# The Quantitative Role of Capital-Goods Imports in U.S. Growth

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A significant body of literature has found that technological improvements embodied in new capital goods account for a large share of U.S. output growth. This phenomenon, known as investment-specific technological change, has stimulated the growth rate of output by raising the efficiency of equipment and software (E&S) in the production of final output. In an influential contribution, Jeremy Greenwood, Zvi Hercowitz, and Per Krusell (1997) found that investment-specific technological change accounted for nearly 60 percent of growth in U.S. output per hour during the postwar period.

A notable fact is that an increasing share of U.S. aggregate E&S investment expenditure has been allocated to capital-goods imports. While capital-goods imports were only 3.5 percent of E&S investment in 1967, by 2008 their share had risen tenfold to 36 percent. The goal of this paper is to measure the contribution of capital-goods imports to growth in U.S. output per hour using a simple growth accounting exercise. We find that capital-goods imports have contributed 20 to 30 percent to growth in U.S. output per hour between 1967 and 2008. We also find that, overall, the average contribution of the stock of E&S to growth in U.S. output per hour has been about 70 percent. This implies that capital-goods imports have explained 30 to 40 percent of the average contribution of the stock of E&S to U.S. growth in output per hour. More importantly, we find that capital-goods imports have represented an increasing source of growth for the U.S. economy. Indeed, we show that, over the sample period, the average contribution of capital-goods imports to growth in U.S. output per hour has increased noticeably.

## I. Growth Accounting

In this section, we present the methodology that we follow to compute the contributions to output growth and describe the data and the parameter values that we use in our analysis.

### *A. Methodology*

We consider a constant-returns-to-scale technology. We assume that output, $y_t$, is produced according to:

$$y_t = a_t k_{s,t}^{\alpha_s} k_{e,t}^{\alpha_e} l_t^{1-\alpha_s-\alpha_e}, \tag{1}$$

with $0 < \alpha_s, \alpha_e < 1$ and $\alpha_s + \alpha_e < 1$. In (1), $a_t$ corresponds to total-factor productivity (TFP), $k_{s,t}$ and $k_{e,t}$ denote the stocks of structures and E&S, respectively, with $\alpha_s$ and $\alpha_e$ indicating their factor shares, and $l_t$ represents the number of labor hours. We allow for two types of capital—structures and E&S—to properly account for the effects on measured growth in the stock of E&S capital of investment-specific technological change, that is, of technological improvements stemming from the introduction of new and more productive capital goods. If instead, only a single type of capital were allowed, thus combining together the stocks of structures and E&S, one would understate the measured contribution of capital to U.S. growth; at the same time, the unexplained contribution to U.S. growth, commonly attributed to TFP, would be overstated.

The stock of structures evolves according to:

$$k_{s,t+1} = (1 - \delta_{s,t})\, k_{s,t} + i_{s,t}, \tag{2}$$

with $0 < \delta_{s,t} < 1$, where $\delta_{s,t}$ is the depreciation rate for structures, and $i_{s,t}$ denotes investment in structures. In contrast, the stock of E&S evolves according to:

$$k_{e,t+1} = (1 - \delta_{e,t})\, k_{e,t} + q_{e,t} i_{e,t}, \tag{3}$$

with $0 < \delta_{e,t} < 1$, where $\delta_{e,t}$ is the depreciation rate for E&S, and $i_{e,t}$ denotes E&S investment. The term $q_{e,t}$ corresponds to the level of investment-specific productivity. It reflects the state of the technology for producing new units of E&S. It indicates, in fact, the amount of new E&S that can be obtained with one unit of output, and it is equivalent to the inverse of the price of E&S investment in units of output.

In order to measure the contributions of TFP, structures, and E&S capital to growth in U.S. output per hour, we rewrite the production function (1) as:

$$\frac{y_t}{l_t} = a_t \cdot \left(\frac{k_{s,t}}{l_t}\right)^{\alpha_s} \cdot \left(\frac{k_{e,t}}{l_t}\right)^{\alpha_e}. \tag{4}$$

This equation allows to decompose observed growth in U.S. output per hour into the contributions arising from TFP growth, growth in the structures-per-hour ratio, and growth in the E&S-per-hour ratio.

