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ESSAYS ON INTERNATIONAL RESEARCH AND DEVELOPMENT SPILLOVERS

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ESSAYS ON INTERNATIONAL RESEARCH AND DEVELOPMENT SPILLOVERS

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The dissertation consists of three essays on international research and development spillovers. In the first essay, I investigate the degree to which differences in institutional arrangements among Sub-Saharan African countries determine the extent of benefits they derive from foreign research and development spillovers. In particular, I compare the international research and development spillovers for English common law and French civil law Sub-Saharan African countries. I show that differences in the legal origin of the company law or commercial codes in these countries may reflect the extent of barriers they place in the paths of firms that engage in the investment process. To tests this hypothesis, I constructed foreign R&D spillovers variable using imports as weights and employed the endogenous growth framework to estimate elasticities of productivity with respect to foreign R&D spillovers for a sample of 17 English common law and French Civil law Sub-Saharan African countries over the period 1980-2004. My results find support for the hypothesis. In particular, foreign R&D spillovers were higher in the English common law countries than in the French civil law countries.

In the second essay, I examine the question of whether technical cooperation grants and overseas development assistance grants induce R&D knowledge spillovers in Sub-Saharan African countries. I test this hypothesis using data for 11 Sub-Saharan African countries over the period 1980-2004. I constructed foreign R&D spillovers using the technical cooperation grants and overseas development assistance grants as weights and employed the endogenous growth framework to provide quantitative estimates of foreign R&D spillover effects in 11 Sub-Saharan

African countries. I find that technical cooperation grants and overseas development assistance grants are major mechanisms through which returns to R&D investments in G7 countries flows to Sub-Saharan African countries. However, their influence has declined over the years.

Finally, the third essay tests the hypothesis that the relationship between a country's exporters and their foreign purchasing agents may lead to the exchange of ideas and thereby improve the manufacturing process and productivity in the exporting country. I test this hypothesis using disaggregated export data from OECD countries. The foreign R&D capital stock in this essay was constructed as exports weighted average of domestic R&D capital stock. I find empirical support for the hypothesis. In particular, capital goods exports generate more learning effects and therefore best explain productivity in OECD countries than non-capital goods exports.

DEDICATION

I dedicate this dissertation to my parents: Mpuan William Walley and Abena Njunibi

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INTRODUCTION

This dissertation consists of three essays on the relationship between productivity and foreign Research and Development (R&D) spillovers. The three essays employ the recent endogenous growth framework (Romer(1990), Grossman and Helpman(1991) and Aghion and Howitt(1992)) to provide estimates of the elasticity of productivity with respect to foreign R&D capital stocks in industrial countries through various mechanisms including imports, technical cooperation grants, overseas development grants and exports of goods and services. Interest in international R&D spillovers in developing countries stems from the fact that most of these countries invest little (if any) in research and development and thus rely heavily on the international knowledge pool to raise productivity and reduce poverty.

In particular, chapter one has two main objectives: first it provides extensive cross-country and time series evidence on the relationship between productivity in Sub-Saharan African countries and foreign R&D spillovers from OECD countries using an updated dataset on domestic R&D capital stock in OECD countries from 1980-2004. Chapter one also extends existing studies by examining the degree to which differences in institutional arrangements in Sub-Saharan African countries affect the process of knowledge accumulation and productivity. The empirical approach draws on the endogenous growth framework used by (Coe and Helpman (1995)) extended to reflect differences in the institutional arrangements within the context of Sub-Saharan Africa. Following (Coe and Helpman (1995)), I constructed the international R&D knowledge spillovers variable as trade weighted foreign R&D capital stock of major OECD countries.

My estimates suggest that spillovers to Sub-Saharan African countries are substantial. In particular, a 1% increase in domestic R&D capital stock in the major OECD countries will increase productivity in a Sub-Saharan African country by about 0.0011% on average. However, the extent of benefits from R&D capital developed in industrial countries declined in all countries in the sample over the period 1980-2004. In terms of the sources of R&D spillovers, the estimates suggest that the United States is the major source of spillovers in Sub-Saharan African countries. In particular, a 1% increase in domestic R&D spillovers in the United States raised productivity by an average of 0.0004% for all the 17 countries in the sample.

Finally, the legal origin of the company law or commercial codes of Sub-Saharan African countries affect the degree of knowledge spillovers. In particular, Sub-Saharan African countries that adopted the English common law legal system benefit more from the R&D spillovers than countries under the French civil law. More Specifically, a 1% increase in domestic R&D capital stock in OECD countries raised productivity for English common law countries by an average of 0.0015% compared to 0.0008% for French civil law countries from 1980-2004.

In the second essay, I explore two alternative channels of international R&D knowledge spillovers: technical cooperation grants and overseas development assistance grants. Specifically, the chapter examines the question of whether technical cooperation grants and overseas development assistance grants induce R&D knowledge spillovers in Sub-Saharan African countries. The empirical strategy consist in constructing technical cooperation grants and overseas development assistance grants weighted foreign R&D spillovers variable and including it in the endogenous framework that establishes a link between productivity and foreign R&D capital stock . A dynamic OLS econometric approach is then applied to the data to examine whether there is a relationship between productivity and R&D spillovers induced by technical cooperation grants and oversea development assistance grants.

I find that technical cooperation grants and overseas development assistance grants are major mechanisms through which returns to R&D investments in G7 countries flows to Sub-Saharan African countries. In particular, a 1% increase in domestic R&D capital stock in G7 countries leads to an average increase in productivity in all the 11 Sub-Saharan countries of 0.0021%, 0.0033% and 0.0044% through technical cooperation, overseas development assistance and imports respectively. This evidence thus supports the hypothesis that international R&D spillovers are also aid related. The evidence also showed that aid is effective in countries with good policies. Finally, aid-induced externalities are influenced by colonial linkages.

Finally, chapter three tests the hypothesis that the relationship between a country's exporters and their foreign purchasing agents may lead to the exchange of ideas and thereby improve the manufacturing process and productivity in the exporting country using disaggregated export data from OECD countries. The foreign R&D capital stock in this chapter was constructed as exports weighted average of domestic R&D capital stock.

This approach was first proposed by Funk (2001) as a way to emphasize the pure idea exchange between exporters and their foreign purchasing agents and how it improves the manufacturing process.

I find empirical support for the hypothesis that the relationship between exporters and their foreign purchasing agents may lead to the exchange of ideas that enhances the manufacturing process and thus raises domestic productivity. In particular, a one percent increase in bilateral exports weighted foreign R&D stocks results in about 0.0011% increase in domestic productivity. Similarly, a one percent increase in bilateral capital goods exports weighted foreign R&D stocks results in about 0.0028% increase in domestic productivity. Finally, a one percent increase in bilateral non-capital goods exports weighted foreign R&D stocks results in about 0.0018% increase in domestic productivity.

CHAPTER ONE: INTERNATIONAL R&D SPILLOVERS AND INSTITUTIONS IN SUB-SAHARAN AFRICA.

1.0 Introduction

The purpose of this study is to examine how import patterns and differences in institutional arrangements in Sub-Saharan African countries affect the process of knowledge accumulation and productivity. Theoretically, (Grossman and Helpman (1991, page 166)) suggest that "international trade in tangible commodities facilitates the exchange of intangible ideas". In particular, Grossman and Helpman, argue that, trade may increase contacts between domestic and foreign individuals leading to the exchange of technical information that may enhance knowledge accumulation and productivity. Second, local researchers may gain insights from inspecting and using new intermediates not available locally.

However, the empirical evidence is inconclusive and largely based on data from advanced countries[1]. For example, (Coe and Helpman(1995)) find in a study involving 21 OECD countries that international R&D spillovers are trade related. However, (Kao and Chiang (1999)) applied dynamic OLS estimation to Coe and Helpman's dataset and made this observation "…the DOLS estimates suggests that the impact of foreign R&D on total factor productivity is insignificant. Given the superiority of the Dynamic OLS (DOLS) over Fully Modified (FM) as suggested by Kao and Chiang, we lean to rejecting Coe and Helpman's hypothesis that international spillovers are trade related". Similarly, (Funk

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[1] Coe, Helpman and Hoffmaister (1997) studied the impact of R&D spillovers in 77 developing countries that included some Sub-Saharan African countries.

(2001)) found that when panel cointegration methods are used, there is no evidence that research spillovers among OECD countries are transmitted through imports.

Second, to the best of my knowledge, evidence on the role of institutions in explaining differences in foreign R&D spillovers in Sub-Saharan African countries is non-existent. For instance, (Coe, Helpman and Hoffmaister (1997)) studied the impact of R&D spillovers in 77 developing countries that included some Sub-Saharan African countries. However, their study did not examine the role of differences in institutional arrangements on R&D spillovers and productivity. Moreover, the study covered the period from 1971-1990. The present study extends their dataset from 1990-2004.

The first goal of this paper is to provide extensive cross-country and time series evidence on the relationship between productivity in Sub-Saharan African countries and foreign R&D spillovers from OECD countries using an updated dataset on domestic R&D capital stock in OECD countries from 1980-2004[2] . In particular, I provide estimates of the average elasticity of total factor productivity in each Sub-Saharan African country with respect to foreign R&D spillovers from the major OECD countries[3] using a panel data model. Such an analysis would provide empirical evidence and contribute to the broader debate about the existence of trade induced learning effects and whether such effects explain productivity over time. It would also enable me to compare spillovers before and after the introduction of the economic reforms in Sub-Saharan

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[2] I thank Coe, Helpman and Hoffmasiter for kindly making this dataset available to me.
[3] See appendix for the list of OECD countries included.

Africa in order to examine the impact of trade liberalization on spillovers while controlling for other potential factors that may affect spillovers and productivity.

Second, I also provide estimates of average elasticity of total factor productivity in a specific Sub-Saharan African country with respect to foreign R&D capital stock in each G7 country in order to shed some light on the major sources of foreign R&D spillovers for Sub-Saharan African countries. Such an analysis may have implications for trade policy[4]. Following (Coe and Helpman (1995), Lichenberg and van Potttelsberghe (1999), Kao and Chiang(1999)), I constructed two import weighted domestic R&D capital stock of the trade partners as proxies for knowledge spillovers and applied panel unit root and cointegration techniques to gain a better understanding of the long-run relationships between international R&D spillovers and productivity in Sub-Sahara African countries.

Panel cointegration approaches have gained wide acceptance partly because of their statistical power over their univariate counter-parts; Breitung and Pesaran (2005). In particular, co-integrated equations have the property of super-consistency. That is, as the number of observations increases, OLS estimates of co-integrating equations converge on the true parameter values faster than in the case where the variables are stationary, Stock (1987). Hence the parameters are robust to problems of endogeneity, omitted variable and measurement errors that plague most empirical work; (Banerjiee (1999), Phillips and Moon (2000), and Baltagi and Kao (2000)). My cross-country evidence is supportive of a

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[4] In particular, the G7 countries accounted for nearly 92% of R&D investments worldwide in 1992.

relationship between productivity in Sub-Saharan African countries and R&D spillovers from OECD countries. However, the effect of R&D spillovers on productivity has declined significantly over the last two decades in nearly all of the countries in the sample. The U.S is the major source of R&D spillovers for most countries in the sample.

The second goal of this paper is to examine the degree to which differences in institutional arrangements affects foreign R&D spillovers in Sub-Saharan African countries. Recent growth studies have emphasized the importance of institutions as a vehicle for productivity and growth in developing countries, (Acemoglu et al (2001), Hall and Jones (1999)). Sub-Saharan African countries inherited different sets of institutional arrangements reflecting the structure of the company laws or commercial codes of their former colonial masters. However, countries in the region differ in terms of progress made in reforming these institutions since independence and such differences may reflect the extent of barriers they place in the paths of firms that engage in the investment process. For example, (Parente and Prescott (1994)) constructed a variant of the neoclassical model in which investment promotes productivity but countries differ in terms of the barriers they place in the paths of firms that engage in this process.

In particular, cross-country empirical evidence suggests that the English common law countries provide more flexible investment environments for firms and entrepreneurs than do the French civil law countries, (La Porta et al (1999, 2008)). Such differences may be reflected in differences in the degree to which foreign R&D spillovers affect productivity in Sub-Saharan African countries. However, existing studies that examined the link between productivity and foreign R&D spillovers did not control for the role of institutions[5]. Following (Coe, Helpman and Hoffmaister (2008), La Porta et al (2008), Park(2001)), I proxy institutions with an index of patent protection and the legal origin of each country's commercial law or company codes. The evidence supports the hypothesis that institutional differences partly explain the degree of foreign R&D spillovers. In particular, foreign R&D spillovers were higher in the English common law Sub-Saharan African countries than the levels in the French civil law Sub-Saharan African countries. However, foreign R&D spillovers have declined for both English common law countries and French civil law countries over the last two decades.

The issues of knowledge spillovers are of significant importance in Sub-Saharan African countries because the countries in this region carry out little, if any, investment in R&D. Consequently, sustained economic growth and poverty reduction in the medium to long-term would depend on how much returns to R&D investments of the advanced industrialized countries spillover to Sub-Saharan African countries. In particular, the long periods of economic stagnation have led to widespread poverty and low living standards that requires decades of sustained growth to reverse. Therefore, policies that enhance spillovers in the medium to long-term would put Africa on the path to sustained growth and poverty reduction. In my estimation, I control for human capital and economic performance in OECD countries as reflected in GDP growth.

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[5] Coe, Helpman and Hoffmaister (2008) included an index of patent protection, a proxy variable representing the legal origin of the company law or commercial code of OECD countries, index of the quality of education and an index of the ease of doing business in a study involving 24 OECD countries over the period 1971-2004. Their results suggest that institutions are a major determinant of R&D spillovers in OECD countries.

The rest of paper is organized as follows: Section 1.2 reviews the existing literature on the relationship between trade and foreign R&D spillovers. Section 1.3 outlines the theoretical framework and model specification. Section 1.4 describes the data used in the study and trends in certain key indices of trade and growth in Sub-Saharan Africa. Section 1.5 discusses the empirical results. Concluding remarks are made in section 1.6.

1.2. Related Literature on Trade, Institutions and the Transmission of Knowledge

The question of whether integration through trade facilitates international knowledge spillovers was first analyzed empirically by (Coe and Helpman (1995)) for OECD countries and later extended to the context of developing countries by (Coe, Helpman and Hoffmaister (1997)). In both studies, the evidence showed that trade was an important vehicle for the transmission of knowledge embodied in capital goods. Extensions to Coe and Helpman's approach have taken three forms: alternative definition of foreign R&D spillovers, alternative channels of knowledge diffusion, and application of modern econometrics techniques such as panel unit root and cointegration techniques and more recently Fully modified OLS and dynamic OLS , (Coe and Helpman (1995), Kellar (1998), Xu and Wang (1999), Kao and Chiang (1999), Coe, Helpman and Hoffmaister (1997, 2008)).

Coe and Helpman(1995) defined foreign R&D capital stock as import -weighted domestic R&D capital stock of the trade partner. In order to test the robustness of Coe and Hepman's results, Keller (1999) constructed foreign R&D spillover variable based on randomly generated weights and found a link between productivity and the constructed foreign R&D capital stock. He therefore wondered whether the link between total factor productivity and international R&D can be attributed to the size of trade with advanced economies as suggested by Coe and Helpman.

Funk (2001) replaced the import weights with export weights in the construction of R&D spillovers. His approach is based on (Grossman and Helpman's (1991)) hypothesis that, local exports may lead to exchange of ideas between exporters and their foreign purchasing agents leading to knowledge accumulation that may enhance the manufacturing process. According to Funk, "using bilateral-exports weights removes the emphasis from knowledge acquired through direct, hands-on experience with imported intermediate inputs and places more emphasis on the pure idea exchange and knowledge spillovers gained from formal and informal contacts". Funk found the export-weighted foreign R&D capital stock performed better than the Import-weighted R&D capital stock.

Lichenberg and van Potttelsberghe (1999) criticized Coe and Helpman's approach as suffering from aggregation bias. They proposed an alternative approach which weights the domestic R&D capital stock of the advanced country by the fraction of imports in the advanced country's GDP and showed that this approach performs better than the Coe and Helpman's approach. Other alternative weights used include weights based on inward and outward FDI flows; (van Pottelsberghe and Lichtenberg (2001)), weights based on the bilateral technological proximity between countries, (Park (1995); Guellec and van Pottelsberghe (2004)); weights based on indirect trade (Lumenga-Neso *et al.* (2005)), and weights based on information technology (Zhu and Jeon (2007)).

The second set of extensions focused on alternative mechanisms of knowledge transfer and productivity. In particular, knowledge spillovers through foreign direct investment have received significant attention, (Markusen (2002), van Potttelsberghe and Lichenberg (1999). For example, Fosfuri, Motta and Ronde (2001)) observed that a multinational enterprise may serve a foreign market through either foreign direct investment or exports. If it chooses FDI, it must train host-country workers. However, both the Multinational Corporation and local firms can bid for the services of the worker. Therefore, knowledge spillover occurs if the local company wins the bid. However, the empirical evidence is mixed; (Lichenberg and van Potttelsberghe(1999). Zhu and Jeon(2007)).

More recent extensions applying advances in panel unit root and co-integration approaches have found less evidence to support the relationship between productivity and foreign R&D capital stock. In particular, (Kao and Chiang (1999)) re-visited Coe and Helpman's international R&D spillover regressions by using OLS, Fully Modified OLS (FM-OLS) and Dynamic OLS (DOLS) proposed by (Kao and Chiang (1999)). The results from these estimation methods support the existence of a linkage between domestic R&D capital stock and total factor productivity. However, the evidence did not support the link between foreign R&D capital stock and productivity. Similar outcomes were obtained by Funk (2001) using dynamic OLS estimation. In a recent study, (Coe, Helpman and Hoffmaister (2008)) re-visited their earlier paper by applying panel unit root and co-integration approaches. Their results confirmed earlier conclusions that there exists substantial knowledge spillover within the OECD block.

The review thus far shows a clear lack of consensus about the link between foreign R&D spillovers and productivity. The lack of consensus implies that further evidence is needed to shed more light about the existence of trade related international R&D spillovers. Moreover, the bulk of the evidence is based on the context of OECD countries. There is the need for more evidence involving north-south trade[6]. The focus on Sub-Saharan African countries in this study thus fills that gap in the literature. Second, existing studies fail to account for the impact of institutions on the link between foreign R&D spillovers and productivity. Differences in institutions may account for differences in the degree of benefits from R&D spillovers. Coe and Helpman (2008) include institutional variables such as the legal origin of the company law or commercial codes of countries, patent protection, ease of doing business index developed by the World Bank and the quality of tertiary education in order to allow for parameter heterogeneity based on a country's institutional characteristics. Coe, Helpman and Hoffmaister find that "institutional differences are important for total factor productivity in OECD countries and they impact the degree of R&D spillovers". That is, countries with better institutions may benefit more from R&D spillovers than other countries with less functional institutions. Therefore, ignoring institutions may lead to omitted variable bias.

However, the focus of the (Coe, Helpman and Hoffmaister (2008)) study was on OECD countries. There is therefore the need for evidence that controls for differences in

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[6] Coe, Helpman and Hoffmaister (1997) studied international R&D spillovers for 77 developing countries from 1971-1990. He found substantial spillovers in developing countries. Madden and Savage(2000) studied the role R&D plays in technology progress for a sample of OECD and Asian economies from 1980-1995.

institutions from developing countries. For instance, the structure of the company law or commercial codes differs across developing countries depending on a country's colonial past. In particular, there are two main types of laws: the English common law and the French civil law which has subsets such as the German civil law, the Scandinavian civil law and the socialist law among others. These laws may differ in terms of their effect on private investment. In particular, the laws of the English common law countries have been found to be associated with better investor protection, contractual enforcement and Financial development (La Porta et al(2008)).

