An Exploratory Study of Causality between IT Investment and Economic Performance at the Country Level

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Abstract

This paper investigated the causal relationship between IT investment and economic performance with the office, computing and accounting machinery (OCAM) and gross domestic product (GDP) statistics from the United States for the period 1961 to 2001. Due to non-stationary aspects of series, found by unit root tests, it was deemed applicable to apply growth models using the first difference of the series. The results indicate that IT investment growth causes economic performance growth, but is not caused by economic performance growth; IT investment growth affects economic performance growth over longer time periods.

Keywords:

IT investment; Economic performance; Granger causality

Introduction

The greater resource firms or countries allocate to IT capital, the more concern there is for the effectiveness of the IT investment [22]. Many researchers studied the relationship between IT investment and output at the various level of analysis (for a review see [8, 25]). The studies, conducted in the 1980s and early 1990s, provoked a long-running debate about the effectiveness of IT investment. From mid 1990s to recent the studies, which used broader knowledge stock and more refined research methods, revealed positive and significant impacts from IT investments (e.g. [3, 4, 5, 7, 11, 12]). To investigate the relationship between the above variables, the existing studies have derived research equations from neo-classical growth theory [5]. A central tenet of the theory is the importance of changes in the factors of production, principally physical capital and labor for output growth, such as gross domestic product (GDP) growth [11, 12], a firm's output [5, 7].

Some country-level studies have found that there have been significant and positive impacts from national IT investment in U.S. economy for decades [20, 26]. Contribution of IT investment to GDP growth has increased over time since 1948 [20]. Furthermore, a few studies in IS literature have found that changes in IT capital per worker have positive and significant influence on changes in GDP per worker in the developed countries, while there was no evidence of a positive relationship for developing countries [11, 12].

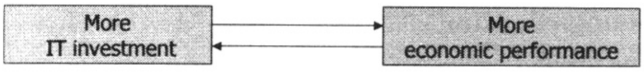
Despite many empirical findings of positive and significant results about the effect of IT investment on economic performance (e.g., [11, 12]), questions regarding the mechanisms and the direction of causality in those studies remain an issue requiring further investigation [1, 4, 8]. Arguably, rather than IT causing greater output, better firms or, even, the average firms with unexpectedly high sales, may spend their windfall on computers, believing that this would pay off. The firms may get more opportunities for IT investment due to better economic performance [1]. In addition, increased economy raises the intensiveness of information processing related with coordination [13]. This increases demand for more timely and precise information. The demand facilitates making the massive financial investments for IT. Empirically, Hu and Plant [19] identified the effect of firm performance on IT investment, and Kobelsky, Richardson, and Zmud [21] uncovered that firm earnings affects IT investment. Their results confirm the view that there needs to be greater understanding of whether the positive effect of IT investment on output in existing studies may be mis-specified due to reverse causality (see Figure 1 in the next page).

To fully understand the causal relationship between IT investment and economic performance, the research question is:

> *Is there a causal relationship between IT investment (growth) and economic performance (growth) at the country level and, if so, what is the direction of causality?*

The remainder of the paper is organized as follows: the second section reviews literature related to the causality relationships between IT investment and performance; the third section discusses the empirical framework and methodology for exploring causality, and data; the fourth section presents the results; finally, the last section summarizes the key findings, describes the contributions, and suggests further research.

- Neo-classical growth theory: IT capital as one of capitals
- e.g., Brynjolfsson [3], Brynjolfsson & Hitt [4], Brynjolfsson, Hitt, & Yang [7], Dewan & Min [11, 12]



- Increased economy raises the intensiveness of information processing (larger economy, more information related with coordination, then more IT investment for processing information) [13]
- Investing capability for IT investment (better performance, larger budgeting for IT) [1]
- e.g., Hu & Plant [19], Kobelsky, Richardson, & Zmud [21]

Figure 1 – Causal Mechanism Proposed in Literature

Literature review

The simple concept that X causes Y raises subtle issues that may go beyond econometrics [13] (for a review of causality see [17]). In the physical sciences, many experiments can be repeatedly performed under controlled conditions to directly test suggested causal mechanisms. However, given the non-experimental nature of most economic data, it is difficult or often impossible to determine cause-and-effect relationships from the available data, in the strict philosophical sense. Since conflicting causal mechanisms may be proposed, the concept of causality has been developed in the economics literature that can be tested with statistical tools and that has seen considerable usage in recent years by, among others, Granger [15].