Having computed the contribution of growth in the E&S-per-hour ratio to growth in U.S. output per hour, we go on to follow two complementary approaches to assess the quantitative role of capital-goods imports in growth in the stock of E&S and, ultimately, in growth in output per hour. The first approach is based on the perpetual inventory model as described in equation (3). More specifically, it separates the accumulation in the stock of E&S, into a component driven by capital-goods imports and one driven by domestic E&S investment. The second approach does not rely on any explicit assumption and, instead, it simply uses chain-weighted price and real series to compute the contributions of capital-goods imports and domestic E&S investment to growth in real aggregate E&S investment and in the stock of E&S.

In the context of the first approach, we assume that aggregate E&S investment is a Cobb-Douglas aggregate of capital-goods imports and domestic E&S investment:

$$i_{e,t} = i_{m,t}^{\theta_t} i_{d,t}^{1-\theta_t}, \tag{5}$$

where $\theta_t$ is the expenditure share of capital-goods imports in aggregate E&S investment, $i_{m,t}$ denotes capital-goods imports, and $i_{d,t}$ is domestic E&S investment. Under this specification, the expenditure share of capital-goods imports in aggregate E&S investment determines the contribution of capital-goods imports to growth in aggregate E&S investment. We also assume that the overall stock of E&S is measured as the sum of one component driven by capital-goods imports and one driven by domestic E&S investment. This assumption allows us to decompose growth in the stock of E&S into the contributions stemming from capital-goods imports and from domestic E&S investment. Accordingly, we construct the stocks of imported E&S, $k_{m,t}$, and domestic E&S, $k_{d,t}$, with a method similar to that described in equation (3):

$$k_{m,t+1} = (1 - \delta_{e,t})\, k_{m,t} + \theta_t q_{e,t} i_{e,t}, \tag{6}$$

$$k_{d,t+1} = (1 - \delta_{e,t})\, k_{d,t} + (1 - \theta_t) q_{e,t} i_{e,t}. \tag{7}$$

In order to measure the contributions of imported and domestic E&S to growth in U.S. output per hour, we multiply the change in the E&S-to-hours ratio with the respective contributions of imported and domestic E&S to growth in the stock of E&S.

The second approach appeals to one standard implication of a conventional neoclassical growth model that, along a balanced growth path, real investment and the stock of capital both grow at a common rate. In the context of our accounting framework, this feature implies that the average growth rate in the stock of E&S, $k_{e,t}$, is virtually equal to the average growth rate of $q_{e,t}i_{e,t}$. Average growth in $q_{e,t}i_{e,t}$, in turn, is equal to the average growth rate in measured real E&S investment. The term $q_{e,t}i_{e,t}$, in fact, is the product of the inverse of the relative price of E&S investment in terms of consumption and of current-dollar E&S investment divided by the consumption deflator. This implies that $q_{e,t}i_{e,t}$ is simply current-dollar E&S investment divided by its own deflator. We then use the chain-weighting formula in Karl Whelan (2002) for the calculation of contributions to percent changes in a real aggregate series to decompose growth in measured real E&S investment into the contributions attributable to capital-goods imports and to domestic E&S investment, $c^e_{m,t}$ and $c^e_{d,t}$. Specifically, these contributions are computed according to:

$$c^e_{j,t} = \frac{\left(\frac{p_{j,t}}{\Pi_{e,t}} + p_{j,t-1}\right) \cdot \left(i^r_{j,t} - i^r_{j,t-1}\right)}{\sum\limits_{j=d,m} \left(\frac{p_{j,t}}{\Pi_{e,t}} + p_{j,t-1}\right) \cdot i^r_{j,t-1}}, \quad j = m, d, \tag{8}$$

where $p_{m,t}$ and $p_{d,t}$ are the price indices for capital-goods imports and domestic E&S investment, $\Pi_{e,t}$ is the period-$t$ growth rate of the deflator for real aggregate E&S investment, and $i^r_{m,t}$ and $i^r_{d,t}$ are real capital-goods imports and real domestic E&S investment. The formula above implies that, each period, the sum of the contributions $c^e_{m,t}$ and $c^e_{d,t}$ are equal to the percent change in real aggregate E&S investment. Therefore, over the sample we consider, the average values of $c^e_{m,t}$ and $c^e_{d,t}$ measure the average contributions of capital-goods imports and domestic E&S investment to growth in measured real E&S investment and to growth in the stock of E&S.