La Porta et al (1999) use a sample of 49 countries to show that investor's rights and contractual enforcements are highest in countries under common law, intermediate in countries under German or Scandinavian civil law, and lowest in countries under French civil law. Second, English common law countries have better business regulations and better property -rights protection. Levine, Loayza and Beck (2000) show that countries under French civil law tend to have a lower degree of financial development than countries under the common law system. English common law countries have also been associated with efficient debt collection systems (Djankov et al (2003)) and less burden of entry regulations (Djankov et al (2002)). This evidence suggests that the laws of the English common law countries provide a more flexible business environment for firms and entrepreneurs than the French civil law countries. This study therefore explores the extent to which differences between the English common countries and the French civil law countries is reflected in differences in the degree of benefits from international R&D spillovers.

The differences between the common law and civil law traditions have both theoretical and historical explanations. Theoretically, the English common law is more decentralized, and is formed by appellate judges who establish precedents by solving specific legal disputes and can be more freely interpreted by judges. The French civil law on the other hand, is more centralized and relies on detailed written codes that have to be strictly followed by all judges (Merryman(1969)). Historically, the Common law was influenced by "landed aristocrats and merchants who wanted a system of law that would provide strong protections for property and contract rights, and limit the crown's ability to interfere in markets" (Mahoney (2001, p.504)). According to Mahoney(2001, p.505) the French civil law developed as it did because the revolutionary generation, and Napoleon after it, wished to use state power to alter property rights and attempted to insure that judges did not interfere. The problem with this hypothesis is that "it does not explain why France, which initiated the civil law system, performs much better than its colonial transplants" (Aghion and Howitt (2009, p. 240)). This study therefore controls for institutions by including patent protection and the legal origin in the regression equation. In the next section I explain the theoretical foundation of the empirical model and discuss the structure of the empirical model.

1.3 The Theoretical Framework

Until recently, quantifying the importance of spillovers to returns to R&D investment in other countries was nearly impossible partly because the basic underlying assumption of the existing neoclassical growth paradigm was that technological progress is exogenous (Coe, Helpman and Hoffmaister (2008)). The effect of technological progress on productivity and growth was often captured in growth studies by including a time trend or its square as one of the regression variables. The time trend variable however reflects not just changes in technology but other factors as well and is therefore not a suitable proxy for technological progress.

The development of endogenous growth models therefore provided a significant breakthrough in quantifying the importance of R&D spillovers on total factor productivity. Theoretically, endogenous growth models establish a link between growth in a country and international knowledge spillovers. The basic underlying assumption with these models is that technological progress is endogenous. In particular, these models view the process of innovation as endogenous in the sense that firms and entrepreneurs try to take advantage of profit incentives by investing in research and development. If the research and development is successful, the profits that accrue from the investment flows to the firm or entrepreneur usually for a specific period of time. Successful R&D investments may lead to the creation of new intermediate inputs or improve upon existing inputs thereby enhancing productivity of firms and the economy at large, (Romer (1990), Grossman and Helpman(1991), Aghion and Howitt (1992)). These intermediate inputs to a large extent embody the accumulated knowledge of the advanced industrialized countries.

Therefore, increased economic interaction through trade between R&D intensive countries and other countries may lead to knowledge gain through inspection and use of a variety of intermediate goods imported and through increased contacts and exchange of ideas and technical information thereby enhancing efficiency and productivity of firms in foreign country, (Coe and Helpman 1995)).

Since a country's R&D investment either expands the number of input varieties or improves and refines the qualities of existing inputs and techniques, it implies that endogenous growth models establish a link between R&D investment and total factor productivity. Previous studies such as (Coe and Helpman (1995), Keller (1999), Kao and Chiang (1999)) exploited this linkage to study the impact of R&D spillovers in OECD countries. In this section, I extend Coe and Helpman's approach to the context of Sub-Saharan Africa to provide evidence on the existence of trade related learning effects and the extent to which institutional differences explain differences in R&D spillovers.

In the next section, I explain the theoretical foundation of the empirical model as well as the extension of the Coe and Helpman's model to the context of Sub-Saharan African countries with different institutional arrangements.

1.3.1 The Empirical Model

The structure of the model in this section follows the approach of (Broda, Greensfield and Weinstein (2006), and Acemoglu (2009)) extended to reflect differences in institutions within the context of Sub-Saharan African countries. Specifically, consider a world consisting of J countries, indexed i=1, 2, 3, …, J. Suppose each economy consists of firms that combine capital, labor and intermediate inputs to produce a unique final good that is demanded for domestic use and by foreigners. The unique final good is produced competitively using the production function:

$$Y_t = \left(A_t L_t\right)^{1-\theta} D_t^{\theta} \quad 0 < \theta < 1, \tag{0.1}$$

Where L is total labor input, A is a constant which captures quality changes over time, D is the CES index of the intermediate inputs. Following (Dixit and Stiglitz (1977)), I specify D as follows:

$$D = \left[\int_0^{N(t)} x(j)^{\psi}\, dj\right]^{1/\psi}, \quad \psi > 1 \tag{0.2}$$

Where ψ measures the elasticity of substitution between inputs of variety j, N (t) denotes the different levels of varieties of inputs available to be used in the production process at time t. In a symmetric equilibrium, all produced inputs would bear the same price and manufacturers would employ equal quantities of each input.

That is, x(j)=x in equilibrium. Substituting x(j)=x into (0.2) and substituting the result into (0.1) yields:

$$Y(t) = \left(A_t L_t\right)^{1-\theta} (N(t) x^{\psi})^{\theta/\psi} \quad 0 < \theta < 1,\ \psi > 1 \tag{0.3}$$

Following (Broda, Greensfield and Weinstein (2006)), I assume that each intermediate input is produced one-for-one with capital. Since there are N(t) varieties of intermediates available to be used for production at time t, the total amount of capital K used in equilibrium would equal K=N(t).x. Plugging the K=N(t)x into (0.3) yields:

$$Y(t) = \left(A_t L_t\right)^{1-\theta} K_t^{\theta} N(t)^{(\frac{1-\psi}{\psi})\theta} \quad 0 < \theta < 1, \tag{0.4}$$

For each country, if we define total factor productivity as:

$$F = \frac{Y}{L^{1-\theta}K^{\theta}}, \quad 0 < \theta < 1 \tag{0.5}$$

then, we can express F as

$$F = A^{1-\theta}N^{(1-\psi/\psi)\theta}, \quad 0 < \theta < 1. \tag{0.6}$$

Equation (0.6) establishes a link between total factor productivity and the number of new inputs varieties available. That is, equation (0.6) suggests that, research and development may lead to the creation of different varieties of inputs, and the expanding varieties of inputs may raise the productivity of final good firms.

Coe and Helpman (1995) suggest that, an open economy may benefit from R&D investments made domestically as well as from foreign sources through trade. If we denote domestic R&D capital stock at time t=T as (S^d) and knowledge spillovers from other countries as (S^f), then, knowledge capital can be expressed as:

$$N(t) = S = (S^d)^{\delta_1}(S^f)^{\delta_2} \tag{0.7}$$

substituting(0.7) into equation (0.6) and taking logs of both sides yields

$$\log F_{it} = \eta_i + \delta_1 \log S_{it}^d + \delta_2 \log S_{it}^f \tag{0.8}$$

Equation (0.8) represents the baseline model used by (Coe and Helpman (1995)). I augment equation (0.8) with two institutions variables as follows:

$$\text{LogF}_{it} = \eta_{it} + \delta_{1t}\left[m_{it} \times \log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}FRD_{jt}\right)\right] +$$
$$\delta_{2t}\left[\text{patent} \times m_{it} \times \log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}FRD_{jt}\right)\right] + \Omega_{it}X_{it}$$
$$+\delta_{5t}\left[\text{comlaw} \times m_{it} \times \log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}FRD_{jt}\right)\right]$$
$$+\delta_{6t}\left[\text{civlaw} \times m_{it} \times \log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}FRD_{jt}\right)\right] + \varepsilon_{it} \tag{0.9}$$

where F is labor productivity, η captures both time effects reflecting the effects of exogenous technological changes over time and country-specific fixed effects. Patent is an index of patent protection, M is the bilateral imports of country i from trade partner j, FRD denotes foreign R&D capital stock, m_i is imports as a percentage of GDP, X consist of exogenous variables that explain productivity. Comlaw and Civlaw are dummy variables representing English common law countries and French civil law countries respectively.

Eaton and Kortum (2001), UNIDO (2005) have suggested that most of the world's capital is produced in a small number of R&D intensive advanced countries, while the rest of the world generally imports its equipment[7]. Second, even for developing countries that do invest in R&D capital stocks, only partial data are available. It is therefore difficult to measure the effects of domestic R&D effort on total factor productivity for the

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[7] Note that, the source of capital goods imports for most developing countries has shifted over the last 25 years. In particular, while 92% of capital goods imports in the 1980s originated in developed countries, this proportion fell to 59% by 2000-2005, due largely to Asian LDCs which sourced more than half of their capital goods imports from other developing countries; UNCTAD (2006).

countries in the sample. Consequently, I follow the approach of (Coe, Helpman and Hoffmaister(1997)) and assume that the effect of domestic R&D capital stocks on total factor productivity is sufficiently small that it can be ignored.

Among the variables captured in X are human capital and the log of first difference of population weighted GDP of OECD countries. The quality of the work force may affect productivity directly and also indirectly through its effect on foreign R&D spillovers. In particular, extracting the technology content of imported intermediates requires high level knowledge and skills. Therefore, a country endowed with a skilled work force may gain more from foreign R&D spillovers through trade than other countries with less endowed human capital. The population weighted GDP of OECD countries controls for movements in economic performance in the industrial countries that may influence exports and enhance productivity in developing countries.

I control for the role of institutions using two dummy variables: comlaw and civlaw representing English common law countries and French Civil law countries respectively. The hypothesis here is that, the common law countries provide more flexible investment environment for firms and entrepreneurs than do the French civil law countries. The second institution variable is patent protection. Patent protection may influence productivity directly and also indirectly through providing incentives to entrepreneurs to invest more resources in R&D in order to create more varieties of new and improved inputs which would ultimately enhance productivity, (Coe, Helpman and Hoffmaister(2008)). Finally, as a robustness check, I use two different definitions of foreign R&D spillovers proposed by (Coe and Helpman (1995)) and (Lichenberg and van Potttelsberghe (1999)). Both definitions are weighted averages of the domestic R&D capital stocks of the trade partner countries. However, they differ in the construction of the weights. Coe and Helpman use import shares as weights while Lichenberg and van Potttelsberghe use the ratio of imports to GDP of trade partners as weights.

Equation (0.9) differs from the (Coe, Helpman and Hoffmaister(1997)) baseline specification in three major ways: First, I control for institutions by including patent protection and dummy variables representing the legal origins of the company law or commercial codes of Sub-Saharan African countries. Second, I use two different definitions of foreign R&D spillovers. Third, the foreign R&D spillovers variable in my study was constructed using total import shares as weights due to data constraints. Coe et al (1997) used capital goods imports as weights which is more consistent with the theory.

1.4 Data

The empirical results are based on a pooled dataset for 17 Sub-Saharan African countries over the period 1971-2004. Table 1.1 summarizes the data for all countries in the sample. The definitions and sources of variables are provided in the appendix. Productivity defined here as GDP per worker varied widely for the countries in the sample. In particular, productivity was lower in 2004 when compared to the level in 1980 in 9 of the 17 Sub-Saharan African countries sampled. The decline was 40% or more in 4 of the 9 countries that recorded a decline in 2004. The most dramatic decline of roughly 80% was recorded in Democratic republic of Congo. This was due largely to the protracted armed conflict in the Congo DR over the last decades; although some other relatively stable countries such as Togo and Zambia also recorded significant declines averaging about 42%.

The overall increase or decrease in spillovers is sensitive to the definition of R&D spillovers. In particular, data on the foreign R&D capital stock variable based on the (Coe and Helpman (1995)) approach show a significant increase in spillovers in 2004 when compared to the level in 1980 for all countries in the sample. In most countries, the increase in 2004 was more than twice the level in 1980. This reflects the significant increase in imports since the foreign R&D capital stock for each Sub-Saharan African country was constructed as a weighted average of the domestic R&D capital stock of their OECD trade partners. The weights are based on total bilateral imports of goods and services from their OECD trade partners.

In contrast, with the exception of four countries: Gabon, Ghana, Senegal and Sudan, the level of foreign R&D capital stock based on the (Lichenberg and van Potttelsberghe (1999)) approach was lower in 2004 than in 1980. The difference between this definition and the definition based on the Coe and Helpman approach stems from the manner in which the weights are computed. In the approach based on (Lichenberg and van Potttelsberghe (1999)) the weights are based on the ratio of total bilateral imports to the GDP of the trade partner.

The idea is that the more one imports intermediate inputs from a trade partner the greater the chances of learning new ideas and knowledge to enhance productivity. However, there has been a significant decline in the share of intermediates imported from OECD countries due to rising south-south trade and that may explain the decline in 2004 R&D spillovers, (UNCTAD (2006)).

Similar trends are also revealed in the ratio of imports to GDP in developing countries. With the exception of Gabon and Ghana, imports from OECD countries as a ratio of GDP in 2004 was lower in all the remaining 15 countries than the levels in 1980. Thus, although imports may have increased under the economic recovery reforms, the source of such imports has changed dramatically from OECD countries to developing countries. Nearly 92% of imports of developing countries were sourced from OECD countries in 1992. However, this fraction declined to 59% by 2000-2005.

Although secondary school enrollment increased in all countries in 2004 when compared with the level in 1980, enrollment rates are still very low with most countries having rates below 50%. Enrollment rates also show some much needed variation ranging between 10% in Niger and 50% in Gabon. Finally, index of patent protection improved in all countries in 2004 compared with the levels in 1980.

Table 1.1: Summary Statistics

Country	GDP Per Worker (F)	R&D Spillover (CH)	R&D Spillover (LP)	Ratio of imports to GDP		Secondary Enrolment (%)		Index of Patent Protection (1-5)	
	$\frac{F_{2004}}{F_{1980}}$	$\frac{S_{2004}}{S_{1980}}$	$\frac{S_{2004}}{S_{1980}}$	1980	2004	1980	2004	1980	2004
Benin	1.10	3.24	0.92	0.15	0.09	12	32	1.70	2.93
Burundi	0.83	3.01	0.46	0.07	0.07	2	13	2.08	2.15
Cameroon	1.42	2.61	0.58	0.18	0.07	8	27	1.58	3.06
Congo DR	0.21	2.52	0.55	0.03	0.06	9	22	1.38	2.23
Côte d'Ivoire	0.97	2.85	0.71	0.20	0.16	9	22	1.58	3.06
Gabon	1.00	2.28	1.08	0.14	0.16	15	50	1.58	3.06
Gambia	0.93	2.48	0.93	0.39	0.36	12	45	-	-
Ghana	1.12	2.14	1.56	0.15	0.21	40	43	1.38	3.35
Kenya	1.02	3.30	0.62	0.19	0.09	9	48	1.38	3.22
Malawi	1.69	3.14	0.40	0.05	0.03	4	28	1.29	2.15
Niger	0.97	2.42	0.36	0.32	0.08	4	10	1.70	2.93
Senegal	0.95	2.35	1.28	0.01	0.01	10	22	1.58	2.93
Togo	0.53	3.28	0.38	0.10	0.03	31	40	1.70	2.93
Sudan	1.57	4.77	2.78	0.67	0.44	7	33	-	2.61
Uganda	1.15	3.14	0.68	0.01	0.02	4	18	1.71	2.98
Zambia	0.60	2.10	0.53	0.43	0.06	13	30	1.54	1.94
Zimbabwe	0.42	2.37	0.22	0.16	0.05	8	40	1.74	2.60
Average	0.97	2.82	0.83	0.19	0.12	11.59	30.76	1.59	2.76
Standard deviation	0.39	0.65	0.61	0.17	0.12	9.79	12.14	0.20	0.43

Spillover CH denotes the foreign R&D capital stock weighted by the share of imports proposed by Coe and Helpman's definition. Spillover LP denotes the foreign R&D capital stock weighted by the ratio of the imports of a Sub-Saharan African country i to the GDP of its trade partner proposed by Lichtenberg and van Pottelsberghe (1998). Numbers in parenthesis are p-values. Patent Protection is an index which range from 1 (low) to 5 from Park (2005). S denotes R&D Spillovers. The secondary school enrolment is used as a proxy for Human capital. It is defined as the ratio of secondary school enrolment to Secondary-School –Age Population.

1.4.1 Trends in Trade in Sub-Saharan Africa

Figure 1 depicts the percentage change in the volume of imports and exports of goods and services over the period 1980-2004. As the graphs indicate, the percentage change in both imports and exports declined prior to 1984 before rising sharply after 1984. Most Sub-Saharan African countries started the implementation of the first phase of the structural adjustment programs by mid 1980s[8]. Both import and export volumes growth has remained relatively stable and positive. The picture for terms- of -trade is slightly different. After declining sharply during the early 1980s, terms of trade growth has remained relatively volatile averaging about zero percent.

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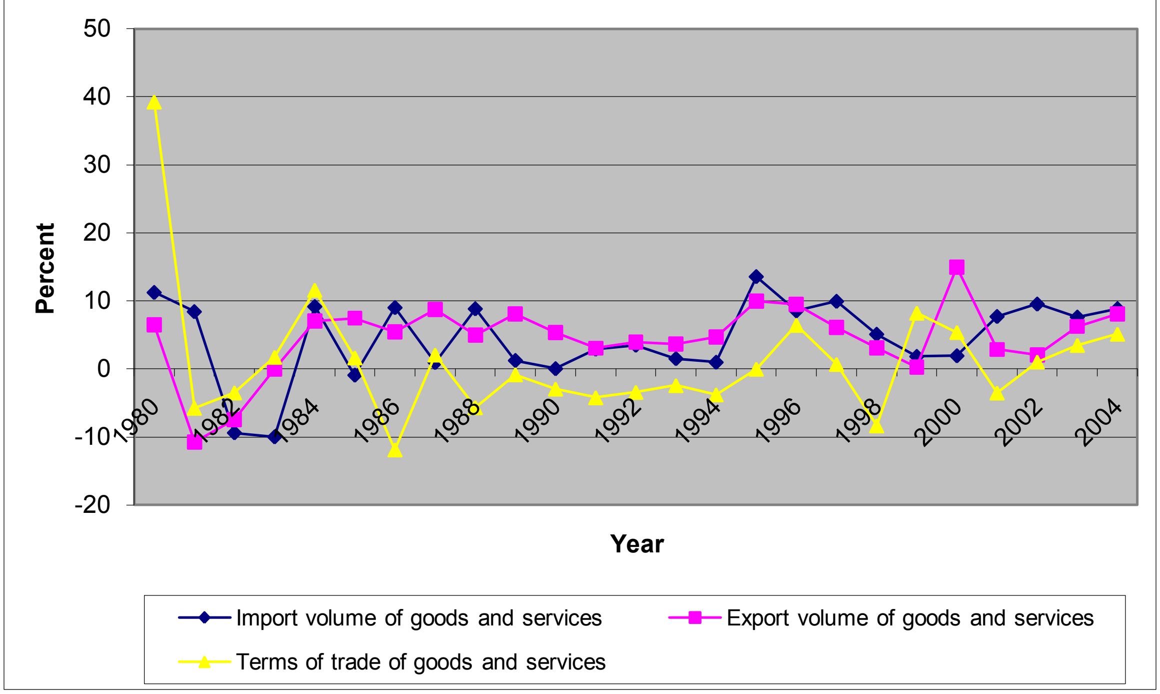
[8] See Appendix for the start dates for phase 1 and phase 2 of the structural adjustment program.