The study of Hu and Plant [19] is the first published application using the causality test between IT investments and firm-level performance in IS literature. While Hu and Plant could not find any statistical evidence that the IT investments caused the improvement of the performance, their causal models suggest that improved firm performance over consecutive years have contributed to the increase of IT investments in the subsequent year. Furthermore, Devaraj and Kohli [9] performed the Granger causality test for not main methodology but one of specification tests, while they did not report any statistical results at their paper.

Another study in IS literature [13] has shown that the evidence for causality from telecommunications investment to economic activity levels was substantially stronger than evidence for causality in the opposite direction. This causality pattern was substantially same for both industrialized countries and developing countries. Moreover, Madden and Savage [23] examined the relationship between gross fixed investment, telecommunications infrastructure and economic growth for a sample of transitional economies in Central and Eastern Europe. They found various results: a feedback at an aggregate level, unidirectional causality from the gross fixed investment to economic growth in the industrial sector, and reverse causality in the services sector.

While the Granger causality test, which was generally accepted as a rigorous method to test the existence and direction of causality, has shown much application in various areas (see [13]), especially economics, there are only a few studies on the relationship between IT investments and output. Moreover, as distributed lag model approaches, as like Granger causality (equation (1) and (2) in the empirical framework section), need enough longer time series [18]. Firm-level data may not be proper because one cannot get the longer time series for distributed lag model with secondary data [2]. In addition, instantaneous causality that existing studies used in research equations is difficult to identify in economics [16, pp. 204-208]. With an understanding of the significance of the issue, scarcity of causality study concerning relationship between IT investment and economic performance, and the limitation in existing studies, this article attempts to find the causality between IT investment and economic performance at the country level.

Empirical framework

Granger [15] suggested that the causal relationship between two variables could be determined by examining over time the way they move with respect to each other. The test procedure comprises: to conduct two separate hypothesis tests and to discern causality or lack of causality through consideration of the results of both tests. Specifically, the first hypothesis test consists of the null hypothesis that X does not cause Y, as opposed to the alternative hypothesis that X causes Y [24]. Conversely, the second hypothesis test consists of the null hypothesis that Y does not cause X, as opposed to the alternative hypothesis that Y causes X. These can be written as equations:

$$X_t = c + \sum_{j=1}^{k} \alpha_j X_{t-j} + \sum_{j=1}^{k} \beta_j Y_{t-j} + \varepsilon_t \quad (1)$$

$$Y_t = d + \sum_{j=1}^{k} \gamma_j X_{t-j} + \sum_{j=1}^{k} \delta_j Y_{t-j} + \mu_t \quad (2)$$

where c and d are constant terms, ε_t and μ_t are two uncorrelated white noise error terms.

The F-tests are used for testing the existence of causality. Let $H_0^1: \gamma_1 = \gamma_2 = \ldots = \gamma_k = 0$ and $H_0^2: \beta_1 = \beta_2 = \ldots = \beta_k = 0$. In general, hypothesis tests can result in four possible outcomes that are as follows:

(1) X causes Y but Y does not cause X, meaning that unidirectional causality runs from X to Y, if H_0^1 can be rejected but H_0^2 is not rejected.

(2) Y causes X but X does not cause Y, meaning that unidirectional causality runs from Y to X, if H_0^1 is not rejected but H_0^2 can be rejected.

(3) There is bi-directional causality (or 'feedback') between X and Y if both H_0^1 and H_0^2 are rejected.

(4) X and Y are independent, meaning that causality runs neither from X to Y nor from Y to X, though the variables appear to be correlated, if neither H_0^1 nor H_0^2 is rejected.

Before continuing to make progress, it is necessary to examine some caveats of the Granger causality test. It is very sensitive to the methods employed in dealing with any non-stationary time series and the choice of lag structures [29]. First, a check is conducted with unit root tests such as the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test whether time series are stationary or not. When the time series are stationary, equation (1) and (2) can be simply used to analyze Granger causality. Otherwise, other methods employed in dealing with any non-stationary series have to be used because the theory behind autoregressive-moving average (ARMA) estimation, which is the base of equation (1) and (2), is based on stationary series [28].