### *B. Data and parameter values*

We use annual data from the National Income and Product Accounts Tables of the Bureau of Economic Analysis (BEA), unless otherwise noted, with our sample ranging from 1967 to

2008. We deflate all the nominal variables in our analysis with the implicit price deflator for consumption, defined as the ratio between nominal and real consumption. Real consumption is the chain-weighted sum of personal consumption expenditure on nondurables and nonhousing services and government consumption, while nominal consumption is the sum of the corresponding current-dollar measures for these series. The series for investment-specific productivity is the inverse of the relative price of E&S investment in terms of consumption, with this relative price computed as the ratio between the E&S investment deflator and the consumption deflator. The E&S investment deflator is the implicit price deflator for aggregate E&S investment, defined as the ratio between nominal and real aggregate E&S investment. Aggregate real E&S investment, in turn, is the chain-weighted sum of private and government nonresidential fixed investment in E&S, while nominal E&S investment is the corresponding current-dollar series.

We construct the series for the stocks of structures and E&S using the perpetual-inventory methods as described in equations (2) and (3). The initial stock of structures is the current-dollar value in 1967 from the BEA Fixed Assets Tables divided by the corresponding consumption deflator. Starting with this initial value, we compute the stock of structures by iterating on the law of motion (2), using observed investment in structures. The initial stock of E&S is also the current-dollar value in 1967 from the BEA Fixed Assets Tables, adjusted using investment-specific productivity in 1967 by dividing it by the corresponding E&S investment deflator. Starting with this initial value, we compute the stock of E&S by iterating on the law of motion (3) using observed investment-specific productivity and E&S investment.

In constructing the stocks of structures and E&S through the perpetual inventory method, we use the historical depreciation rates, $\delta_{s,t}$ and $\delta_{e,t}$, rather than their sample averages. We measure these depreciation rates using the notion of physical depreciation. This notion is different from the one used by the BEA whose measure is based, instead, on the notion of economic depreciation. As shown by Stephen D. Oliner (1993) and others, with investment measured in efficiency units, one should obtain depreciation rates consistent with the notion of physical depreciation. We, therefore, compute the physical depreciation rate for E&S, $\delta_{e,t}$, as:

$$\delta_{e,t} = 1 - (1 - d_{e,t}) \frac{q_{e,t}}{q_{e,t-1}}, \tag{9}$$

where $d_{e,t}$ denotes economic depreciation, measured as the ratio between current-cost depreciation and the previous-year current-cost net stock from the BEA Fixed Assets Tables. With regard to structures, the physical depreciation rate, $\delta_{s,t}$, coincides with the economic depreciation rate.

The real series for domestic E&S investment is the chain-weighted difference between real aggregate E&S investment and real capital-goods imports, while the price series for domestic E&S investment is the corresponding chain-weighted price index. We measure the expenditure share of capital-goods imports in aggregate E&S investment as the ratio of capital-goods imports over aggregate E&S investment, both expressed in current dollars. Output is gross national product minus gross farm and gross housing value added. Labor hours are total aggregate hours in nonfarm payrolls from the Bureau of Labor Statistics. TFP is computed according to the production function in (1).

Finally, we follow the strategy of Paul Gomme and Peter Rupert (2007) to obtain an average capital factor share of 0.285. We then adopt the balanced-growth-path methodology of Greenwood, Hercowitz, and Krusell (1997) to decompose the capital share into the factor shares of structures and E&S. Using data from our sample period, the parameter values we obtained are $\alpha_{s,t} = 0.1352$ and $\alpha_{e,t} = 0.1496$.