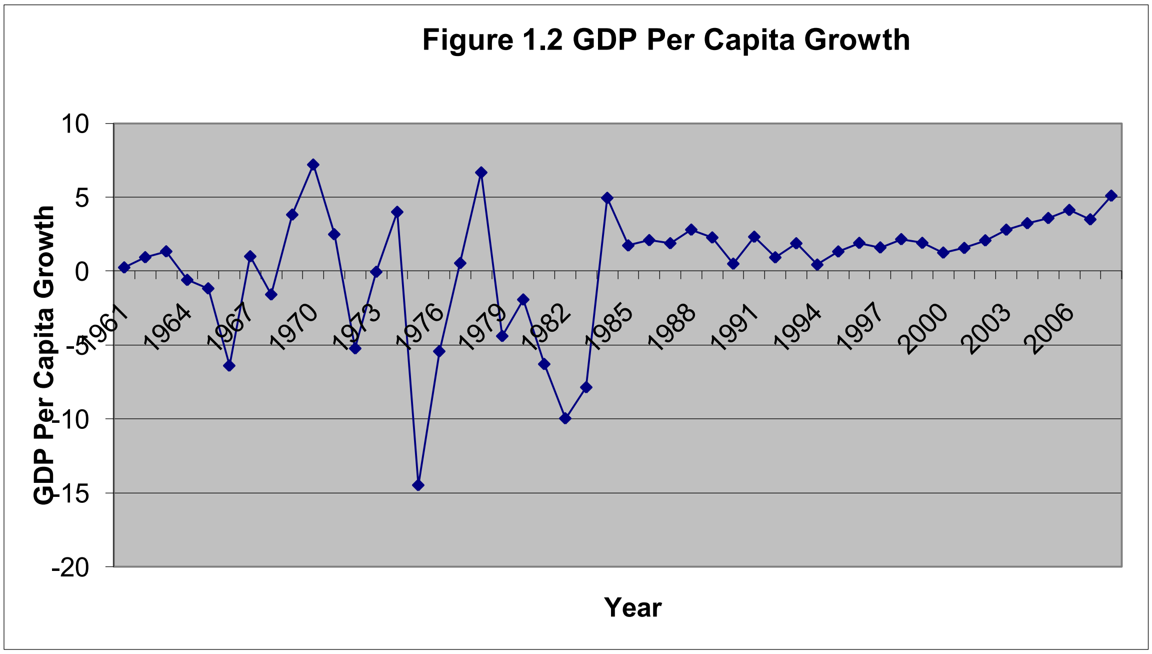
Figure 1.1 Trends in Trade Indices For Sub-Saharan Africa



The study examines how trade over the last two decades affected R&D spillovers.

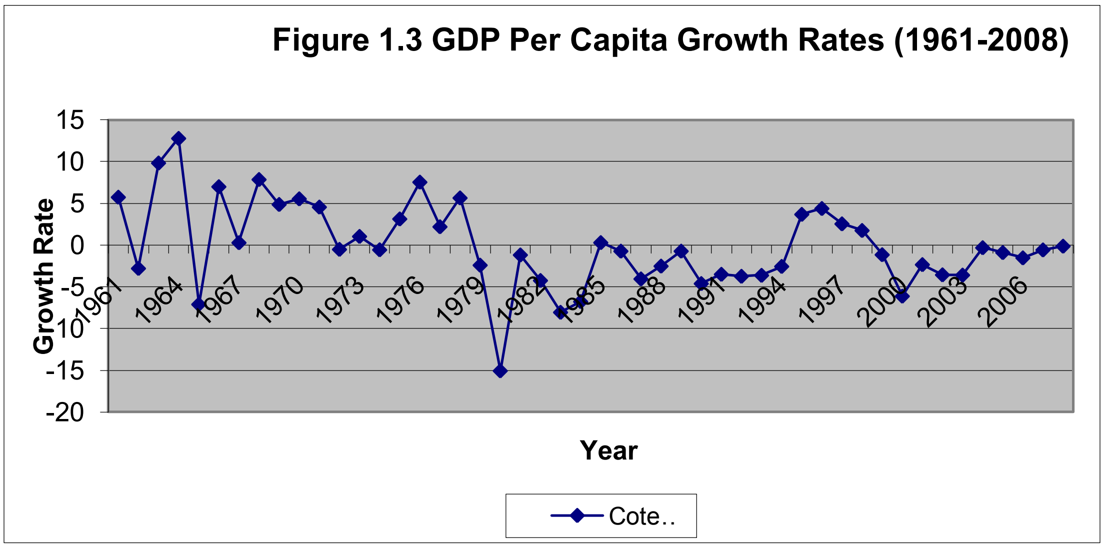
1.4.2 Trends in GDP growth in Sub-Saharan Africa

Economic growth in Sub-Saharan Africa has been characterized by periods of low and volatile growth and periods of economic stagnation. GDP per capita growth for Su-Saharan African countries average 2% per annum between 1960 and mid 1970s before stagnating in the late 1970s and early 1980s. Since the introduction of economic reforms in the mid 1980s however, several Sub-Saharan African countries have recorded positive growth rates. There are also significant disparities in growth at the individual country levels. According to (Fosu (2010)), some SSA countries that were considered growth laggards in the 1960s have become growth leaders in recent years. For example, figure 1 shows Ghana's GDP per capita growth from 1961-2008. The growth rate was negative and highly volatile for several years between 1961 and 1984. However, after the introduction of the structural adjustment reforms, Ghana has recorded positive growth reaching about 5% by 2008.



Source: Data for Figure 1 was obtained from the World Development Indicators Database

On the other hand, other countries that were considered growth leaders have become growth laggards. For example, figure 1.2 shows GDP per capita growth rate of Cote d'voire from 1961-2008. Cote d'Ivoire was considered one of Africa's growth leaders in the 1960s. However, in the last decade its GDP per capital growth rate has declined. Some of these countries were affected by domestic violence mostly from election related disputes such as the case of Cote d'Ivoire. On the other hand, others still performed poorly despite the absence of conflict or political instability. Some explanations offered in the growth literature include differences in institutions, differences in human capital, the location of the country (i.e whether land locked or coastal), terms of trade and oil price shocks. However, the recent oil price shocks did not appear to have affected Sub-Saharan African countries in any significant way.



Source: Data for Figure 1 was obtained from the World Development Indicators Database

1.5 Empirical Results

1.5.1 Panel Unit Root Tests Results

In this section I discuss the empirical results of the study. My first interest is to provide evidence about the existence of trade induced learning effects and the extent to which it explains productivity in Sub-Saharan African countries. Second, I examine the extent to which differences in institutional arrangements explain why some Sub-Saharan African countries benefit more from R&D spillovers than others. Since, my interest is to study the long-run relationship between productivity and foreign R&D spillovers while controlling for human capital and institutions, I first examined the unit root properties of the variables in the sample in order to avoid estimating a spurious regression.

The time series literature suggest that if the variables in the model are all unit root or I(1), then they may have a long-run relationship. On the other hand, if some variables are stationary while others are non-stationary, then care must be taken to avoid estimating a spurious regression and producing misleading conclusions. Table 1.2 reports the results of panel unit root tests using tests proposed by Levin, Lin & Chu (2002) and Im, Pesaran and Shin (2003). The null hypothesis in both tests is that the variable is stationary after first difference (has a unit root). However, the Levine, Lin and Chu t-test assumes common unit root process. That is, the coefficient on the lagged level of the dependent variable is (i.e rho) is treated as common across countries while the Im, Pesaran and Shin (2003) W-test treats rho as heterogeneous among countries[9].

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[9] Interested readers should consult Kao and Chiang (1999) for a review.

Table 1.2: Panel Unit Root Test Results

Variable	Levin, Lin & Chu t Test	Im, Pesaran and Shin Test
Log(GDP Per Worker)	-0.60128 (0.274)	0.465 (0.679)
Log(Spillover1)	-1.628 (0.052)	1.050 (0.853)
Log(Spillover2)	1.953 (0.025)	-1.435 (0.076)
Ratio of imports to GDP	-5.850 (0.000)	-4.718 (0.000)
Human Capital	2.886 (0.998)	4.553 (1.000)
Patent Protection	14.917 (1.000)	21.758 (1.000)

Spillover 1 denotes the foreign R&D capital stock based on Coe and Helpman's definition. Spillover 2 denotes the foreign R&D capital stock based on LP's definition. Numbers in parenthesis are p-values. Patent Protection is an index which range from 1 (low) to 5. The null hypothesis of unit root is rejected if the test statistics is significant.

The results in table 1.2 show that R&D spillovers based on the definition proposed by (Lichenberg and van Potttelsberghe (1999)) and total imports as a ratio of GDP are stationary while the GDP per worker, the bilateral import weighted foreign R&D spillover proposed by Coe and Helpman, Human capital and index of patent protection are strictly unit root (un-stationary)[10]. Panel unit root tests of the first difference of all variables indicated stationarity of all first differenced variables. Results of co-integration test on the levels of the variables were mixed. Therefore, in order to avoid estimating a spurious regression and potentially reaching misleading conclusions, I decided to estimate a panel regression of equation (0.9) in first difference.

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[10] All the variables were, however, stationary in first difference.

1.5.2 R&D Spillovers and Productivity in Sub-Saharan Africa.

Table 1.3 reports the results of equation (0.9) for a pooled sample of 17 Sub-Saharan African countries from 1980-2004. As a robustness check, I report results for both definitions of foreign R&D spillovers discussed earlier. That is, the import weighted foreign R&D spillovers variable proposed by (Coe and Helpman (1995)) and the definition proposed by (Lichenberg and van Potttelsberghe(1999)). All regressions were estimated in first differences[11] while controlling for human capital[12]. Column (CH) of table 1.3 reports results based on (Coe and Helpman (1995)) definition of foreign R&D spillovers. In order to make the knowledge spillover variable more reflective of the import intensity of a country, foreign R&D capital stock variable is often interacted with the ratio of imports to GDP in the literature. I followed that convention in this study.

The coefficient of the foreign R&D spillover in column (CH) is positive and significant as expected. This implies that, for a given level of imports as a percentage of GDP, an increase in the R&D capital stock of a trade partner by 1% would increase the productivity of a Sub-Saharan country by 0.006% on average in all the countries in the sample. Capital stock defined as the secondary school enrollment also has the right sign and is different than zero, implying that improvement in the quality of the work force

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[11] I also performed panel co-integration test on specification (1.9). The results were mixed. Second, since some of the variables were stationary while others were non-stationary and in order to avoid spurious regression results, I estimate specification (1.9) in first difference.

[12] I performed an endogeneity test using the Granger Causality test by regressing the first difference of each of the independent variables on four lags of the dependent variable. This is an F-test on the joint significance of the of the lagged values of the first difference of the dependent variable. The estimated coefficients were insignificant which is consistent with the independent variables being strictly exogenous.

would enhance productivity in Sub-Saharan African countries. The results are thus consistent with results of (Coe, Helpman and Hoffmaister(1997)) who found a link between foreign R&D capital stock and human capital as important determinants of productivity in a sample of 77 developing countries. The results are also consistent with the results of (Coe and Helpman(1995), and Coe, Helpman and Hoffmaister (2008)) who found similar results for OECD countries.

Column (LP) reports results of specification (0.9) based on Lichenberg and van Potttelsberghe's(LP) definition of foreign R&D capital stock. The difference between this definition and that of CH is mainly based on the differences in the weights used. The CH uses the share of bilateral imports as weights while the LP uses the ratio of imports to the GDP of the trade partner as weights. In both cases, the important point is that, the degree to which foreign R&D spillovers affects productivity depends largely on the intensity of imports of intermediate inputs from the trade partner. The results using this alternative definition of foreign R&D spillovers is also consistent with the hypothesis that international R&D spillovers are trade related. The coefficients of 0.006 and 0.011 for both definitions are consistent with coefficients obtained in similar studies for OECD countries and Coe, Helpman and Hoffmaister's study for developing countries.

Table 1.3: The Effect of Alternative Foreign R&D Capital Stock on Total Factor Productivity in Sub-Saharan Africa Countries (pooled data, 1980-2004, 17 Countries)

	(CH)	(LP)	(CH&LP)
Δ(m_i. log Spillover CH)	0.006 (3.081)		0.048 (2.190)
Δ(m_i. log Spillover LP)		0.011 (2.427)	-0.075 (-1.782)
Δ(log Human cap)	0.131 (1.898)	0.130 (1.884)	0.155 (3.804)
Fixed Effects	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes
R^2	**0.12**	**0.12**	**0.10**
Standard error	**0.038**	**0.038**	**0.038**
F Test	**2.098*** **	**2.082*** **	**1.86***
Pooled Observations	**323**	**323**	**340**

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. Spillover (LP) denotes foreign R&D capital stock using the ratio of bilateral imports of adeveloping country i to the GDP of its trade partner j as weights. Spillover (CH) denotes foreign R&D capital stock using the bilateral imports shares of developing countries in the sample as weights. Human Cap denotes human capital. All regressions include unreported country fixed effects.

The CH uses the share of bilateral imports as weights while the LP uses the ratio of imports to the GDP of the trade partner as weights. In both cases, the important point is that, the degree to which foreign R&D spillovers affects productivity depends largely on the intensity of imports of intermediate inputs from the trade partner. The results using this alternative definition of foreign R&D spillovers is also consistent with the hypothesis that international R&D spillovers are trade related. The coefficients of 0.006 and 0.011 for both definitions are consistent with coefficients obtained in similar studies for OECD countries and Coe, Helpman and Hoffmaister's study for developing countries.

The last column in table 1.3 reports results based on the alternative definitions of foreign R&D capital stock. The LP foreign R&D capital stock variable is significant at the 10% level but has the wrong sign. The CH variable has the right sign and different than zero. Similar results were obtained by (Coe, Helpman and Hoffmaiaster (2008)) for OECD countries. This may imply the existence of multi-collinearity between the two variables. Coe, Helpman and Hoffmaister interpreted this to mean that the CH definition of foreign R&D capital stock performs better than the LP definition of R&D capital stock. In the next section, I discuss results of my preferred specification which controls for both human capital and institutions and also discuss the estimates of average elasticities of productivity with respect to foreign R&D spillovers.

1.5.3 Trade, Institutions and International R&D Spillovers

Table 1.4 reports the results of panel data estimation of equation (9). The first column is my preferred specification which also includes patent protection which is used as a proxy for institutions. The coefficient of foreign R&D spillovers is still positive and significantly different than zero suggesting that foreign R&D spillovers in Sub-Saharan African countries are trade related. The coefficient is also slightly larger compared with earlier estimates that did not control for patent protection although patent protection is not significantly from zero.

The column labeled legal origin controls for the legal origin of the company law or the commercial codes of a country. In particular, (La Porta et al (2008)) document that:

(1) some countries offer more legal protection of outside investors' interests than others. (2) legal rules protecting investors vary systematically among legal traditions or origins with the laws of common law countries (originating in English law) being more protective of outside investors than laws of civil law (originating in Roman law) and particularly French civil law countries. (3) Legal investor protection is a strong predictor of financial development. The implication is that, countries with different company law or commercial codes may offer different degrees of investor protection, which could be reflected in the estimated coefficient on the R&D capital; (Coe, Helpman and Hoffmaister(2008)).

Institutional barriers may for example increases transaction costs and adversely affect imports of intermediate and capital goods. Since the accumulated knowledge of the developed countries are embodied in the intermediate and capital goods, the implication is that, countries with significant barriers to trade may reduce the amount of spillovers from foreign R&D capital stock through higher transaction cost.

To test this hypothesis, I first proxied institutions with the legal origin of the company law or commercial codes of developing countries in the sample. In particular, dummy variables representing countries operating under the English and French legal systems were interacted with the foreign R&D capital stock. The German, Socialist and Scandinavian legal systems were ignored because no countries in my sample had these legal systems.

Table 1.4: Total Factor Productivity, Institutions and Foreign R&D Spillovers in Sub-Saharan African Countries (Dynamic OLS, 1980-2004, 17 Countries)

	Base Model	**Legal Origin**	**Pre & Post SAP**	**Patent Protection**
Δ(m_i. log Spillover CH)	0.008 (4.543)			0.024 (2.747)
Δ(log Human cap)	0.137 (3.660)	0.129 (2.550)	0.126 (2.659)	0.138 (3.701)
Δ(log Patent)	-0.008 (-0.978)	-0.005 (-0.511)		
Δ(logPatent × m_i Log (spillover CH)				-0.007 (1.860)
Civlaw × Δ(m_i. log spillover CH)		-0.007 (-0.678)		
Comlaw × Δ(m_i.log spillover CH)		0.006 (4.638)		
PRE-1990 × Δ(m_i.log spillover CH)			0.001 (0.275)	
POST-1990 × Δ(m_i.log spillover CH)			0.007 (1.979)	
Δ(log OECD GDP)	0.204 (1.714)			
R^2	**0.11**	**0.16**	**0.15**	**0.12**
Standard Error	**0.037**	**0.035**	**0.035**	**0.038**
F-Test	**1.7776***	**1.559***	**1.567***	**2.048****
Pooled Obs	**340**	**408**	**408**	**340**

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. Spillover (LP) denotes foreign R&D capital stock using the ratio of bilateral imports of a developing country i to the GDP of its trade partner j as weights. Spillover (CH) denotes foreign R&D capital stock using the bilateral imports shares of developing countries in the sample as weights. Human Cap denotes human capital. Patent denotes an index of patent protection from 1(low) to 5, French and English dummy variables representing French and English legal origins respectively. PRE-1990 and POST-1990 are dummy variables representing pre-structural adjustment period (1989 or earlier) and structural adjustment period (1990 or after). All regressions include unreported country fixed effects. SAP denotes structural Adjustment Program.

The results in column (2) of table 1.4 suggest that common law Sub-Saharan African countries benefit more from foreign R&D spillovers than French civil law Sub-Saharan African countries. The coefficient of the French civil law dummy variable interacted with Foreign R&D spillovers is negative and not significantly different than zero. The results are consistent with the conclusion of (Coe, Helpman and Hoffmaister(2008)) who found that countries with French and Scandinavian-based legal system benefit less than other countries from a given level of foreign R&D capital stock in OECD countries.

Prior to the introduction of the economic reforms in the mid 1980s to the early 1990s, most Sub-Saharan African countries pursued inward looking policies that were designed to protect local industries. As part of the economic recovery programs, Sub-Saharan African countries were required to liberalize trade and become integrated into the world economy. While integration may provide certain benefits such as access to the larger international markets and international knowledge pool through imports, FDI and licensing, it may also increase competition from foreign firms in the domestic economy and drive down profits, (Grossman and Helpman(1991)). One of the goals of this study was to compare R&D spillovers before and after the introduction of the reforms. The challenge is that countries in the region differ in terms of the timing of the reforms. However, most countries in my sample joined the reforms by late 1980s. Moreover, in most of these countries, actual implementation in the 1980s was either slow or was at an early stage, (World Bank (1999)). For these reasons, I defined two dummy variables representing pre-reform period (i.e before 1989) and post-reform period 1990-2004. I interacted the two dummy variables with the foreign R&D spillovers variable. The results of this hypothesis are reported in column (3) of table 1.4. The coefficient of the pre-reform variable had the right sign but was not different from zero. The coefficient of the Post 1990 dummy variable had the right sign and was also significantly different than zero. That is, spillovers are larger after the reforms. However, since imports declined over the last 25 years, the elasticities of productivity with respect to foreign R&D spillovers were rather higher in the 1980s than in the 1990s and 2000s.

