibles, change in the natural log

Note to table: variable names and descriptions for all capital input variables in the dataset. Variables not suffixed by an asset are aggregates over all assets.

Table 4: Assets: Tangible capital and intangibles (IPPs) capitalised in national accounts

Asset	Description
Tangible capital	
B	Buildings and structures (excluding dwellings)
OME	Other Machinery and Equipment
TraEq	Transport Equipment
Cult	Cultivated biological resources
othtan	Other tangibles aggregate: B, OME, TraEq, Cult
IT	IT hardware equipment
CT	Telecommunications equipment
ICTtan	ICT tangible equipment aggregate: IT, CT
National accounts intangibles (IPPs)	
SoftDBoa	Own-account software and databases
SoftDBp	Purchased software and databases
SoftDB	Software and databases: aggregate of purchased and own-account
RD	Research and Development
Min	Mineral exploration
Art	Artistic Originals
naintan	National accounts intangibles aggregate: SoftDB, RD, Min, Art
All other CHS intangibles	
Designoa	Own-account Design
Designp	Purchased Design
Design	Design: aggregate of purchased and own-account
FPI	Financial Product Innovation
Train	Training
Brandoa	Own-account brand/reputational capital
Brandp	Purchased brand/reputational capital
Brand	Brand capital: aggregate of purchased and own-account
Orgoa	Own-account organisational capital
Orgp	Purchased organisational capital
Org	Organisational capital: aggregate of purchased and own-account
othintan	Other CHS intangibles aggregate: Design, FPI, Train, Brand, Org
intan	Total intangibles aggregate: naintan and othintan

Note to table: Asset breakdown capital input variables. Note: some higher aggregations are only included for some capital and growth-accounting variables. Detailed asset breakdown available for all variables.

2.4. Labour input

Data on labour input are data from the ONS and the Bank of England. Hours worked are annual person hours worked by all persons engaged, including employed and self-employed and those with more than one job (the ONS series usually termed "productivity hours"). Data on hours worked are published at: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/compendiumofdatarelatedtolabourproductivitybylowlevelindustry.

For estimates of labour services and labour composition we use data produced at the Bank of England,[4] estimated from Labour Force Survey (LFS) microdata. In order to maintain sufficient sample cell sizes for our narrow industry definitions, the only composition groups used are education (highest qualification attained) and industry. Education is split into three groups: high, medium, and low. Estimates of hours worked for each worker type are constructed from the LFS microdata, and growth in labour services are estimated by aggregating across different worker types (i.e. types are according to industry and educational attainment) using shares of labour compensation for each worker type, for each industry *j*:

[4] We thank Douglas Rendle of the Bank of England for producing these estimates.

$$\Delta \ln L_j^{BOE,LFS} = \sum_b \overline{s}_{b,j} \Delta \ln H_{b,j}^{BOE,LFS} \quad b \in High, Medium, Low\ (educational\ attainment)\ (14)$$

$$where: s_{b,j} = \frac{P_{Lb,j} L_{b,j}}{\sum_b P_{Lb,j} L_{b,j}}, \overline{s} = 0.5 * (s_t + s_{t-1})$$

Estimates of labour composition are therefore estimated for each industry j as:

$$\Delta ln(L/H)_j^{BOE,LFS} = \Delta ln L_j^{BOE,LFS} - \Delta ln H_j^{BOE,LFS} \quad (15)$$

Estimates of DlnH (and hence DlnL) derived from the LFS microdata are more volatile than ONS productivity hours. To maintain consistency with official ONS data on hours worked and national accounts we therefore re-estimate DlnL, derived as:

$$\Delta ln L_j = \Delta ln(L/H)_j^{BOE,LFS} + \Delta ln H_j^{ONS} \quad (16)$$

Data on labour compensation are based on data from ONS, constructed from data for compensation of employees from the Input Output Supply Use Tables (SUTs) at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables plus a proportion of mixed income. We are grateful to the ONS for providing data on mixed income at detailed industry-level. Mixed income (MI) is compensation earned by the self-employed and conceptually includes returns to both capital and labour. We therefore derive the component that represents a return to labour as:

$$s = CoE/(P^V V^{na} - MI) \quad (17)$$

Where CoE is national accounts compensation of employees. We make an adjustment to labour compensation for industry C26 in 2001 where, in that industry-year, labour compensation is greater than value-added. We therefore replace labour compensation as nominal value-added multiplied by the mean labour income share (1997-2019) for that one observation.

Table 5 provides details on variable names and descriptions for labour input variables.