## II. Findings

Table 1 presents the average contributions of TFP, structures per hour, and E&S per hour to U.S. growth in output per hour. The first column of Table 1 shows the average contributions for the full sample period. Between 1967 and 2008, E&S per hour has contributed 72.4 percent to growth in U.S. output per hour, while TFP and structures per hour have contributed 12.8 percent and 14.8 percent respectively. The second column of Table 1 shows the average contributions to growth in U.S. output per hour over the second half of the sample period, that is from 1987. It shows an increase in the contribution of E&S to growth in U.S. output per hour to 76 percent.

Table 1: Growth in U.S. output per hour

| Average annual contributions (percent) | | |
|---|---|---|
| | 1967-2008 | 1987-2008 |
| TFP | 12.8 | 14.5 |
| Structures | 14.8 | 9.2 |
| E&S | 72.4 | 76.3 |

Table 2 splits the average contribution of E&S per hour to U.S. growth in output per hour into the average contributions of imported and domestic E&S per hour. We obtain these contributions using the first approach described in Section A. The first column of Table 2 shows the average contributions for the full sample period. Between 1967 and 2008, imported E&S per hour has contributed 20.3 percent to growth in U.S. output per hour, while domestic E&S per hour has contributed 52.1 percent. This implies that capital-goods imports have explained nearly 30 percent of the average contribution of E&S per hour to U.S. growth in output per hour. The second column of Table 2 shows the average contributions over the second half of the sample period. It shows that capital-goods imports have been an increasing source of growth for the U.S. economy. In particular, the contribution of imported E&S per hour to growth in U.S. output per hour has increased to 30.1 percent between 1987 and 2008. In contrast, the contribution of domestic E&S per hour has decreased to 46.2 percent.

Table 2: Growth in U.S. output per hour

| Average annual contributions (percent) | | |
|---|---|---|
| | 1967-2008 | 1987-2008 |
| E&S | 72.4 | 76.3 |
| Domestic E&S | 52.1 | 46.2 |
| Imported E&S | 20.3 | 30.1 |

Table 3 splits the average contribution of E&S per hour to U.S. growth in output per hour into the average contributions of capital-goods imports and domestic E&S investment. We obtain these figures by calculating the contributions to percent changes in measured real E&S investment using the second approach outlined in Section A. The first column of Table 3 shows the average contributions for the full sample period. Our calculations show that, between 1967 and 2008, capital-goods imports have contributed 41.6 percent to growth in aggregate E&S investment. This implies that their contribution to growth in output per hour was 30.8 percent. We also obtain that, throughout the sample period, domestic E&S contributed 57.4 percent to E&S investment growth, thus contributing 41.6 percent to growth in output per hour. The second column of Table 3 shows the average contributions over the second half of the sample period. It shows, once again, but based on a conceptually different approach, that capital-goods imports have been an increasing source of growth for the U.S. economy. We find that, between 1987 and 2008, the contribution of capital-goods imports to E&S investment growth moved up to 54.4, implying a higher contribution to growth in U.S. output per hour of 41.5 percent. In contrast, the measured contribution of domestic E&S investment to E&S investment growth moved down to 45.6 percent, implying a lower contribution to growth in U.S. output per hour of 34.8 percent.

Table 3: Growth in U.S. output per hour

| Average annual contributions (percent) | | |
|---|---|---|
| | 1967-2008 | 1987-2008 |
| E&S | 72.4 | 76.3 |
| Domestic E&S inv. | 41.6 | 34.8 |
| Capital-goods imp. | 30.8 | 41.5 |

## III. Concluding Remarks

The salient findings of this paper are that capital-goods imports have contributed 20 to 30 percent to growth in U.S. output per hour between 1967 and 2008, and that this contribution has even risen to a measured 30 to 40 percent in the last 20 years. These findings imply that capital-goods imports have represented an increasing source of growth in U.S. output per hour. In related work, Michele Cavallo and Anthony Landry (2009) show that the relative price of capital-goods imports has fallen more rapidly than the relative price of domestic E&S investment over the sample period. This observation, together with the finding that a significant portion of the increase in the stock of E&S has stemmed from higher capital-goods imports, hints that the decline in the relative price of capital-goods imports has been a key driving force behind the observed increase in the stock of E&S.

## References


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## Notes

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