Strong intellectual property rights protection may offer incentives for more investments in R&D and consequently lead to high productivity through access to new and improved inputs. Table 1.1 showed that all countries in the sample strengthened intellectual property rights between 1980 and 2004. In particular, the strength of intellectual property rights proxied by the index of patent protection among Sub-Saharan African countries increased on average from 1.59 in 1980 to 2.76 in 2004. The index ranges from 1 to 5, where 1 implies less stringent intellectual property rights protection. If patent laws are enforced, it may encourage more R&D investments and that may enhance spillovers and productivity of Sub-Saharan African countries that trade with the high technology countries. To test this hypothesis, I interacted the index of patent protection with the augmented foreign R&D spillovers variable in equation (9). The results are reported in column (4) of table 1.4. The results suggest that the effect of foreign R&D spillovers on productivity in Sub-Saharan African countries is smaller the stronger the intellectual property rights protection as reflected by patent protection. Finally, notice that the inclusion of the interaction terms increased the coefficient significantly and also raised the percentage of the variation in productivity explained by the explanatory variables. The results are consistent with the results of (Coe, Helpman and Hoffmaister(2008)) who arrived at similar conclusions.

Some have argued that productivity in Sub-Saharan Africa may have been boosted by growth of GDP in OECD countries that resulted in demand for exports from developing countries. Therefore, improvement in productivity may be the result of higher demand for exports from developing countries and not due to increases in foreign R&D spillovers due to trade liberalization. To test this theory, I controlled for the first difference of logarithm of weighted OECD GDP. The variable was significant and positive implying that economic performance in OECD countries as measured by GDP growth may indeed boost productivity in Sub-Sharan African countries. However, controlling for OECD GDP growth did not alter the link between foreign R&D spillovers and productivity in Sub-Saharan African countries.

1.5.4 Quantitative Assessment of R&D Spillovers in Sub-Saharan Africa

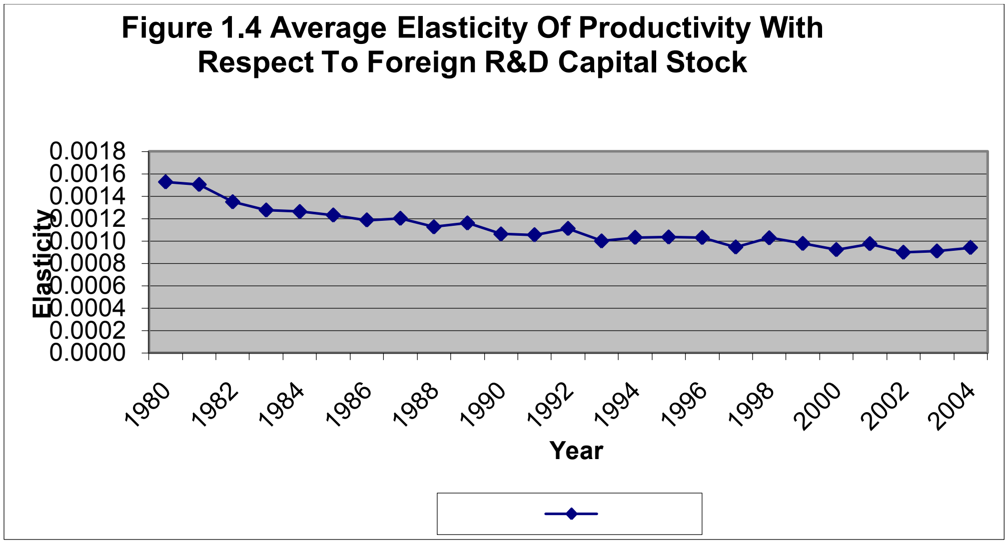
In this section I provide estimates of time varying average elasticity of productivity in Sub-Saharan African countries with respect to foreign R&D spillovers from OECD countries. The estimates are obtained by multiplying the coefficient of foreign R&D spillovers from column (1) of table 1.4 and the ratio of imports to GDP in each Sub-Saharan African country. The results from 1980-2004 are reported in Table 1.5. The results show that foreign R&D spillovers from OECD countries raised productivity in all the countries in the sample. For example, a 1% increase in domestic R&D capital stock in OECD countries raised productivity in Sub-Saharan African countries by an average of 0.0015% in 1980 and 0.0009% in 2004.

On average, a 1% increase in domestic R&D capital stock in OECD countries increased productivity by 0.0011% for all 17 Sub-Saharan African countries in the sample from 1980-2004. The average elasticity from 1980-1989 is 0.0013% compared with 0.0010% from 1990-2004. These results are consistent with results from similar studies in the literature. For example, (Grilliches (1988)) document that studies for industrial countries typically find elasticities of total factor productivity with respect to domestic R&D capital stocks to be in the range of 0.06 and 0.1. Coe and Helpman(1995) find values in the range of 0.02 to 0.08 for major industrial countries and in the range of 0.04 to 0.26 for the smaller industrial countries.

Table 1.5: Country-Specific Time-Varying Estimates of the Impact of R&D Capital Stock on Total Factor Productivity using Dynamic OLS Estimation Technique

Variable	1980	1985	1990	1995	2000	2004
Benin	0.0012	0.0016	0.0005	0.0015	0.0011	0.0007
Burundi	0.0005	0.0006	0.0007	0.0008	0.0005	0.0006
Cameroon	0.0014	0.0009	0.0008	0.0006	0.0006	0.0006
Congo DR	0.0002	0.0005	0.0005	0.0006	0.0003	0.0005
Côte d''Ivoire	0.0016	0.0013	0.0008	0.0014	0.0008	0.0013
Gabon	0.0011	0.0019	0.0009	0.0011	0.0018	0.0013
Gambia	0.0031	0.0026	0.0030	0.0014	0.0019	0.0029
Ghana	0.0012	0.0009	0.0013	0.0016	0.0023	0.0016
Kenya	0.0015	0.0010	0.0011	0.0014	0.0007	0.0007
Malawi	0.0004	0.0003	0.0008	0.0005	0.0002	0.0002
Niger	0.0026	0.0014	0.0009	0.0008	0.0005	0.0007
Senegal	0.0001	0.0001	0.0002	0.0002	0.0001	0.0001
Togo	0.0008	0.0006	0.0005	0.0004	0.0003	0.0002
Sudan	0.0053	0.0049	0.0028	0.0026	0.0029	0.0035
Uganda	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002
Zambia	0.0035	0.0007	0.0012	0.0003	0.0003	0.0005
Zimbabwe	0.0013	0.0015	0.0018	0.0022	0.0011	0.0004
Average	**0.0015**	**0.0012**	**0.0011**	**0.0010**	**0.0009**	**0.0009**

Table 1.5 also show that the impact of foreign R&D spillovers on productivity in Sub-Saharan African countries have declined consistently from 1980 to 2004. Figure 1.4 depicts the average elasticity of productivity with respect to R&D spillovers for all the 17 countries in the sample.



The graph above shows a non-negligible increases in productivity in Sub-Saharan African countries in response to foreign R&D spillovers from industrialized countries. However, the degree of benefits has consistently declined over time. The declining trend in elasticity of productivity with respect to foreign R&D spillovers from industrial countries may be attributed largely to the gradual shift from north-south trade to south-south trade in intermediate inputs. In particular, there has been a gradual shift in the sourcing of Least Developed Countries (LDCs) capital goods imports over the last 25 years from developed countries to developing countries. Table 1.6 reports imports of capital goods by origin, in LDCs, 1980-2005 as a percentage of total capital goods imports. The data suggest a shift in the sourcing of capital goods imports from OECD to developing countries over the last 25 years. In particular, Africa and Haiti's imports of capital goods from OECD countries declined by 30% from 1980-1989 to 2000-2005 while rising sharply by 382% from 1980-1989 to 2000-2005 for developing countries. The shift also reflects the rise of technologically advanced developing countries as exporters of capital goods, UNCTAD (2007). Theoretically, the growth in South-South trade in capital goods and the decline in North-South trade in capital goods should cause foreign R&D spillovers from OECD to have a declining effect on productivity in Sub-Saharan African countries.

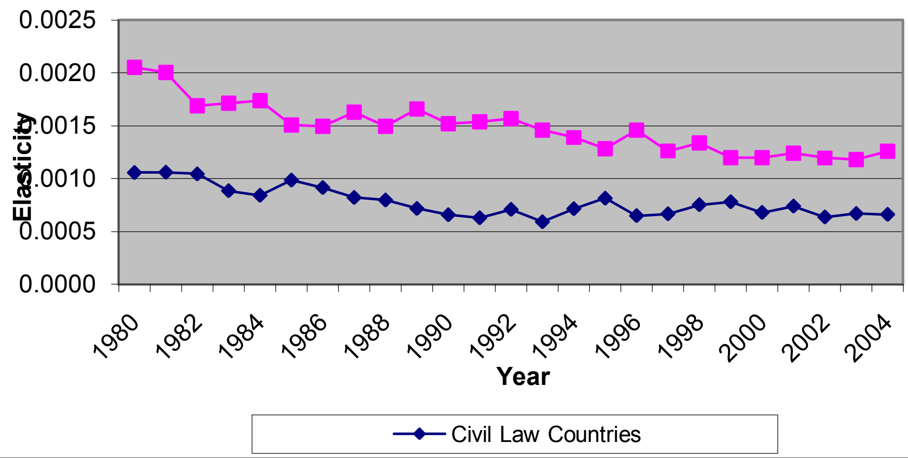
There are also cross-country disparities. In particular, Burundi, Congo DR, Gabon, Ghana and Uganda, recorded an increase in the average elasticity of total factor productivity with respect to foreign R&D spillovers between 1980 and 2004. The value for Senegal stayed at 0.0001 in 1980 and 2004. The remaining 11 countries representing roughly 65% of the sample recorded significant declines in average elasticity of total factor productivity with respect to R&D spillovers from 1980-2004. The largest decline was recorded by Zambia from 0.0035 to 0.0005 over the period 1980-2004. This represents roughly 86% decline in average elasticity of productivity with respect to foreign R&D spillovers from OECD countries. Some of these disparities are due largely to declining patterns of imports from OECD countries.

However, other factors such as differences in institutional arrangements, conflict or the extent of natural resource endowment. Sudan for instance, enjoyed the largest benefits from R&D spillovers from OECD countries. In particular, a 1% increase in R&D investments in OECD countries increased productivity by 0.0053% in 1980 and 0.0035% in 2004 in Sudan. Although, elasticity declined, it was still higher than the average benefits for all the countries in the sample. This robust benefits may be attributed to the fact Sudan is a major oil exporter. Capital goods import value for oil exporting countries increased sharply between 1990 and 2005, (UNCTAD (2007)).

Figure 1.4 depicts the time varying elasticity of productivity with respect to R&D spillovers from OECD countries for the French Civil Law and English Common Law Sub-Saharan African countries in the sample. The graph show that average elasticity of productivity with respect to foreign R&D spillovers for English common law countries exceeded the average for the French civil law countries over the entire sample period from 1980-2004. However, average elasticities for both English common law and French civil law Sub-Saharan African countries have declined over the since 1980. This decline may be due to the decline in the imports of intermediates from major OECD countries due largely to the expansion in south-south trade. Table 1.6 show that imports of intermediates from advanced countries to developing countries have fallen from 92% in 1980 to 59% from 2000-2005. This may explain the decline in average elasticity of productivity with respect to R&D spillovers from OECD countries. Finally, Figure 1.4 show that the gap between the average elasticity of productivity with respect to R&D capital stock from OECD countries in English common law countries and French civil law countries have narrowed in recent years.

Estimates of elasticity of productivity with respect to foreign R&D spillovers computed so far were based on R&D spillovers from OECD countries as a group. However, it may be helpful to quantify the extent to which Sub-Saharan African countries benefit in terms of higher productivity from returns to R&D investments in specific G7 countries.

Figure 1.5 Average Elasticity of Productivity with Respect to R&D spillovers in Sub-Saharan Africa



The goal is to examine the major sources of foreign R&D spillovers. Since a large fraction of investments in R&D spillovers is made in the G7 countries, the focus of the analysis in this section is restricted to the G7 countries.

Table 1.6 report estimates of the elasticity of productivity in the Sub-Saharan African country indicated in the row with respect to the foreign R&D capital stock in the country indicated in the column[13] for 2004. For example, when domestic R&D capital stock of a G7 country i, S_i^d, increases by 1%, the foreign R&D capital stock of a Sub-Saharan African country j, S_j^f, rises by $\frac{m_i^j S_i^d}{\sum_j m_i^j S_i^d}$ percent, and country j's output rises by

[13] The focus on G7 countries is due largely to the fact that they account for nearly 92% of R&D investments worldwide.

$m^j\theta_j \frac{m_i^j S_i^d}{\sum_j m_i^j S_i^d}$ percent[14], where m^j is country j's import share and m_i^j is the fraction of j's imports coming from country i. The average elasticities in table 1.7 show that the United States is the most important source of R&D spillovers for Sub-Saharan African countries. In particular, a 1% increase in domestic R&D capital stock in the United States raised productivity on average in each of the 17 Sub-Saharan African countries by 0.0004% in 2004 compared with an average of 0.0002 for Japan, 0.0001 for France and Germany, and the U.K respectively. Canada and Italy had the least impact on productivity in the 17 Sub-Saharan African countries raising productivity by close to zero percent in 2004[15].

Ghana and Gambia had the largest increase in productivity from a 1% increase in domestic R&D capital stock in the United States with values of 0.0011% and 0.002% respectively. France's domestic R&D investments had the largest impact on productivity in the Francophone African countries. United Kingdom's investments in R&D appear to have the greatest impact on productivity in Francophone African countries. This evidence appear to confirm the role of colonial influences on trade and hence productivity in Sub-Saharan African countries.

R&D investments in G7 raise productivity more in Sudan than in any other African countries. This may be due to the high concentration of capital goods imports in

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14 This formula was taken from Coe and Helpman (1995).

15 The values are not zero if rounded to six decimal places.

the oil exporting countries. In particular, capital goods imports increased by about $20 billion dollars in developing countries, but bulk of this increase went to oil exporting countries.

Table 1.7: Average Elasticity of Total Factor Productivity in a Specific Sub-Saharan African Country With Respect to Domestic R&D Capital Stock in a G7 Country in 2004.

Country	Canada	France	Germany	Italy	Japan	U.K	U.S
Benin	0.0000	0.0003	0.0000	0.0000	0.0001	0.0001	0.0001
Burundi	0.0000	0.0001	0.0001	0.0000	0.0003	0.0000	0.0001
Cameroon	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0003
Congo DR	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0003
Côte d''Ivoire	0.0000	0.0006	0.0001	0.0000	0.0001	0.0000	0.0004
Gabon	0.0000	0.0005	0.0000	0.0000	0.0001	0.0001	0.0006
Gambia	0.0000	0.0001	0.0003	0.0000	0.0001	0.0003	0.0020
Ghana	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0011
Kenya	0.0000	0.0000	0.0001	0.0000	0.0002	0.0001	0.0003
Malawi	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Niger	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0005
Senegal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Togo	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001
Sudan	0.0001	0.0002	0.0008	0.0001	0.0013	0.0004	0.0007
Uganda	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Zambia	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002
Zimbabwe	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002
Average	0.0000	0.0001	0.0001	0.0000	0.0002	0.0001	0.0004

1.6 Conclusion

The question of whether returns to R&D investments in certain countries influence productivity in other countries has received significant attention since the development of endogenous growth models that established a framework linking productivity and innovation. Earlier empirical studies starting with the seminal work of Coe and Helpman (1995) identified trade as the main vehicle for knowledge diffusion. However, more recent studies using modern econometrics techniques have questioned the existence of any trade related learning effects. Second evidence from developing countries is very limited. Third, the role of institutions in explaining R&D spillovers in developing countries is yet to be explored. This paper therefore provides cross-country evidence of the link between productivity and trade induced learning effects from Sub-Saharan Africa. I also provide evidence of the role of institutions in explaining R&D spillovers from Sub-Saharan African countries.

My estimates suggest that spillovers to Sub-Saharan African countries are substantial. In particular, a 1% increase in domestic R&D capital stock in the major OECD countries will increase productivity in a Sub-Saharan African country by about 0.0011% on average. However, the average elasticity of productivity in Sub-Saharan African country with respect to foreign R&D spillovers from OECD countries has declined consistently from 0.0015% in 1980 to 0.0009% in 2004 for all the 17 countries in the sample.

In terms of the sources of R&D spillovers, the estimates suggest that the United States is the major source of spillovers in Sub-Saharan African countries. In particular, a 1% increase in domestic R&D spillovers in the United States raised productivity by an average of 0.0004% for all the 17 countries in the sample[16]. This may be expected since United States accounts for over 40% of the World's R&D investments.

The legal origin of the company law or commercial codes of Sub-Saharan African countries affect the degree of knowledge spillovers. In particular, Sub-Saharan African countries that adopted the English common law legal system benefit more from the R&D spillovers than countries under the French civil law. In particular, a 1% increase in domestic R&D capital stock in OECD countries raised productivity for English common law countries by an average of 0.0015% compared to 0.0008% for French civil law countries from 1980-2004. There is however a trend decline in benefits for both legal systems.

Finally, my estimates suggest that total spillover effects from major OECD countries may have increased output in the 17 Sub-Saharan African countries by $10 million 2004. This shows that, although developing countries do benefit from returns from investments in R&D capital stocks, such benefits and small and declining.

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[16] Canada was the least important as a source of foreign R&D spillovers for countries in the sample followed by Italy. Japan, France and Germany were also major sources of foreign R&D spillovers.

Appendix 1.A

Table 1.6 Imports of capital Goods, by origin, in LDCs, 1980-2005 (percentage of total capital goods imports).

	1980-1989		1990-1999		2000-2005	
Group	**OECD**	**LDC**	**OECD**	**LDC**	**OECD**	**LDC**
LDCs	**91.5**	**8.5**	**75.4**	**24.6**	**59.0**	**41.0**
Africa& Haiti	95.0	5.0	88.6	11.4	66.3	33.7
Asia	81.7	18.3	51.2	48.8	43.4	56.6
Islands	92.0	8.0	84.4	15.6	73.8	26.2
Advanced LDCs	**89.4**	**10.6**	**72.3**	**27.7**	**57.5**	**42.5**
Africa	97.4	2.6	90.8	9.2	83.5	16.5
Latin America	94.4	5.6	85.8	14.2	82.9	17.1
Asia	85.9	14.1	67.2	32.8	51.1	48.9

Source: The Least Developed Countries Report 2007. See this report for the definitions of LDCs, Advanced LDCs and capital goods.

Table 1.8 The Legal Origin of Sub-Saharan African Countries

COUNTRY	LEGAL ORIGIN	List of OECD countries
Benin	French	Canada
Burundi	French	Denmark
Cameroon	French	France
Congo DR	French	Germany
Cote d'Ivoire	French	Italy
Gabon	French	Japan
Gambia	English	Netherlands
Ghana	English	Spain
Kenya	English	Switzerland
Malawi	English	U.K
Niger	French	U.S
Senegal	French	
Togo	French	
Sudan	English	
Uganda	English	
Zambia	English	
Zimbabwe	English	

Source: La porta et al (1999).