Second, one has to decide the appropriate lag structures. Standard practice calls for selecting the lag structure that maximizes the adjusted R^2 or minimizes the Akaike Information Criterion (AIC) [27]. Specifically, one selects the maximal lag that X can affect Y, and estimates all regressions, so varying the size of the lag within the maximum lag; then selects the best lag structure for Granger causality with the highest adjusted R^2 or the lowest AIC among regression models.

If IT investment (ITI) and GDP substitute for X and Y, respectively, equation (1) and (2) can be written:

$$ITI_t = c + \sum_{j=1}^{k} \alpha_j ITI_{t-j} + \sum_{j=1}^{k} \beta_j GDP_{t-j} + \varepsilon_t \quad (3)$$

$$GDP_t = d + \sum_{j=1}^{k} \gamma_j ITI_{t-j} + \sum_{j=1}^{k} \delta_j GDP_{t-j} + \mu_t \quad (4)$$

where c and d are constant terms, ε_t and μ_t are two uncorrelated white noise error terms.

The Granger causality test in this paper employs 41 years of annual data from 1961 to 2001 on *real* GDP (GDP in billions of chained 1996 dollars) and *real* OCAM [1] (office, computing and accounting machinery) from the United States.[2] The data are obtained from the U.S. Bureau of Economic Analysis (BEA) National Income and Product Account (NIPA) Tables.[3] Real GDP and real OCAM[4] are used as operational definitions of economic performance and IT investment at the country level, respectively.

Results

Based on the ADF test with a null hypothesis of non-stationary series, GDP is non-stationary at its level, while IT investment is stationary at its level (See Table 1 reported by EViews 4.0 [28]). Both GDP and IT investment are stationary at the first difference at the one per cent significance level. The PP test also provides similar results. For the first differences of all time series this causality test between IT investment growth and GDP growth can go further with equation (3) and (4).

Table 1 – Unit root tests

Variables	Augmented Dickey-Fuller (ADF)	Phillips-Perron (PP)
ITI	-8.399**	1.534
ITI growth	-5.254**	-2.147*
GDP	-1.098	-0.338
GDP growth	-4.322**	-4.294**

Notes: ** means statistically significant at the 1% level, and * means significant at the 5% level. Both are based on MacKinnon critical values.

The maximal lag length varies among previous studies. Francalanci and Galal [14] used four years, Shafer and Byrd [30] took three years, and Hu and Plant [19] used two years. BEA assumes that the life of computer hardware is seven years [31], so the maximal lag is six years. Based on compromise on various maximal lag lengths in previous literature, this study decided that the maximal lag length would be five years (k=5).

Table 2 – Tests of causality between IT investment growth and GDP growth

Null Hypothesis	Lag	F-Statistic	Probability	Adjusted R^2	AIC
H_0^1: GDP growth does not Granger cause IT investment growth.	1	0.04	0.834	.598	7.285
	2	2.24	0.122	.838	6.448
	3	1.73	0.182	.837	6.523
	4	0.97	0.438	.854	6.472
	<u>5</u>	<u>1.38</u>	0.268	.878	6.358
H_0^2: IT investment growth does not Granger cause GDP growth.	1	0.59	0.449	.670	11.773
	2	10.29**	0.000	.788	11.348
	3	6.84**	0.001	.795	11.333
	4	5.65**	0.002	.791	11.367
	<u>5</u>	<u>5.11</u>**	0.002	.802	11.325

Note: ** means statistically significant at the 1% level.

The F-statistics of the Granger causality tests are summarized in Table 2. To reject the null hypothesis (H_0^1 or H_0^2) that the Granger causality test has non-causation, higher values for the F-statistics than critical values are required. The null hypothesis that GDP growth does not Granger cause IT investment growth (H_0^1) cannot be rejected in all lags because F-statistics in all lags are not statistically significant. For the highest adjusted R^2 or the lowest AIC selected lag length (lag=5, underlined in Table 2), the F-statistic is not statistically significant (F=1.38, p=0.268). Hence, Granger causality from GDP growth to IT

[1] Real OCAM is acquired from current OCAM divided by OCAM price index.

[2] Information technology can be defined in various ways [6]. Some researchers consider specifically the BEA's category: Office, Computing and Accounting Machinery (OCAM) for computer capital, while others treat the BEA's broader category: Information Processing Equipment (IPE). Broadly, software and related services are sometimes included in the IT investment. As suggested by Brynjolfsson [3], this paper considers narrowly the OCAM category as operational definitions of IT investment; so computers and peripheral equipment, and office and account equipment subcategory are included in the IT investment data set.