Table 5: Labour input variables

Variable	Description
H	Annual person-hours worked for all persons engaged (employed plus self-employed), billions
DlnL	Growth in Labour Services, change in the natural log
DlnH	Growth in hours worked, change in the natural log
DlnLH	Growth in labour composition (i.e. labour services per hour worked), change in the natural log
PLL	Total nominal labour compensation incorporating the proportion of mixed income allocated to labour, £ billions, current prices

Note to table: variable names and descriptions for all labour input variables in the dataset

2.5. Growth-accounting variables

Using data on capital and labour input described above, we carry out growth-accounting on the basis of both labour productivity growth (Dln(V/H)) and value-added growth (DlnV) for alternative models based on national accounts definitions (na) and including all CHS intangibles (ii).

We start with data for different types of capital and labour. In this paper, capital services includes both tangible (K^{tan}) and intangible (R) asset types. Intangible assets include those already capitalised in national accounts (naintan: R^{na}) and those currently uncapitalised in national accounts (othintan: R^{oth}). As set out above, we first build a real capital stock via the perpetual inventory method using estimates of real investment. Real investment is nominal investment deflated by an investment price index. The investment price is converted into a rental price using the Hall-Jorgenson relation, with an industry-specific net rate of return estimated such that capital

compensation in each industry is exhausted,[5] see for example Oulton & Wallis (2016) and Oulton & Srinivasan (2003).

Capital and labour produce (value-added) output Q_j in industry j. Thus, for each industry, we have the following value-added defined $\Delta lnTFP_j$:

$$\Delta ln(V/H)_j \equiv \overline{w}^V_{K,j} \Delta\, ln(K/H)_j + \overline{w}^V_{L,j} \Delta\, ln(L/H)_j + \Delta lnTFP^V_j \qquad (18)$$

$$\Delta lnV_j \equiv \overline{w}^V_{K,j} \Delta\, ln\, K_j + \overline{w}^V_{L,j} \Delta\, ln\, L_j + \Delta lnTFP^V_j$$

$$where: w_{K,j} = \frac{P_{K,j}K_j}{P_{Q,j}Q_j}, w_{L,j} = \frac{P_{L,j}L_j}{P_{Q,j}Q_j}, \overline{w} = 0.5 * (w_t + w_{t-1}),$$

$$and: \quad P_{K,j}K_j = \sum_a P_{Ka,j}K_{a,j},\ P_{L,j}L_j = \sum_b P_{Lb,j}L_{b,j}$$

Where terms in w are shares of factor costs (the sum of factor payments over capital or labour types in industry j) in industry nominal value-added, averaged over two periods.

Table 6: Growth-accounting variables

Variable	Description
capconva_na_asset	Contribution of capital to growth in value-added, national accounts definition, by asset, change in the natural log
capconvah_na_asset	Contribution of capital deepening (capital services per hour worked) to growth in labour productivity, national accounts definition, by asset, change in the natural log
capconva_ii_asset	Contribution of capital to growth in value-added, adjusted for capitalisation of all CHS intangibles, by asset, change in the natural log
capconvah_ii_asset	Contribution of capital deepening (capital services per hour worked) to growth in labour productivity, adjusted for capitalisation of all CHS intangibles, by asset, change in the natural log
labconva_na	Contribution of labour services to growth in value-added, national accounts definition, change in the natural log
labconvah_na	Contribution of labour composition (labour services per hour worked) to growth in labour productivity, national accounts definition, change in the natural log
labconva_ii	Contribution of labour services to growth in value-added, adjusted for capitalisation of all CHS intangibles, change in the natural log
labconvah_ii	Contribution of labour composition (labour services per hour worked) to growth in labour productivity, adjusted for capitalisation of all CHS intangibles, change in the natural log
DlnTFP_na	Total factor productivity growth, national accounts definition, estimated from decomposition of growth in value added, change in the natural log
DlnTFPh_na	Total factor productivity growth, national accounts definition, estimated from decomposition of growth in value added per hour worked, change in the natural log
DlnTFP_ii	Total factor productivity growth, adjusted for capitalisation of all CHS intangibles, estimated from decomposition of growth in value added, change in the natural log
DlnTFPh_ii	Total factor productivity growth, adjusted for capitalisation of all CHS intangibles, estimated from decomposition of growth in value added per hour worked, change in the natural log

Note to table: variable names and descriptions for growth-accounting variables

[5] In calculating rental prices we set the capital gain terms for buildings to zero to avoid generating negative user costs for buildings, as described in Statistics New Zealand (2010).

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