Appendix 1.B

Data Sources and Variable Definition

The dependent variable is labor productivity, measured as real GDP per worker (LRGDPW). Data for this variable was taken from the Penn World Tables version 6.3. A number of studies have suggested various approaches for measuring foreign R&D capital stock. In this paper, I follow the literature and adopt the approaches of Coe and Helpman(1995) and Lichtenberg and van Pottesberge (1998). Coe and Helpman (1995) measure foreign R&D capital stock of a developing country i as a weighted average of domestic R&D capital stock of the trading partner, where the weights are the bilateral import-share of a developing country.

$$S_{1i} = \sum_{j^{1}i} w_{ij} S_j^d$$

$$w_{ij} = \frac{M_{ij}}{\sum_{j \neq i} M_{ij}}, \qquad \sum_{j \neq i} w_{ij} = 1$$

where S_j^d denotes domestic R&D capital stock of trading partner j. The R&D expenditure for the business sector comes from OECD directorate of Science, Technology and industry, published in the Main Science and Technology Indicators. M_{ij} denotes country i's imports of goods and services from country j. The bilateral imports which are on a c.i.f basis are from IMF's Direction of Trade Statistics (DOT) online database.

I used Coe, Helpman and Hoffmaister's dataset on domestic R&D capital stock to construct my foreign R&D capital stock variable. Coe, Helpman and Hoffmaister constructed the domestic R&D capital stock using the perpetual inventory method.:

$S_t^d = (1-\delta)S_{t-1}^d + RD_{t-1}$. where δ =0.05 is the depreciation rate. Data for business sector R&D expenditure was obtained from Directorate of Science Technology, and Industry published in Main Science and Technology Indicators. The initial R&D capital stock is constructed as

$$S_{1970} = \frac{RD_{1970}}{\delta + g}$$

where g is the annual average logarithmic growth rate from 1970 -1985. That is:

$$g = \log\left(\frac{RD_{1985}}{RD_{1970}}\right)/15$$

Lichtenberg and Van Pottesberge (1998) proposed an alternative definition of foreign R&D capital stock as follows: $S_2 = \sum_{j \neq i}\left(\frac{M_{ij}}{Y_j}\right)S_j^d$

Where Y_j is the nominal GDP of trade partner country j. Data on nominal GDP come from the World Bank's World Development Indicators online database.

Measuring institutions presents a challenge for most researchers. Some of the commonly used proxy variables include corruption, doing business, judiciary independence, and legal origin among others. However, data on most of these variables are either only available for a few years or are time invariant. In this paper I proxy the level of institutional development with the legal origin of a country's company law or commercial code and patent protection, La Porta et al (2008).

I measure human capital as the secondary school enrollment as a percentage of secondary school aged population in each country. The data for this variable was obtained from UNESCO online education database. The index of patent protection ranges from 1(lowest protection) to 5 (highest protection). Data on the index of patent protection come from Park and Lippoldt (2005). Finally, OECD GDP and population data were obtained from World Bank's World Development Indicators.

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CHAPTER TWO: AID-INDUCED R&D SPILLOVERS AND PRODUCTIVITY IN SUB-SAHARAN AFRICA: EVIDENCE FROM TECHNICAL COOPERATION GRANTS AND OVERSEAS DEVELOPMENT ASSISTANCE GRANTS.

2.0 Introduction

Interest in the mechanisms through which returns to R&D investments in one country spillover to affect productivity and growth in other countries has grown since the development of endogenous growth models. These growth models provide a framework that links productivity and innovation done by private entrepreneurs and firms seeking profit incentives by investing in Research and Development(R&D), ((Romer,(1990), Grossman and Helpman(1991), Aghion and Howitt(1992)). However, for the most part, the focus has been on trade related R&D spillovers with mixed results. More recent studies have shifted attention to foreign direct investments but the evidence is inconclusive, (Fosfuri, Motta and Ronde(2001), Keller(1998), Zhu and Jeon (2007))[17].

In this paper I explore two alternative channels of international R&D knowledge spillovers. Specifically, I examine productivity and foreign R&D spillovers that operate through technical cooperation grants and Overseas Development Assistance (ODA) grants[18]. I examine these spillovers for 11 Sub-Saharan African countries using the endogenous growth framework. The main question I address is whether technical

[17] Smeets (2008) surveys the recent theoretical and empirical literature on FDI knowledge spillovers.

[18] See the appendix for the definitions of technical cooperation grants and overseas development assistance grants.

cooperation grants and overseas development assistance grants induce R&D knowledge spillovers in Sub-Saharan African countries. That is, do the largest recipients of technical cooperation grants and overseas development assistance grants benefit more from R&D spillovers? To the best of my knowledge, this represents the first attempt to explore the effects of aid-induced international knowledge spillovers on productivity in developing countries.

Aid flow constitutes a major source of income for many poverty stricken developing countries. According to the World Bank, total worldwide foreign aid averaged about $77 billion per year during 2002-04, and 172 countries were net recipients of aid over the period. In Sub-Saharan Africa, aid supports knowledge accumulation activities, institutional reforms and infrastructural development. All of these activities may enhance efficiency of labor and firms and thereby improve productivity and reduce poverty.

In particular, technical cooperation grants and ODA grants often involve "activities financed by a donor country whose primary purpose is to augment the level of knowledge, skills, technical know-how or productive aptitudes of the population of developing countries, i.e., increasing their stock of human intellectual capital, or their capacity for more effective use of their existing factor endowment",(OECD (2009)). This may involve sharing of best practices and better ways of organizing development activities in order to enhance efficiency and productivity. It may also involve workshops or seminars to share new research findings. It is therefore reasonable to suggest that an increase in technical cooperation grants and overseas development assistance grants may open channels of communication that may give rise to the diffusion of more technical information and facilitate the accumulation of knowledge and skill development and thereby enhance labor efficiency and productivity.

To test this hypothesis, I follow (Coe and Helpman(1995)) and construct technical cooperation and ODA weighted foreign R&D capital stock as proxies for international R&D spillovers. I then apply dynamic OLS estimation techniques to the endogenous growth framework establishing a link between productivity and R&D spillovers to provide estimates of elasticities of labor productivity with respect to foreign R&D spillovers through technical cooperation grants and overseas development assistance grants for 11 Sub-Saharan African countries from 1980-2004. These elasticity estimates would enable me to examine the importance of aid induced learning effects and the extent to which they explain productivity in Sub-Saharan Africa.

The elasticity estimates would also shed some light on the current debate about the effectiveness of aid on growth, (Burnside and Dollar (2000, 2004), Easterly, Levine and Roodman (2004)). Earlier studies on the effectiveness of aid flow on growth used the neoclassical growth model which is based on the assumption that technological progress is an exogenous process. These studies were thus unable to quantify the importance of aid-induced learning effects and how it explains productivity and growth. The estimates of elasticity of productivity with respect to R&D spillovers through technical cooperation grants and overseas development assistance grants provided in this study would thus enhance our understanding of aid-induced knowledge externalities and their effects on productivity and growth in Sub-Saharan Africa.

I also provide estimates of the elasticity of productivity in each Sub-Saharan African country with respect to aid-induced R&D spillovers from each G7 country. These elasticity estimates shed light on the main sources of aid- induced learning for Sub-Saharan African countries. The existing empirical evidence suggests that aid flow depends on three key factors: population size, donor interest which may take the form of colonial or political considerations or relationships, and income levels in developing countries, (Burnside and Dollar (2000), Alesina and Dollar (2000), Wall (2008), Boschini and Olofsgard (2002)). I investigate whether after controlling for other factors, aid induced-learning in Sub-Saharan Africa is greatest in countries with the largest population. Second, I use the elasticities of productivity in Sub-Saharan African countries with respect to foreign R&D spillovers in each G7 country to assess whether aid-induced learning effects are based on colonial linkages. Finally, I also use the elasticities of productivity with respect to foreign R&D spillovers over time to assess whether there is any significant difference between the poverty rank of a country and the degree to which it benefits from aid-induced learning.

I find that Technical cooperation grants and overseas development assistance grants are major mechanisms through which returns to R&D investments in G7 countries flows to Sub-Saharan African countries. In particular, a 1% increase in domestic R&D capital stock in G7 countries[19] leads to an average increase in productivity in all the 11 Sub-Saharan countries of 0.0021%, 0.0033% and 0.0044% through technical cooperation,

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[19] I excluded Italy from the study due to the lack of consistent time series on technical cooperation grants and overseas development grants.

overseas development assistance and imports respectively. This evidence thus supports the hypothesis that international R&D spillovers are also trade related. The evidence also showed that aid is effective in countries with good policies. Finally, aid-induced externalities are influenced by colonial linkages.

The rest of the paper is structured as follows: after this introductory section, section 2.1 reviews the literature on aid-induced R&D spillovers in developing countries. Section 2.2 discusses the empirical model and the econometrics estimation techniques. Section 2.3 describes the important features of the data used. Section 2.4 discusses the empirical results including the panel unit root and co-integration results and results of the quantitative analysis on the relationship between aid-induced international knowledge spillovers and productivity in Sub-Saharan African countries. Conclusions and policy recommendations are provided in the section 2.5.

2.1 Related Literature Review.

Trade has for sometime now been seen as the main vehicle for knowledge diffusion. In particular, trade facilitates knowledge transfer by opening channels of communication leading to the exchange of ideas. Trade may also provide local researchers the opportunity to gain new insights by inspecting and using intermediates not available locally and thereby enhance firm efficiency and productivity, (Grossman and Helpman(1991)). Several empirical studies have found support for this hypothesis although the evidence is inconclusive, (Coe and Helpman (1995), Coe, Helpman and Hoffmiaster(1997), Keller (1998), Xu and Wang (1999), Kao and Chiang (1999), Funk (2001), Zhu and Jeon(2007)).

This chapter shares some similarities with the trade related literature in that I also use the endogenous framework to assess the importance of knowledge spillovers on productivity and growth. However, the current chapter differs in two ways: First, Coe and Helpman's approach is based on the assumption that knowledge developed in the advanced industrialized countries is embodied in capital goods. Consequently, more open economies that trade with the industrial countries can access this knowledge through importing and studying intermediates not available locally.

However, as (Funk (2001)) observed, this approach emphasizes direct hands-on experience with imported intermediate inputs and places less emphasis on pure idea exchange and knowledge spillovers gained from formal and informal contacts. According to Funk, "unless the knowledge embodied in imports is somehow extracted and increases the productivity of domestic researchers, the impact of an imported intermediate has a one-time static effect". This study therefore focuses on knowledge spillovers through pure idea exchange and formal or informal contacts induced by technical cooperation and overseas development assistance (ODA) grants. The focus is therefore on examining the role of disembodied knowledge spillovers on productivity in Sub-Saharan Africa.

The second difference arises from the construction of the foreign R&D spillover variable. Coe and Helpman construct the foreign R&D knowledge spillover variable as import share weighted average of the domestic R&D capital stock of the trade partners. I construct the foreign R&D spillovers as technical cooperation grants and Overseas Development Assistance grants (ODA) grants weighted domestic R&D capital stock.

More recent studies have explored foreign direct investments as an alternative channel of international knowledge spillovers. In particular, the literature identifies imitation or reverse engineering, vertical integration and worker mobility as some mechanisms through which FDI may induce international knowledge spillovers, (Smeets(2008), Saggi(2006)). However, as Smeets noted, some empirical studies use total factor productivity while others use labor productivity and that makes comparisons very difficult. Second, the potential endogeneity of FDI is not always properly accounted for, and may bias the results.

The paper is also closely related to the strand of literature that examines the relationship between aid, policies and growth. In particular, (Burnside and Dollar (2000)) used a new database on foreign aid to examine the relationships among foreign aid, economic policies, and growth of per capita GDP for a panel consisting of 56 developing countries and six four-year periods (1970-93). The policy variable was constructed as an index of fiscal surplus, inflation and trade openness. The index was then interacted with foreign aid, and instruments for both aid and aid interacted with policies. The authors find that, aid has a positive impact on growth in developing countries with good fiscal, monetary, and trade policies. The implication of Burnside and Dollar's conclusion was that, donor countries seeking to improve economic growth and reduce widespread poverty in developing countries should allocate aid to developing countries with good policies.

However, (Easterly, Levine and Roodman (2004)) challenged the conclusions of (Burnside and Dollar (2000)) as sensitive to the sample period observed. In particular, Easterly, Levine and Roodman re-assessed the links between aid, policy, and growth using updated dataset from 1993 to 1997 in order to determine whether aid influences growth in the presence of good policies. The authors concluded that "We believe that Burnside and Dollar should be a seminal paper that stimulates additional work on aid effectiveness, but not yet the final answer on this critical issue".

Studies based on neoclassical growth models do not explain the mechanisms through which aid or for that matter policy affects growth. This study examines the effect of aid on growth through productivity. In particular, I provide estimates of the elasticity of productivity with respect to R&D spillovers through technical cooperation grants and overseas development assistance grants using the endogenous growth framework and thus provide insights about aid induced-learning and their effects on productivity in Sub-Saharan African countries.

The paper also contributes to the empirical evidence on the determinants of aid allocation in Sub-Saharan Africa, (Alesina and Dollar (2000); Boschini and Olofsgard (2002), Wall (2000). Alesina and Dollar (2000)) studied the pattern of allocation of foreign aid from various donors to receiving countries. They find considerable evidence that aid is influenced primarily by political and strategic considerations although the economic needs, colonial past and political alliances and policy performance of the recipients do play a role. Alesina and Dollar also found that, at the margin, countries that democratize receive more aid, ceteris paribus. However, foreign direct investments are more sensitive to economic incentives, particularly “good policies” and protection of property rights in the receiving countries". Wall (2008) arrived at similar conclusions, "there should be little doubt that foreign aid is related to the strategic interests of donor countries". The current study investigates the role of colonial past and political alliances, population and economic need in explaining aid induced R&D spillovers in Sub-Saharan Africa. In the next section I outline and discuss the empirical model used in the study.

2.2 The Empirical Model

The empirical model used in this study is an extension of the endogenous growth framework[20]. The endogenous framework provides a link between total factor productivity and foreign R&D spillovers. Following (Coe and Helpman (1995)) and assuming a Cobb-Douglas production technology, I express output (Y) as depending on labor (L), physical capital (K) and knowledge capital (S) as follows[21]:

$$Y = AL^{\alpha}K^{\beta}S^{\lambda}e^{\varepsilon} \tag{0.10}$$

Where Y is output, A is a constant, L is labor, K is physical capital, S is knowledge capital, e is white noise error term. Since knowledge capital for open economies may come from both domestic and foreign sources, we can re-write knowledge capital (S) in equation (0.10) to reflect the two sources as follows:

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[20] The endogenous framework proposed by Romer (1990), Grossman and Helpman(1991) and Aghion and Howitt (1992) links total factor productivity and innovation. This framework has formed the basis of several empirical studies on the relationship between productivity and international R&D spillovers. Interested readers should consult these authors for detailed discussions.

[21] The approach in this study also follows from the approach used by Xu and Wang (1999).

$$Y = AL^{\alpha}K^{\beta}\left[(DRD)^{\alpha_1}(FRD)^{\alpha_2}\right]^{\lambda} e^{\varepsilon} \qquad (0.11)$$

where DRD and FRD are domestic and foreign R&D spillovers respectively. If one defines total factor productivity F as $F = \frac{Y}{L^{\alpha}K^{\beta}}$, then, substituting this term into (0.11) and taking logarithm of both sides of (2) yields the baseline specification of Coe and Helpman[22] which may be expressed as:

$$LogF_{it} = \eta_i + \theta_{1t}LogDRD_{it} + \theta_{2t}\left[m_{it}\log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}FRD_{it}\right)\right] + \theta_{3t}T_t + \varepsilon_{it} \qquad (0.12)$$

where i denotes countries and t denotes time periods. F is total factor productivity, η captures individual country specific effect, DRD is the domestic R&D capital stock, m_i is the ratio of imports to GDP. m_i often is interacted with the foreign R&D capital stock (FRD) to make it reflect the differences in import intensities so that a country that imports more capital goods from the industrial countries should benefit more from foreign R&D spillovers. M_{ij} denotes bilateral imports of country i from trade partner j, T is a time trend and ε is a white noise error term.

I augment the (Coe and Helpman(1995)) framework with two alternative mechanisms of R&D capital spillovers. In particular, I investigate the role of technical cooperation grants and Overseas Development Assistance grants as potential alternative sources of knowledge spillovers in Sub-Saharan African countries. Technical cooperation

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[22] Interested readers should consult Coe and Helpman(1995) for the derivation of equation (0.12)

grants are designed to augment the level of knowledge, skills, technical know-how or productive aptitudes of the population of developing countries, i.e., increasing their stock of human intellectual capital, or their capacity for more effective use of their existing factor endowment", (OECD (2009)). It is therefore plausible to assume that the greater the flow of such grants, the greater the prospect of knowledge accumulation and hence productivity growth.

Productivity also depends on the quality of the work force. A well trained work force can enhance productivity directly and indirectly by facilitating knowledge diffusion through formal and informal contacts. Following (Coe, Helpman and Hoffmaister (1997)), I proxy human capital using the ratio of secondary school enrollment to secondary school-age population. I also control for patent protection. Strong property rights protection as reflected in strong patent protection may enhance productivity directly and also indirectly by offering incentives to entrepreneurs to invest more in R&D, (Park and L*I*ppoldt (2005)).

Finally, Sub-Saharan African countries in the sample engage in little, if any, domestic R&D investments. Even for countries in the region that do invest in R&D, data availability is a serious challenge. Consequently, I follow (Coe, Helpman and Hoffmaister (1997)) and assume that domestic R&D capital stock is negligible and therefore can be ignored[23]. I modify the baseline model (3) to reflect technical

[23] This assumption may not be far from reality for the countries in this sample. South Africa and Tunisia invest heavily in R&D capital stock but they are not included in the sample.

cooperation (TCOOP) grants and Overseas Development Assistance (ODA) grants as potential alternative sources of R&D spillovers. I also augment the baseline model with human capital and proxies for institutions.

$$\begin{aligned} \text{LogF}_{it} = \eta_i + \theta_{1t}\left[m_{it}\log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}\text{FRD}_{jt}\right)\right] + \theta_{2t}T_t + \theta_{3t}H_{it} + \theta_{4t}\text{Patent}_{it} \\ + \theta_{5t}\left[t_{it}\log\left(\sum_{j\neq i}\frac{\text{TCOOP}_{ijt}}{\text{TCOOP}_{it}}\text{FRD}_{jt}\right)\right] \\ + \theta_{6t}\left[o_{it}\log\left(\sum_{j\neq i}\frac{\text{ODA}_{ijt}}{\text{ODA}_{it}}\text{FRD}_{jt}\right)\right] + \varepsilon_{it} \end{aligned} \quad (0.13)$$

Where H is human capital, t_i is the ratio of technical cooperation grants to GDP and $t_{it}\log\left(\sum_{j\neq i}\frac{\text{TCOOP}_{ijt}}{\text{TCOOP}_{it}}\text{FRD}_{jt}\right)$ is the technical cooperation-weighted foreign R&D capital stock, o_i is the ration of overseas development assistance grants to GDP and $o_{it}\log\left(\sum_{j\neq i}\frac{\text{ODA}_{ijt}}{\text{ODA}_{it}}\text{FRD}_{jt}\right)$ is the overseas development assistance- weighted foreign R&D capital stock. Patent is an index of patent protection. It range from 1(low protection) to 5.

A positive θ_1 implies, the effect of foreign R&D capital stock on domestic productivity is larger the more open the economy is to foreign trade, and the effect of foreign trade on productivity is larger the larger is the foreign R&D capital stock. If θ_4 is positive, then the effect of foreign R&D capital stock on domestic productivity is larger the larger is technical cooperation grants. Finally, a positive θ_5 implies the effect of foreign R&D capital stock on domestic productivity is larger the larger is overseas development assistance grants. The specification (4) also differs from that used by (Coe, and Helpman(1995)) in that specification (4) assumes that domestic R&D capital stock in Sub-Saharan African countries is negligible and therefore can be dropped from the baseline equation.