[3] It is possible to get real GDP from Table 1.2 in NIPA tables, current OCAM from Table 5.8, and price indexes from Table 7.8.

[4] From this point either GDP or IT investment is used as real GDP or real IT investment, respectively.

investment growth cannot be found in the sample period.
An additional null hypothesis of non-causality from IT investment growth to GDP growth (H_0^2) is rejected with F=5.11 at the one per cent significance level for the adjusted R^2 or the AIC selected lag length (lag=5). In fact, for others, except one lag model (F=0.59, p=0.449), the null hypotheses that IT investment growth does not Granger cause GDP growth are rejected at the one per cent significance level. In conclusion, this result shows that IT investment growth affects and causes economic performance growth.

Concluding remarks

The Granger causality tests show that IT investment growth causes GDP growth, but is not caused by GDP growth. These results add new evidence, which supports previous empirical studies and the neo-classical growth theory, on the significant effect of IT investment on economic performance. In addition, IT investment growth can affect economic performance growth over long time (e.g., six years) because the lag length of the highest adjusted R^2 or the lowest AIC model is five years.
The application of the Granger causality test with country-level IT investment used in this paper contributes to the academic knowledge stock. First, this paper added the country-level empirical study in the IS literature about the effectiveness of IT investment. Just few empirical studies (e.g., [11, 12]) have analyzed at the country level due to difficulty of rich data gathering for using appropriate statistical methods. Second, it is difficult to find an application of Granger causality tests in IS literature. Using various methods for the same issue can solidify generalization of empirical findings from previous studies. Third, the important question [1, 4] regarding the direction of causality between IT investment and output may be suitably explained by these findings. There was no evidence of reverse causality that some authors asserted. Finally, this article studied the relationship between IT investment and output considering time lags, which is suggested by Dedrick, Gurbaxani, and Kraemer [8], between causes and results. These results show indirectly that not only an instant effect of IT investment on output but also longer (at least, five years) lagged effects of IT investment should be considered. As a result, this study suggests that policy makers need to make proposals to stimulate additional continuous IT investment so firms or countries might gain sustaining output growth.
In further study, it would be necessary to analyze the data from other countries (whether developed or developing countries) for generalization of this analysis. Furthermore, not country-level data (such as GDP) but firm-level data (especially, firm financial performance that is suggested by Dedrick et al. [8] as one of opportunities for future research) needs to be analyzed so that decision-makers in firms can decide on appropriate IT investment. Because of difficulties associated with collecting sufficient long time series of firm-level data to perform Granger causality test, not ordinary least squares (OLS) but other methods being used to analyze panel data will be needed.

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Appendix

Table A – Real IT investment and real GDP

(Unit: Billion Dollars)

Year	Real IT investment	Real GDP	Year	Real IT investment	Real GDP
1961	1.7	545.7	1982	8.3	3,259.2
1962	1.6	586.5	1983	12.8	3,534.9
1963	1.6	618.7	1984	16.3	3,932.7
1964	1.5	664.4	1985	17.6	4,213.0
1965	1.7	720.1	1986	19.7	4,452.9
1966	2.1	789.3	1987	17.7	4,742.5
1967	2.0	834.1	1988	18.4	5,108.3
1968	2.0	911.5	1989	21.3	5,489.1
1969	2.2	985.3	1990	20.0	5,803.2
1970	1.9	1,039.7	1991	20.8	5,986.2
1971	1.7	1,128.6	1992	27.2	6,318.9
1972	2.0	1,240.4	1993	33.4	6,642.3
1973	3.0	1,385.5	1994	39.6	7,054.3
1974	3.8	1,501.0	1995	56.6	7,400.5
1975	3.2	1,635.2	1996	78.7	7,813.2
1976	3.8	1,823.9	1997	110.9	8,318.4
1977	4.0	2,031.4	1998	155.8	8,781.5
1978	6.0	2,295.9	1999	214.4	9,274.3
1979	7.6	2,566.4	2000	253.9	9,824.6
1980	8.6	2,795.6	2001	247.8	10,082.2
1981	9.6	3,131.3			

Sources: U.S. Bureau of Economic Analysis