2.2.1 Dynamic OLS Estimation

The empirical results in this study are based on the dynamic OLS (DOLS) estimation technique suggested by (Saikkonen (1991)). Unlike the OLS, the DOLS estimator includes lead and lag terms of first differenced explanatory variables in the regression equation which corrects for nuisance parameters. It has gained wide acceptance in the economics literature due to its simplicity and more importantly because it results in estimated coefficients with nice limiting distribution properties, (Kao and Chiang(1999)). In this section I briefly review the dynamic OLS estimation approach[24]. I begin by re-writing equation (4) as a single equation framework of the form:

$$Y_{it} = c_i + Z_{it}'\beta + u_{it} \tag{0.14}$$

where i = 1, 2, …, N denotes countries and t =1,2,…T denotes time period, Y_{it} is the dependent variable, c_i captures individual specific effects, Z_{it} represent (K × 1) vector of regressors. The regressors are assumed to be I(1) and not co-integrated. I also assume a

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[24] The review here is based on the work of Breitung and Pesaran(2005). Interested readers should consult this source and several other sources for further details.

homogenous cointegration relationship among Y and Z. That is, the coefficients for all cross-section units are the same.

$$Y_{it} = c_i + Z_{it}{'}\beta + u_{it} \tag{0.15}$$

for i = 1,2, 3, …, N and t = 1, 2, 3, …T.

Where it is assumed that Y_{it} and the K × 1 vector of regressors, Z_{it}'s are I(1) with at most one co-integrating relationship amongst them. The OLS estimator is consistent but inefficient in a model with endogenous regressors. Several remedies have been proposed for OLS models with potential endogenous regressors. In particular, (Pedroni (1995) and Phillips and Moon (1999)) proposed a "fully modified OLS" (FM-OLS) approach to obtain an asymptotically efficient estimator for homogenous cointegration vectors. This estimator adjusts for the effects of endogenous regressors and short-run dynamics of the errors (serial correlation). Specifically, the dependent variable is adjusted for the part of the error that is correlated with the regressors.

However, according to (Kao and Chiang (1999)) "(i) the OLS estimator has a non-negligible bias in finite samples, (ii) the fully modified estimator does not improve over the OLS estimator in general, and (iii) the DOLS estimator may be more promising than OLS or FM estimators in estimating co-integrated panel regressions".
Consequently, I adopt the DOLS approach for this paper.

The DOLS estimator proposed by (Saikkonen (1991)) is based on the error decomposition[25]:

$$u_{it} = \sum_{k=-\infty}^{\infty} \Omega_k \Delta Z_{it} + v_{it} \qquad (0.16)$$

. Where v_{it} is orthogonal to all leads and lags of ΔZ_{it}. Inserting (0.16) into (0.15) yields:

$$Y_{it} = c_i + Z_{it}'\beta + \sum_{k=-\infty}^{\infty} \Omega_k \Delta Z_{it} + v_{it} \qquad (0.17)$$

The infinite sums are usually truncated at some small numbers of leads and lags; (Kao and Chiang (2000), Mark and Sul (2003)). In this study, I truncated the infinite sum at one lag and zero leads because leads and lags outside this range adds little to the fit of the model. Kao and Chiang(2000) show that the limiting distribution of the homogenous DOLS estimator is normal. The empirical results in this study are therefore based on equation (7)[26].

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[25] See Breitung and Pesaran(2005), Kao, Chiang and Chen(1999) for a detailed discussion.

[26] Interested readers should consult Breitung and Pesaran (2005) for a good review of OLS, FM-OLS and DOLS. Kao and Chaing(1999) also explain how to apply these approaches empirically.

2.3 Data

The empirical results are based on a pooled dataset for 11 Sub-Saharan African countries over the period 1980-2004. Table 1.1 summarizes the data for all variables for the 11 countries in the sample. The definitions and sources of variables have been discussed in the appendix. Productivity defined as GDP per worker, declined on average by 5% in all 11 countries in the sample from 1980-2004. The decline was largest in Congo D.R. 79%, Zimbabwe 58% and Zambia 40%. The biggest gainers were Malawi 69%, Cameroon 42% , Uganda 15% and Ghana 12%. The two extremes also reflect the wide variation in productivity among the countries in the sample.

The foreign R&D capital stock through technical cooperation grants increased sharply by a factor of 5.61 on average in all 11 countries from 1980-2004. There were also significant variations across countries ranging from an increase by a factor of 2.22 in Cameroon to 9.60 in Zambia from 1980-2004. The English countries also appear to have recorded the largest increase from 1980-2004. Differences across countries is due largely to differences in the technical cooperation grants since the foreign R&D capital stocks for each Sub-Saharan African country in the sample is constructed as bilateral technical cooperation grants-weighted average of domestic R&D capital stock of G7 countries.

In contrast, foreign R&D capital stock through overseas development assistance grants increased by a factor of 3.13 on average in all 11 countries from 1980-2004. There were also significant variations across countries ranging from an increase of a factor of 1.78 in Cameroon to 6.21 in Ivory Coast from 1980-2004. Differences across countries is also due largely to differences in the overseas development assistance grants since the foreign R&D capital stocks for each Sub-Saharan African country in the sample is constructed as bilateral overseas development assistance grants-weighted average of domestic R&D capital stock of G7 countries.

There is considerable variation in the ratio of technical cooperation grants from the G7 countries to GDP in Sub-Saharan African countries. It ranged from 0.1% in Uganda to 3.7% in Niger in 1980. The ratio declined in four countries: Ivory Coast, Gambia, Niger and Zambia from 1980-2004. It stayed the same in two countries and increased in five countries.

In contrast the ratio of overseas development assistance to GDP increased in nine of the 11 countries in the sample from 1980-2004. It stayed the same in Ivory Coast and declined in Gambia from 9.5% to 2.5%. There was also wide variation across countries in both 1980 and 2004. Secondary school Enrollment to the secondary school-age population was generally low with some wide variations. The ratio was as low as 4% in Niger, 5% in Uganda and 8% in Zimbabwe in 1980. The highest enrollment ratio in the sample in 1980 was 38% in Ghana. Enrollment ratio increased in all countries but was still below 50% for all the countries in the sample in 2004. There were however wide variations ranging from 10% in Niger to 48% in Kenya.

Table 2.0: Summary Statistics

Country	GDP Per Worker (F)	R&D Spillover (TCOOP)	R&D Spillover (ODA)	Ratio of Technical Cooperation Grants to GDP		Ratio of Overseas Development Assistance Grants to GDP		Secondary School Enrolment (%)	
	$\frac{F_{2004}}{F_{1980}}$	$\frac{S_{2004}}{S_{1980}}$	$\frac{S_{2004}}{S_{1980}}$	**1980**	**2004**	**1980**	**2004**	**1980**	**2004**
Cameroon	1.42	2.22	1.78	0.009	0.009	0.011	0.032	16	27
Congo DR	0.21	4.93	2.87	0.002	0.010	0.005	0.112	23	22
Côte d'Ivoire	0.97	6.16	6.21	0.009	0.004	0.011	0.011	18	22
Gambia	0.93	4.12	3.51	0.034	0.018	0.095	0.025	12	45
Ghana	1.12	4.71	2.03	0.007	0.014	0.010	0.171	38	43
Kenya	1.02	5.26	4.25	0.009	0.025	0.016	0.020	19	48
Malawi	1.69	7.14	4.68	0.006	0.020	0.013	0.059	5	28
Niger	0.97	3.02	2.13	0.037	0.018	0.059	0.112	4	10
Uganda	1.15	7.84	2.49	0.001	0.008	0.004	0.021	5	18
Zambia	0.60	9.60	2.10	0.036	0.013	0.033	0.046	16	30
Zimbabwe	0.42	6.71	2.40	0.008	0.008	0.029	0.021	8	40
Average	0.95	5.61	3.13	0.014	0.014	0.026	0.057	14.90	30.27

Spillover TCOOP denotes the technical cooperation grants- weighted foreign R&D capital stock foreign. Spillover ODA denotes the overseas development assistance grants- weighted foreign R&D capital stock. S denotes R&D Spillovers. The secondary school enrolment is used as a proxy for Human capital. It is defined as the ratio of secondary school enrolment to Secondary-School –Age Population.

2.4 Empirical Results

2.4.1 Panel Unit Root and Panel Co-integration Results.

In this section I discuss the dynamic OLS regression equation results for 11 Sub-Saharan African countries. My main interest is to examine whether there is a link between foreign R&D spillovers through technical cooperation grants and overseas development assistance grants and productivity in Sub-Saharan African countries. I first investigated the time series properties of my study variables. In particular, I employed two panel unit root tests proposed by (Levin, Lin & Chu (2002) and Im, Pesaran and Shin (2003)). These two unit root tests have been found to posses more power than their univariate counterparts and have gained widespread acceptance in the time series literature, Breitung and Pesaran. The null hypothesis in both tests is that the variables are non-stationary or I(1). However, the Levine, Lin and Chu t-test assumes common unit root process. That is, the coefficient on the lagged level of the dependent variable (i.e rho) is treated as common across countries while the (Im, Pesaran and Shin (2003)) W-test treats rho as heterogeneous among countries[27].

The results of the tests are reported in table 2.0. With the exception of the ratio of Overseas Development Assistance (ODA) grants to GDP, all the other variables are unit root or non-stationary. The ratio of technical cooperation grants to GDP was also stationary under the Levine, Lin and Chu test but non-stationary under the Im, Pesaran and Shin test. In order to avoid estimating spurious regressions, I also investigated whether the estimated equations are cointegrated. Table 2.1 reports cointegration tests results using panel cointegration tests proposed by (Philips Perron (1998) and Philips and Ouliaris(1990) and Dickey-Fuller(1979)). All test statistics are significant so that the null of no cointegration is strongly rejected. Therefore, the cointegration relationship among variables for all three specifications in table 2.1 is supported.

[27] Interested readers should consult Kao and Chiang (1999) for a review.

Table 2.1 Panel Unit Root Test Results

Variable	Levin, Lin & Chu t Test	Im, Pesaran and Shin Test
Log(GDP Per Worker)	1.88- (0.970)	2.746 (0.997)
Log(Spillover-TCOOP)	-1.260 (0.104)	0.599 (0.726)
Log(Spillover-ODA)	4.678 (1.000)	2.290 (1.000)
Ratio of technical cooperation grants to GDP	-1.333 (0.091)	-0.866 (0.193)
Ratio of overseas Development Assistance grants to GDP	-3.484 (0.0002)	-2.572 (0.0051)
Human Capital	0.302 (0.619)	1.028 (0.848)
Patent Protection	12.759 (1.000)	17.998 (1.000)

Log(spillovers-tcoop) denotes the log of technical cooperation grants- weighted foreign R&D capital stock. log(Spillover ODA) denotes the overseas development assistance grants- weighted foreign R&D capital stock. Numbers in parenthesis are p-values. Patent Protection is an index which range from 1 (low) to 5. The null hypothesis of unit root is rejected if the test statistic is significant.

Table 2.2 Co-integration Tests Results

	Tests	Log(F), ti*log(spillover-tcoop), Human capital, Patent Protection.	Log(F), oi*log(spillover-oda), Human capital, Patent Protection.	Log(F), mi*log(spillover-CH), Human capital, Patent Protection.
Common AR coefficients.	PP	2.628082*	3.221894**	2.341*
	ADF	3.566409***	7.131468***	5.771***

F is GDP per worker. Log(spillovers-tcoop) denotes the log of technical cooperation grants- weighted foreign R&D capital stock. log(Spillover ODA) denotes the overseas development assistance grants-weighted foreign R&D capital stock. Human capital is proxied by secondary school enrollment. It is defined as the ratio of secondary school enrolment to Secondary-School –Age Population. Patent Protection is an index which range from 1 (low) to 5. The null hypothesis of no cointegration is rejected if the test statistics is significant. *, **, *** denotes the level of significance at 10%, 5% and 1% respectively. PP, and ADF report the Philips-Perron t-tests and the augmented Dickey-Fuller tests.

2.4.2 Aid –Induced Learning and Productivity

The role of foreign R&D spillovers on productivity has been studied widely in the literature. However, for the most part, the focus has been on trade related R&D spillovers. Sub-Saharan African countries depend on aid to address the development needs of its citizens. There are however growing concerns over the effectiveness of aid on growth and therefore on its ability to reduce poverty. The goal in this section is to provide some quantitative evidence about the effect of foreign R&D spillovers through technical cooperation grants and overseas development assistance grants on productivity. For the sake of comparison, I also report estimates for R&D spillovers through imports. The results are reported in table 2.3.

Table 2.3 Alternative Channels of Foreign R&D Spillovers, (Dynamic OLS (DOLS) Estimation, Within, Fixed Effects, 1980-2004, 11 Sub-Saharan African Countries)

	Imports	Technical Cooperation Grants	Overseas Development Assistance Grants
Human Capital	0.178 (3.659)	0.168 (3.334)	0.197 (2.758)
Patent	0.095 (7.446)	0.114 (9.841)	0.012 (10.844)
$m_i \times$ log (Spillover – imports)	0.035 (3.844)		
$t_i \times$ log (Spillover –tcoop)		0.143 (3.554)	
$o_i \times$ log (Spillover –ODA)			0.083 (2.487)
R^2	0.95	0.94	0.94
$\bar{R}^2$	0.94	0.93	0.94
Panel observations	253	253	253

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. LOG(Spillover-imports) refers to bilateral import weighted R&D spillovers, LOG(Spillover-tcoop) refers to technical cooperation grants weighted R&D spillovers, LOG(Spillover-ODA) refers to overseas development assistance grants weighted R&D spillovers. mi, ti, and oi refers to the ratio of imports to GDP, technical cooperation grants to GDP, and ODA grants to GDP respectively. All regressions include unreported country fixed effects. The DOLS regressions include zero leads and one lag of the differenced regressors.

Column (1) reports the results of the effect of R&D on productivity through imports. The R&D spillovers through imports variable is interacted with mi, the ratio of bilateral imports to GDP in order to ensure that it reflects differences in import intensities. Similar adjustments have been made with respect to technical cooperation grants and overseas development assistance grants. The coefficient of R&D spillovers interacted with the ratio of imports to GDP is positive and significant implying the effect of foreign R&D

capital stock on domestic productivity is larger the more open the economy is to foreign trade, and the effect of foreign trade on productivity is larger the larger is the foreign R&D capital stock. As expected the coefficients of human capital and patent protection are positive and significant implying that improvement in the quality of the work force and strong intellectual property rights protection both raise productivity.

Columns (2) and (3) report the results of foreign R&D spillovers through technical cooperation grants and ODA grants respectively. The coefficient of R&D spillovers through technical cooperation grants with the ratio of technical cooperation grants to GDP is positive and significant implying the effect of foreign R&D capital stock on domestic productivity is larger the larger is volume of technical cooperation grants. Similarly, the positive and significant coefficient of R&D through overseas development assistance suggests that the effect of foreign R&D capital stock on domestic productivity is larger the larger is volume of overseas development grants. R&D through technical cooperation grants has the largest coefficient followed by the coefficient of overseas development assistance. The elasticities will however depend on the size of imports, technical cooperation grants and overseas development assistance grants. Elasticity estimates are discussed in section 2.4.3 and 2.4.4. The coefficient of imports weighted spillovers of 0.035 is consistent with similar estimates for developing countries and OECD countries. Since the factor shares of labor and physical capital sum to unity, the estimated coefficient of foreign R&D capital through trade of 0.035 is considered theoretically reasonable. Coe, Helpman and Hoffmaister (2008) report estimates ranging from 0.045 to 0.065 for OECD countries. Kao and Chiang (1999) report values ranging from 0.068-0.145 for OECD countries.

Table 2.4 reports the average elasticity of productivity with respect to foreign R&D stocks through imports, technical cooperation grants and overseas Development assistance grants for the years 1980, 1990 & 2004. The results were obtained using the dynamic OLS technique applied to equation (1.4). The elasticities are obtained by multiplying the coefficients of R&D spillovers through imports, technical cooperation grants and overseas development assistance grants in table 3.3 with their respective ratios of imports, technical cooperation grants, and ODA grants to GDP.

Average elasticity of productivity with respect to foreign R&D stocks through imports declined from 0.0068% in 1980 to 0.0036% in 2004 for all the countries in the sample. This represents an average decline of about 47%. The decline from 1980-1990 was relatively low at 26%. At the country level, Table 3.4 show that the impact of foreign R&D capital stock through trade declined in six countries: Cameroon, Ivory Coast, Gambia, Kenya, Malawi, and Niger from 19980-1990. With the exception of Congo DR, Ghana and Uganda, the estimated average elasticity of productivity with respect to foreign R&D spillovers through imports also declined in all other countries from 1980-2004. The growing decline in R&D spillovers from OECD countries through trade may be due to the gradual shift of trade in capital goods from North-South trade to South-South trade[28].

TABLE 2.4 Average Elasticity of Productivity With Respect to Foreign R&D Stocks through Imports, Technical Cooperation Grants and Overseas Development Assistance Grants in 1980, 1990 & 2004

Country	Bilateral Imports			Technical Cooperation Grants			ODA Grants		
	1980	**1990**	**2004**	**1980**	**1990**	**2004**	**1980**	**1990**	**2004**
Cameroon	0.0064	0.0036	0.0026	0.0012	0.0013	0.0013	0.0009	0.0022	0.0026
Congo DR	0.0008	0.0023	0.0021	0.0003	0.0010	0.0014	0.0008	0.0023	0.0021
Ivory Coast	0.0072	0.0035	0.0058	0.0012	0.0014	0.0006	0.0009	0.0015	0.0009
Gambia	0.0132	0.0129	0.0103	0.0048	0.0066	0.0025	0.0076	0.0102	0.0020
Ghana	0.0054	0.0055	0.0066	0.0010	0.0010	0.0020	0.0008	0.0060	0.0136
Kenya	0.0069	0.0051	0.0031	0.0013	0.0020	0.0036	0.0013	0.0084	0.0016
Malawi	0.0017	0.0034	0.0010	0.0008	0.0022	0.0028	0.0011	0.0041	0.0047
Niger	0.0114	0.0042	0.0031	0.0052	0.0051	0.0025	0.0047	0.0084	0.0090
Uganda	0.0005	0.0008	0.0008	0.0002	0.0005	0.0011	0.0003	0.0008	0.0016
Zambia	0.0160	0.0055	0.0023	0.0051	0.0020	0.0018	0.0026	0.0097	0.0036
Zimbabwe	0.0058	0.0081	0.0016	0.0011	0.0024	0.0011	0.0023	0.0034	0.0017
Average	0.0068	0.0050	0.0036	0.0020	0.0023	0.0019	0.0021	0.0052	0.0039

The column labeled technical cooperation grants in table 3.4 reports average elasticity of productivity with respect to foreign R&D stocks through technical cooperation grants for 1980, 1990 & 2004. In contrast to R&D spillovers through imports, the estimated foreign R&D capital stocks through technical cooperation grants raised productivity in 8 out of

[28] The least developed countries sourced 59% of capital goods imports from developed countries during 2000-2005 down from 92% in the 1980s. This shift has been attributed largely to the rise of technologically advanced developing countries such as China, India, Korea, Singapore, Malaysia, Tunisia, and South Africa among others.

the 11 countries in the sample from 1980-1990. Foreign R&D spillovers through technical cooperation grants raised productivity on average by 0.002%, 0.0023% and 0.0019% in 1980, 1990 and 2004 respectively. At the country level, foreign R&D spillovers through technical cooperation raised productivity in six of the 11 countries from 0.0011% to 0.0036% during 1980-2004.

The ODA column in Table 2.4 reports the average elasticity of foreign R&D spillovers through overseas development assistance for 1980, 1990 and 2004. In contrast with the imports and technical cooperation grants, foreign R&D spillovers raised productivity in all 11 countries from 1980-2004 and in 9 out of the 11 countries from 1980-2004. The elasticity stayed the same from 1980-2004 in Ivory Coast and declined in Gambia. On average, foreign R&D spillovers through overseas development assistance raised productivity in all countries by 0.0021%, 0.0052% and 0.0039% in 1980, 1990 and 2004 respectively. The reported elasticities in table 3.4 are comparable to those found in the literature. Grilliches (1988) document that that studies for industrial countries typically find elasticities of total factor productivity with respect to foreign R&D capital stocks to be in the range of 0.06 to 0.1. Coe and Helpman (1995) find elasticities of total factor productivity with respect to foreign R&D capital stocks be in the range of 0.02 to 0.008 for the major industrial countries and in the range of 0.04 to 0.26 for the smaller industrial countries. Coe, Helpman and Hoffmaister (1997) observed that their coefficient of R&D capital stock of 0.7 was not theoretically feasible since factor shares of labor and capital sum up to unity.

Tables 2.5, 2.6 and 2.7 report estimates of elasticity of productivity in the Sub-Saharan African country indicated in the row with respect to the foreign R&D capital stock in the country indicated in the column[29]. For example, when domestic R&D capital stock of a G7 country i, S_i^d, increases by 1%, the foreign R&D capital stock of a Sub-Saharan African country j, S_j^f, rises by $\frac{m_i^j S_i^d}{\sum_j m_i^j S_i^d}$ percent, and country j's output rises by

$m^j \theta_j \frac{m_i^j S_i^d}{\sum_j m_i^j S_i^d}$ percent, where m^j is country j's import share and m_i^j is the fraction of j's imports coming from country i. Similar, estimates were computed using technical cooperation grants and overseas development assistance grants from G7 countries[30]. I will begin my discussion of the results in table 3.5. The results indicate that France, Germany, U.K and the United states were the main sources of foreign R&D spillovers for productivity growth in most Sub-Saharan African countries in 2004. In particular, 1% increase in domestic R&D capital in these countries raised productivity in Sub-Saharan African countries in the sample by an average of 0.0011%, 0.0008%, 0.0008%, and 0.0008% respectively. R&D investments in Canada and Japan have the least influence on productivity in Sub-Saharan African countries through trade.

France has the strongest effect on Francophone African countries, while U.S, U.K Germany respectively, have the strongest effect on the Anglophone African countries.

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[29] The focus on G7 countries is due largely to the fact that they account for nearly 92% of R&D investments worldwide. I however dropped Italy due to incomplete data on technical cooperation grants and overseas development assistance grants.

[30] The formula was taken directly from Coe and Helpman (1995).

The elasticities are reasonable when compared with similar estimates from studies focusing on OECD countries. Zhu and Jeon (2007) found elasticities to be in the range of 0.001 to 0.0223.

The estimated impact of productivity in a Sub-Saharan African from an increase in domestic R&D capital stock through technical cooperation grants mirrors that of imports. Specially, the results in table 3.5 indicate that U.S, France, Germany, and U.K respectively were the main sources of foreign R&D spillovers through technical cooperation for productivity growth in most Sub-Saharan African countries in 2004. In particular, a 1% increase in domestic R&D capital in these countries raised productivity in Sub-Saharan African countries in the sample by an average of 0.0007%, 0.0006%, 0.0005% and 0.0004% respectively. R&D investments in Canada and Japan again had the least influence on productivity in Sub-Saharan African countries through trade.

Table 2.5 Bilateral Elasticity of Productivity with Respect to R&D Stocks through Imports from G7 countries, 2004

	Canada	France	Germany	Japan	U.K	U.S
Cameroon	0.0000	0.0017	0.0005	0.0001	0.0002	0.0001
Congo DR	0.0001	0.0009	0.0008	0.0001	0.0002	0.0001
Ivory Coast	0.0001	0.0040	0.0005	0.0001	0.0009	0.0003
Gambia	0.0000	0.0017	0.0035	0.0004	0.0012	0.0035
Ghana	0.0001	0.0013	0.0016	0.0003	0.0016	0.0017
Kenya	0.0001	0.0003	0.0005	0.0001	0.0012	0.0006
Malawi	0.0000	0.0001	0.0004	0.0000	0.0003	0.0002
Niger	0.0000	0.0013	0.0002	0.0000	0.0014	0.0002
Uganda	0.0000	0.0001	0.0001	0.0000	0.0005	0.0001
Zambia	0.0000	0.0003	0.0002	0.0000	0.0004	0.0014
Zimbabwe	0.0000	0.0001	0.0004	0.0000	0.0005	0.0005
Average	0.0000	0.0011	0.0008	0.0001	0.0008	0.0008

The U.S and U.K had the strongest effect on Anglophone African countries, while France and Germany, had the strongest effect on the Francophone African countries. These findings may be due to a link between aid flow and donor interests. These interests often reflect colonial relationships, (Alesina and Dollar (2000), Wall (2008)).

The estimated impact of productivity in a Sub-Saharan African from an increase in domestic R&D capital stock through overseas development assistance grants also follows the patterns observed for imports and technical cooperation grants. However, the United Kingdom has the strongest impact on Sub-Saharan African countries in terms of the impact of R&D spillovers through overseas development assistance on productivity. In particular, 1% increase in domestic R&D capital stock in U.K raised productivity by

0.0022% on average in all the 11 countries in the sample. The percentage was as high as 0.0079% in Ghana alone.

Table 2.6 Bilateral Elasticity of Productivity with Respect to R&D Stocks through Technical Cooperation Grants from G7 countries, 2004

	Canada	France	Germany	Japan	U.K	U.S
Cameroon	0.0000	0.0004	0.0008	0.0000	0.0000	0.0000
Congo DR	0.0000	0.0002	0.0004	0.0000	0.0000	0.0007
Ivory Coast	0.0000	0.004	0.0001	0.0000	0.0000	0.0001
Gambia	0.0001	0.0004	0.0008	0.0004	0.0001	0.0008
Ghana	0.0000	0.0001	0.0005	0.0001	0.0005	0.0008
Kenya	0.0001	0.0002	0.0006	0.0002	0.0011	0.0015
Malawi	0.0001	0.0000	0.0005	0.0001	0.0009	0.0011
Niger	0.0001	0.0011	0.0007	0.0001	0.0000	0.0006
Uganda	0.0000	0.0000	0.0002	0.0000	0.0006	0.0007
Zambia	0.0000	0.0000	0.0003	0.0001	0.0004	0.0010
Zimbabwe	0.0000	0.0000	0.0003	0.0000	0.0002	0.0006
Average	0.0000	0.0006	0.0005	0.0001	0.0004	0.0007

France, Germany, Japan and the United respectively influenced productivity in Sub-Saharan African countries through overseas development assistance induced foreign R&D spillovers in 2004. In particular, France's ODA induced R&D spillovers raised productivity by 0.0009% compared with 0.0005% in Germany, Japan and U.S respectively.

The above analysis suggests that both technical cooperation grants and overseas development assistance grants are sources of R&D knowledge spillovers in Sub-Saharan

Africa. The results therefore shed some light on the effectiveness of aid on growth. That is aid may affect growth in Sub-Saharan Africa by raising productivity over time.

Table 2.7 Bilateral Elasticity of Productivity with Respect to R&D Stocks through Overseas Development Assistance(ODA) from G7 countries, 2004

	Canada	France	Germany	Japan	U.K	U.S
Cameroon	0.0001	0.0008	0.0013	0.0000	0.0004	0.0001
Congo DR	0.0001	0.0010	0.0008	0.0001	0.0061	0.0009
Ivory Coast	0.0000	0.0006	0.0001	0.0000	0.0001	0.0002
Gambia	0.0001	0.0002	0.0006	0.0002	0.0003	0.0006
Ghana	0.0002	0.0005	0.0007	0.0037	0.0079	0.0007
Kenya	0.0000	0.0001	0.0002	0.0001	0.0007	0.0005
Malawi	0.0001	0.0000	0.0004	0.0002	0.0036	0.0006
Niger	0.0001	0.0063	0.0008	0.0004	0.0008	0.0006
Uganda	0.0000	0.0000	0.0002	0.0001	0.0009	0.0005
Zambia	0.0001	0.0007	0.0004	0.0001	0.0020	0.0005
Zimbabwe	0.0000	0.0000	0.0002	0.0000	0.0012	0.0002
Average	0.0001	0.0009	0.0005	0.0005	0.0022	0.0005

2.4.3 Aid, Policies and Growth

There is an on-going debate about the effectiveness of aid on growth. Some have suggested that aid improves growth in good policy environments, Burnside and Dollar (2000). Burnside and Dollar's conclusion therefore suggests that donor countries that desire growth and poverty reduction should channel their aid to developing countries with good policies. In order to provide evidence to shed some light on the debate about the effectiveness of aid on growth, I first used the average inflation rate as a proxy for monetary policy and interacted this variable with the foreign R&D spillovers through imports, technical cooperation and overseas development assistance grants. The results are reported in table 3.8. Notice that I also control for human capital and patent protection.

The coefficient of foreign R&D spillovers is interacted with inflation. In this context, the interaction term refers to countries with bad policies as reflected in higher inflation. The coefficients of foreign R&D spillovers through imports, technical cooperation and overseas development assistance grants interacted with inflation were not significant.

However, the coefficient for countries with good policies were positive and significant implying that, foreign R&D spillovers through imports, technical cooperation grants and ODA grants influence productivity in Sub-Saharan African countries with good policies but not in bad policy environments. This result thus confirm the findings of Burnside and Dollar(2000) in the sense that increases in productivity would usually be reflected in higher growth since productivity is a major determinant of economic growth.

Table 2.8 Policy Environment and Foreign R&D Spillovers through Imports, Technical Cooperation Grants and ODA Grants
(Dynamic OLS (DOLS) Estimation, Within, Fixed Effects, 1980-2004, 11 Countries)

	Imports	Technical Cooperation Grants	ODA Grants
Human Capital	0.173 (3.485)	0.156 (2.816)	0.196 (2.646)
Patent	0.090 (6.567)	0.111 (9,327)	0.127 (10.809)
Inflation × m_i × log(Spillover–imports)	-0.023 (-0.528)		
m_i × log (Spillover–imports)	0.043 (3.022)		
Inflation × t_i × log (Spillover–tcoop)		0.006 (0.028)	
t_i × log (Spillover–tcoop)		0.159 (3.045)	
Inflation × o_i × log (Spillover–ODA)			-0.035 (-0.515)
o_i × log (Spillover –ODA)			0.088 (2.231)
R^2	0.94	0.94	0.94
$\bar{R}^2$	0.93	0.93	0.93
Panel observations	253	253	253

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. Log(Spillover-imports) refers to bilateral import weighted R&D spillovers, LOG(Spillover-tcoop) refers to technical cooperation grants weighted R&D spillovers, Log(Spillover-ODA) refers to overseas development assistance grants weighted R&D spillovers. mi, ti, and oi refers to the ratio of imports, technical cooperation grants, and ODA grants to GDP respectively. All regressions include unreported country fixed effects. The DOLS regressions include zero leads and one lag of the differenced regressors.

The second approach used to shed light on the link between aid and growth is based on the average elasticity of total factor productivity with respect to foreign R&D capital stocks in the G7 countries reported in tables 3. The World Bank classified adjusting countries in Africa using their progress in terms of fiscal, monetary and exchange rate policies in the 1980s under the structural adjustment program implementation. The review report was based on estimates from 1990-1991. A composite index based on these three policies were constructed and used to rank the adjusting countries' overall macroeconomic policy stance. Since a recent classification does not exist, and lack of the relevant data makes it difficult to replicate their approach, I decided to use the 1990-1991 ranking. Ghana was ranked as adequate, Gambia, Kenya, Malawi, and Uganda were ranked as fair, Zimbabwe and Niger were ranked as poor. Finally Cote d'Ivoire, Cameroon, and Zambia were ranked as very poor. Congo DR. was not part of the study.

I matched the overall macroeconomic policy rank during the 1990-1991 period with their foreign R&D knowledge spillovers through imports, technical cooperation grants and ODA grants for 1980, 1990, and 2004. Countries that were ranked higher such as Ghana, Gambia Kenya and Uganda appear to benefit more from foreign R&D spillovers through imports, technical cooperation grants and overseas development assistance grants even after controlling for human capital and patent protection. However, Niger appears to have benefited significantly from foreign R&D spillovers, although it was ranked as poor in terms of its overall macroeconomic policy stance from 1990-1991[31].

Finally, I also compared the effect of foreign R&D capital stock through technical cooperation grants and overseas development assistance before and after 1990 to

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[31] It would be preferable to have more recent data. Much has changed since 1991 in these countries. Although the analysis in this section is suggestive of the existence of a relationship between aid and growth, readers should exercise due caution.

determine whether there has been a significant shift in spillovers over the last two decades. In particular, Since the first phase of the adjustment programs ended in 1990, I defined two dummy variables representing the period before 1990 and after 1990[32]. The results are reported in table 3.9. The results in column (2) suggest that R&D spillovers through technical cooperation grants were higher during 1980-1989 than the 1990-2004 on average. By contrast, foreign R&D spillovers through ODA grants were higher after 1990.

2.4.4 Determinants of Aid Allocation in Sub-Saharan Africa

A number of studies have suggested that aid allocation is influenced by colonial relationships, population size and to a large extent income levels, (Alesina and Dollar (2000), Wall (2008), Burnside and Dollar (2000)). To tests this hypothesis, I interacted the log of population with foreign R&D spillovers through technical cooperation grants and ODA grants. The results are reported in table 2.10. The evidence suggests that larger Sub-Saharan African countries benefit more from aid induced R&D spillovers. This evidence do not support the conclusions of earlier studies that aid allocation is influenced in part by population with smaller countries benefiting more from aid allocation to developing countries.

Aid is also believed to flow to countries based on their colonial origins with aid from France for example flowing more to Francophone developing countries and aid from the U.K flows more to former British colonies. To investigate this hypothesis, I

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[32] Please note that the starting dates of adjusting countries vary. However, most countries in my sample started the implementation around early to mid 1980s.

used the average elasticity of productivity in each Sub-Saharan African country in the sample with respect to the R&D capital stock of each G7 country except Italy. The argument is that, since a larger volume of aid from a G7 country raises aid induced learning and therefore explains a greater share of the productivity in Sub-Saharan African countries, it is reasonable to use the elasticities of productivity with respect to foreign R&D spillovers through technical cooperation grants and overseas development assistance grants in each G7 country to determine its importance to productivity in each Sub-Saharan African country. The results are reported in tables 2.5 and 2.6. The evidence clearly show the impact of foreign R&D capital stock from France on productivity in Sub-Saharan African countries is strongest in the Francophone countries while elasticities of foreign R&D capital stock from U.K on productivity in Sub-Saharan African countries is strongest in the Anglophone African countries. This clearly confirms the hypothesis advanced by (Alesina and Dollar (2000), Wall (2000)) that aid allocation is heavily influenced by donor interest.

2. 5 Conclusion

Recent studies investigating the relationship between knowledge externalities and productivity have suggested that R&D spillovers are trade related, (Coe and Helpman (1995), Xu and Wang (1999)). In this paper I presented evidence which showed that technical cooperation grants and overseas development assistance grants are alternative channels through which returns to investments in G7 countries enhance productivity in Sub-Saharan African countries.

My estimates suggest that a 1% increase in domestic R&D capital stock in G7 countries would raised productivity on average by 0.0021% , 0.0033% and 0.0044% through technical cooperation grants, overseas development assistance grants and imports of intermediate goods from 1980-2004. This evidence thus lends support to the hypothesis that international R&D knowledge spillovers are trade related. The evidence also supports the hypothesis that aid flow is influenced by colonial past. Aid flow also had the highest effects on productivity in countries with good policies and also by population. Aid induced R&D spillovers appear to have raised productivity more in smaller countries than larger countries[33].

The study findings have some implications for policy. First, donor countries may focus on technical cooperation grants and overseas development assistance grants and more broadly on grants that facilitates knowledge accumulation in developing countries if their desire is to improve productivity and growth in Sub-Saharan African countries. Second, the study also provides some empirical support to earlier claims that aid induced learning effects do raise productivity and hence growth in countries with good policies. Consequently, donor aid allocation may target Sub-Saharan African countries with good policies if their goal is to increase economic growth and reduce the widespread poverty in Sub-Saharan Africa or focus aid on improving institutions.

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[33] There is no specific definition for a small or large population.

Appendix 2.A

Table 2.9 Foreign R&D Spillovers Before and After Structural Adjustment Program (Dynamic OLS (DOLS) Estimation, Within, Fixed Effects, 1980-2004, 11 Countries)

	Imports	**Technical Cooperation Grants**	**Overseas Development Assistance Grants**
Human Capital	0.175 (3.481)	0.161 (2.967)	0.208 (2.641)
Patent	0.096 (6.206)	0.115 (9.658)	0.127 (10.890)
Pre-SAP × m_i × log (Spillover –imports)	0.0361 (3.974)		
Post-SAP × m_i × log (Spillover –imports)	0.036 (3.169)		
Pre-SAP × t_i x log (Spillover –tcoop)		0.143 (3.352)	
Post-SAP ×t_i × log (Spillover –tcoop)		0.122 (1.945)	
Pre-SAP × o_i × log (Spillover –ODA)			0.069 (2.906)
Pre-SAP × o_i × log (Spillover –ODA)			0.095 (2.207)
R^2	0.95	0.94	0.94
$\bar{R}^2$	0.94	0.93	0.93
Panel observations	253	253	253

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. LOG(Spillover-imports) refers to bilateral import weighted R&D spillovers, LOG(Spillover-tcoop) refers to technical cooperation grants weighted R&D spillovers, LOG(Spillover-ODA) refers to overseas development assistance grants weighted R&D spillovers. mi, ti, and oi refers to the ratio of imports, technical cooperation grants, and ODA grants to GDP respectively. All regressions include unreported country fixed effects. The DOLS regressions include zero leads and one lag of the differenced regressors.

Table 2.10 Population Size and Foreign R&D Spillovers through Imports, Technical Cooperation Grants and ODA Grants (Dynamic OLS (DOLS) Estimation, Within, Fixed Effects, 1980-2004, 11 Countries)

	Imports	**Technical Cooperation Grants**	**Overseas Development Assistance Grants**
Human Capital.	0.147 (3.755)	0.124 (2.298)	0.181 (3.154)
Patent	0.071 (4.95)	0.108 (10.727)	0.126 (10.227)
Population × m_i × log (Spillover –imports)	0.044 (3.548)		
m_i x log (Spillover –imports)	0.021 (3.325)		
Population x t_i x log (Spillover –tcoop)		0.178 (2.197)	
ti x log (Spillover –tcoop)		0.096 (2.168)	
Population x oi x log (Spillover –ODA)			0.025 (0.688)
oi x log (Spillover –ODA)			0.065 (3.001)
R^2	0.95	0.94	0.94
$\bar{R}^2$	0.94	0.93	0.93
Panel observations			

Note: The dependent variable is Log(GDP per worker). Numbers in brackets are t-statistics. LOG(Spillover-imports) refers to bilateral import weighted R&D spillovers, LOG(Spillover-tcoop) refers to technical cooperation grants weighted R&D spillovers, LOG(Spillover-ODA) refers to overseas development assistance grants (ODA) weighted R&D spillovers. mi, ti, and oi refers to the ratio of imports, technical cooperation grants, and ODA grants to GDP respectively. All regressions include unreported country fixed effects. The DOLS regressions include zero leads and one lag of the differenced regressors.

Table 2.11 List of Countries

Sub-Saharan African Countries	**OECD Countries**
Cameroon	United States
Congo DR	United Kingdom
Ivory Coast	Canada
Gambia	Japan
Ghana	Germany
Kenya	France
Malawi	
Niger	
Uganda	
Zambia	
Zimbabwe	

Appendix 2.B

Data Sources and Variable Definition

The dependent variable is labor productivity, measured as real GDP per worker (LRGDPW). Data for this variable was taken from the Penn World Tables version 6.3. A number of studies have suggested various approaches for measuring foreign R&D capital stock. In this paper, I follow the literature and adopt the approaches of (Coe and Helpman(1995) and Lichtenberg and van Pottelsberghe (1998)).

Coe and Helpman (1995) measure import weighted foreign R&D capital stock of a developing country i as a weighted average of domestic R&D capital stock of the trading partner, where the weights are the bilateral import-share of a developing country.

$$S_{li} = \sum_{j'i} w_{ij} S_j^d$$

$$w_{ij} = \frac{M_{ij}}{\sum_{j \neq i} M_{ij}}, \qquad \sum_{j \neq i} w_{ij} = 1$$

where S_j^d denotes domestic R&D capital stock of trading partner j. The R&D expenditure for the business sector comes from OECD directorate of Science, Technology and industry, published in the Main Science and Technology Indicators. M_{ij} denotes country i's imports of goods and services from country j. The bilateral imports which are on a c.i.f basis are from IMF's Direction of Trade Statistics (DOT) online database.

I used Coe, Helpman and Hoffmaister's dataset on domestic R&D capital stock to construct my foreign R&D capital stock variable. Coe, Helpman and Hoffmaister constructed the domestic R&D capital stock using the perpetual inventory method: $S_t^d = (1-\delta)S_{t-1}^d + RD_{t-1}$. where δ = 0.05 is the depreciation rate. Data for business sector R&D expenditure was obtained from Directorate of Science Technology, and Industry published in Main Science and Technology Indicators. The initial R&D capital stock was obtained as

$$S_{1970} = \frac{RD_{1970}}{\delta + g}$$

where g is the annual average logarithmic growth rate from 1970 -1985. That is:

$$g = \log\left(\frac{RD_{1985}}{RD_{1970}}\right)/15$$

Foreign R&D spillovers through technical cooperation grants and overseas development assistance grants are constructed using the same approach as the import weighted foreign R&D spillovers. The difference arises from the weights used. Technical cooperation grants are "activities financed by a donor country whose primary purpose is to augment the level of knowledge, skills, technical know-how or productive aptitudes of the population of developing countries, i.e., increasing their stock of human intellectual capital, or their capacity for more effective use of their existing factor endowment" OECD (2009). ODA Grants "covers transfers, in money or in kind, for which no repayment is required. It includes grants for technical co-operation, grant-like flows, i.e., loans extended by governments or official agencies in currencies of the donor countries but repayable in recipients' currencies and transfer of resources through sales of commodities for recipients' currencies, less local currency balances used by the donor for other than development purposes (for example, to defray the local costs of embassy operations). The following are excluded: reparations and indemnification payments to private individuals, insurance and similar payments to residents of developing countries, and loans extended in and repayable in recipients' currencies",(OECD(2009)). Technical cooperation grants and overseas development assistance grants was obtained from OECD International Development Statistics Financial Flows - Part I (Developing Countries) *Vol 2009 release 01*

I measure human capital as the secondary school enrollment as a percentage of secondary school aged population in each country. The data for this variable was obtained from UNESCO online education database. The index of patent protection ranges from 1(lowest protection) to 5 (highest protection). Data on the index of patent protection come from (Park and Lippoldt (2005)).

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CHAPTER THREE: THE ROLE OF EXPORT RELATIONSHIPS IN THE INTERNATIONAL TRANSMISSION OF KNOWLEDGE: EVIDENCE FROM DISAGGREGATED DATA FROM OECD COUNTRIES.

3.0 Introduction

Studies on trade as a vehicle for knowledge diffusion have for the most part focused on knowledge embodied in imports of intermediate goods with mixed results, (Coe and Helpman(1995), Coe, Helpman and Hoffmaister(1997,2008), Keller(1999), Xu and Wang(1999), Kao and Chiang(1999)). Disembodied knowledge diffusion arising from pure idea exchange involving domestic firms and their foreign purchasing agents has received limited attention in the trade and foreign R&D literature[34]. The approach in this chapter deviates from the focus on imports as a vehicle for knowledge spillovers and instead emphasizes the importance of outward orientation to domestic productivity through pure idea exchange involving exporters and their foreign purchasing agents.

According to (Grossman and Helpman(1991, page 166)), the relationship between a country's exporters and their foreign purchasing agents may lead to the exchange of ideas and thereby improve the manufacturing process and productivity in the exporting country. The suggestions may take the form of ideas for new intermediate inputs or improvements of existing inputs. The number of such suggestions is likely to increase with the quantity of goods exported. Since foreign markets are competitive, exporters

[34] Funk studied export patterns and international R&D spillovers among OECD countries.

have incentives to implement the suggestions of foreign purchasing agents in order to avoid loss of market share to competitors.

The purpose of this study is to test Grossman and Helpman's hypothesis using disaggregated data on exports among OECD countries. I distinguish between learning effects of capital goods exports and non-capital goods exports. The distinction between capital goods and non-capital goods trade is important for three reasons: First, it enables me to examine what kinds of traded goods bear the greatest learning effect and, hence, best explain a country's productivity and long-term growth[35]. Moreover, the theory of trade related R&D spillovers is more consistent with capital goods trade than total trade and has been found to perform better empirically, (Coe, Helpman and Hoffmaister(1997), Xu and Wang(1999)). Second, capital goods tend to have higher technology content than non-capital goods and by implication should bear the greatest learning effects and hence, best explain a country's enduring growth than non-capital goods, (Chuang (1998), Xu and Wang (1999)). This study therefore provides empirical evidence to test this hypothesis.

Third, an analysis of the capital goods exports in my sample suggests wide variation in the share of capital goods exports in total exports across OECD countries and also over time. In particular, Figure 1 plots the share of capital goods exports for four

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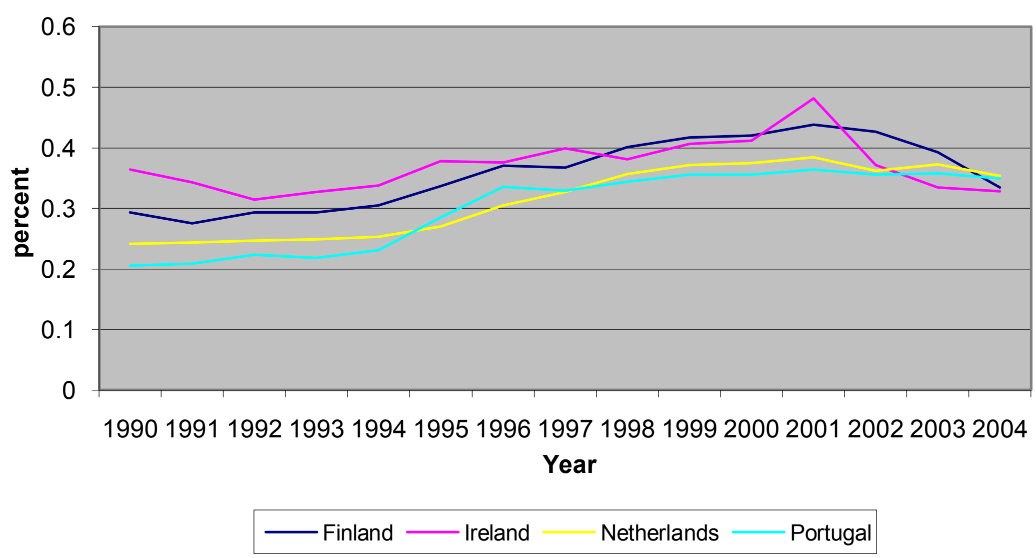
[35] Westphal et al (1984) studied Korea's exports of capital goods and related Services and their effects on its development strategy and the way they conform to its dynamic comparative advantage. They find that production of certain categories of capital goods appear to reflect the specifications of foreign purchasing agents. However, it was unclear what fraction of the capital goods exports were based on new knowledge that originated from Korea's entrepreneurs rather than imitations of existing technologies produced in the west.

OECD countries from 1990-2004: Finland, Ireland, Netherlands and Portugal. The share of capital goods exports was relatively stable from 1990-1994 before trending upwards to a peak around 2001. It then declined in all four countries thereafter. There is also considerable variation in the share of capital goods exports across countries. In particular, it varies from an average of 0.076 in Greece to 0.81 in Japan from 1990-2004. Thus, studies that used total trade may distort the measure of foreign R&D spillovers embodied in total trade. This study avoids the high level of aggregation and its potential distortionary effects on the measurement of R&D spillovers variable and thus sheds light on the relationship between exports induced learning effects and productivity by distinguishing between capital goods and non-capital goods learning effects.

Figure 3.1 Capital Goods Exports to OECD countries as a Share of Total Exports



The empirical strategy consists of constructing capital goods and non-capital goods exports weighted average of domestic R&D capital stocks of trade partners as proxies for export-induced international R&D knowledge spillovers in a regression equation that also controls for domestic R&D capital stock, human capital and patent protection. I then examine the relationship between export-induced learning effects and productivity by computing the elasticities of total factor productivity with respect to exports induced international R&D spillovers using dynamic OLS technique. This comparison would enable me to examine which categories of export goods bear the greatest learning effects and thus, best explain a country's productivity and long-run growth. As a robustness check, I also constructed total exports-weighted R&D spillovers variable and compared its relationship with total factor productivity with that of capital goods exports and non-capital goods exports.

I find empirical support for the hypothesis that the relationship between exporters and their foreign purchasing agents may lead to the exchange of ideas that enhances the manufacturing process and thus raises domestic productivity. In particular, a one percent increase in bilateral exports weighted foreign R&D stocks results in about 0.0011% increase in domestic productivity. Similarly, a one percent increase in bilateral capital goods exports weighted foreign R&D stocks results in about 0.0028% increase in domestic productivity. Finally, a one percent increase in bilateral non-capital goods exports weighted foreign R&D stocks results in about 0.0018% increase in domestic productivity.

The study is related to some earlier theoretical and empirical studies that examined the issue of exports and knowledge accumulation. In particular, (Chuang (1998)) developed a growth theory of trade -induced learning and showed that exports and imports are equally important sources of trade related learning. However, the nature or characteristics of the traded goods influence the effect of learning. In particular, according to Chuang, trading goods with a greater extent of learning (e.g., compare manufactured goods with agricultural products) accelerates the effect of trade-induced learning and hence enduring growth. What is lacking in Chuang's opinion is empirical tests on what kinds of traded goods bear the greatest learning effect and, hence, best explain a country's enduring growth. This study seeks to identify such evidence for exports among OECD countries.

This paper is also closely related to the work of (Funk (2001)) who examined export patterns and international R&D spillovers among OECD countries. Funk argued that knowledge embodied in imports must first be extracted and then applied by local researchers to enhance firm efficiency and productivity. Unless this process is successful, the impact of an imported intermediate has a one time, static effect. However, the knowledge acquired by advanced countries through export relationships may be exploited further through learning-by-doing as the exporter produces for the external market, (Feeney (1999)).

Funk therefore constructed a new foreign R&D measure by using the same domestic R&D capital stocks data first used by (Coe and Helpman (1995)), but with bilateral export shares as weights instead of the bilateral import shares commonly used in the literature. This approach in Funk's opinion removes the emphasis from knowledge acquired through direct, hands-on experience with imported intermediate inputs and places more emphasis on the pure idea exchange and knowledge spillovers gained from formal and informal contacts". However, as he noted in his conclusion, his paper does not differentiate between the types of goods and services being traded and therefore may suffer from aggregation bias. The current study follows Funk's approach of constructing the export weighted foreign R&D spillovers but distinguishes between capital goods export weighted R&D spillovers and non-capital goods export weighted R&D spillovers in order to assess the relative learning effects of different categories of exported goods and how they explain productivity.

The paper is also closely related to a number of case studies on the relationship between foreign R&D spillovers and productivity, (Westphal et al (1984), Bernstein(1996), Park(1995), Bernstein and Mohnen(1998) , Branstetter (1996)). In particular, (Westphal et al (1984)), examined Korea's exports of capital goods and related services and their effects on its development strategy and the way they conform to its dynamic comparative advantage. The study involved five kinds of project-related exports: overseas construction, plant exports, direct investment, licensing and technical agreements, and consulting services. They find that "the bulk of this export activity appears to have been performed in accord with detailed specifications provided by the purchaser". However, existing evidence is based largely on aggregated data and therefore only measures the overall effects of international R&D spillovers but not the relative importance of R&D spillovers embodied in trade. This study provides evidence based on disaggregated data among OECD countries.

Xu and Wang(1999) decomposed total imports into capital goods imports and non-capital goods imports and calculated the capital goods imports and non-capital goods imports weighted R&D spillovers in (Coe and Helpman(1995)) regressions. They find that, the capital goods import weighted-R&D spillover variable explained more of the variation in productivity across countries than the total imports weighted R&D spillovers variable. They also find that the non-capital goods import weighted R&D spillovers variable was statistically insignificant. The focus of this paper is on export- induced learning.

The rest of the paper is organized as follows: section 3.1 discusses the empirical model. Section 3.2 discusses key features of the data. Section 3.3 discusses the empirical results. Concluding remarks are discussed in section 3.4.

3.1 The Empirical Model

The model discussed in this section reflects the important features of the endogenous framework due to (Romer (1990), Grossman and Helpman(1991), Aghion and Howitt (1992)). The form as discussed in this section is based on (Coe, Helpman and Hoffmaister (1997)) empirical model extended to reflect international R&D spillovers due to pure idea exchange between exporters and their foreign purchasing agents. Coe, Helpman and Hoffmaister begin with a Cobb-Douglas production function of the form:

$$\mathrm{LogY} = \mathrm{LogA} + \beta \mathrm{LogK} + \gamma \mathrm{LogL_Y} + (1-\beta-\gamma)\mathrm{LogD} \tag{0.18}$$

Where Y is output, A is a constant, β and γ are parameters between zero and one. L_Y is labor employed in the final goods sector, D is the CES index of intermediate inputs. Assume the index D takes the form:

$$D = \left[\int_0^n x\ j^{\ 1-\alpha}\right]^{1/1-\alpha} \tag{0.19}$$

where n is number of intermediate inputs available and note that n may vary across countries and over time. x(j) are horizontally differentiated intermediate inputs which are assumed to be imperfect substitutes, $\alpha > 1$ is the elasticity of substitution. Since the different varieties of intermediate inputs are imperfect substitutes, in a symmetric equilibrium, the different varieties of inputs would bear the same price and manufacturers of final goods would employ equal quantities of each. It can therefore be shown that in equilibrium,

$$D = n^{1/\alpha-1} L_D \tag{0.20}$$

Where L_D is labor employed in the manufacturing of intermediates x(j). Plugging (0.20) into (0.18) and using the market clearing condition $L = L_Y + L_D$ yields

$$\log Y = \log B + \beta \log K + (1-\beta)\log L + [\frac{(1-\beta-\gamma)}{\alpha-1}]\log n \tag{0.21}$$

where B is a constant.

If total factor productivity is defined as as $\log F = \log Y - \beta \log K - (1-\beta)\log L$, then (4) can be re-written as:

$$\log F = \log B + [\frac{(1-\beta-\gamma)}{\alpha-1}]\log n \qquad (0.22)$$

That is, productivity in a country can be expressed as a function of the number of available varieties of intermediate inputs. Externally oriented countries may also benefit from intermediate inputs of its trade partners. Equation (0.22) can be re-written in a panel format as follows:

$$\mathrm{LogF}_{it} = \eta_i + \theta_{1t}\mathrm{LogDRD}_{it} + \theta_{2t}\left[m_{it}\log\left(\sum_{j\neq i}\frac{M_{ijt}}{M_{it}}\mathrm{FRD}_{it}\right)\right] + \theta_{3t}T_t + \varepsilon_{it} \qquad (0.23)$$

Where i denote countries and t denotes time periods. F is total factor productivity, η_i captures individual country-specific effects, DRD are the domestic R&D capital stock, m_i is the ratio of imports to GDP. m_i is often interacted with the foreign R&D capital stock (FRD) to make it reflect the differences in import intensities, so that a country that imports more capital goods from the industrial countries should benefit more from foreign R&D spillovers. M_{ij} denotes bilateral imports country i from trade partner j, T is a time trend and ε is a white noise error term. Equation (0.23) captures the key elements of the baseline model used by (Coe and Helpman (1995), Coe, Helpman and Hoffmaister (1997)).

I extend the baseline equation of (Coe and Helpman (1995)) in (0.23) by including capital goods and non-capital goods export weighted foreign R&D spillovers.

As a robustness check, I also include total exports weighted international R&D spillovers. The goal is to examine the link between different categories of capital goods exports and international R&D spillovers among OECD countries and compare that to disembodied knowledge diffusion through total goods exports. The augmented equation thus takes the form:

$$\begin{aligned}
\mathrm{LogF}_{it} = {} & \eta_i + \theta_{1t}\left[e_{0it}\log\left(\sum_{j\neq i}\frac{\mathrm{texp}_{ijt}}{\mathrm{texp}_{it}}\mathrm{FRD}_{jt}\right)\right] + \theta_{2t}T_t + \theta_{3t}H_{it} \\
& + \theta_{4t}\mathrm{patent}_{it} \\
& + \theta_{5t}\left[e_{1it}\log\left(\sum_{j\neq i}\frac{\mathrm{cap}_{ijt}}{\mathrm{cap}_{it}}\mathrm{FRD}_{jt}\right)\right] \\
& + \theta_{6t}\left[e_{2it}\log\left(\sum_{j\neq i}\frac{\mathrm{noncap}_{ijt}}{\mathrm{noncap}_{it}}\mathrm{FRD}_{jt}\right)\right] + \varepsilon_{it},
\end{aligned} \tag{0.24}$$

where F is total factor productivity, η captures individual country-specific effects[36], texp refers to total exports, e_0, e_1, and e_2 are ratios of total exports, capital goods exports and non-capital goods exports as a percentage of GDP. They are interacted with the logarithm of foreign R&D spillovers variable to ensure that it reflects the intensity of exports among OECD countries. FRD refers to the foreign R&D capital stock,

$\log\left(\sum_{j\neq i}\frac{\mathrm{texp}_{ijt}}{\mathrm{texp}_{it}}\mathrm{FRD}_{jt}\right)$ is the total export weighted R&D spillovers,

$\log\left(\sum_{j\neq i}\frac{\mathrm{cap}_{ijt}}{\mathrm{cap}_{it}}\mathrm{FRD}_{jt}\right)$ is the capital goods exports weighted R&D spillovers,

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[36] I also include time effects in all regression equations.

$\log\left(\sum_{j \neq i} \frac{\text{noncap}_{ijt}}{\text{noncap}_{it}} \text{FRD}_{jt}\right)$ is the non-capital goods exports weighted R&D spillovers. H denotes human capital, T is a time trend and patent is an index of patent protection[37].

A positive θ_1 implies that the effect of total export weighted foreign R&D capital stock on domestic productivity is larger the greater is the quantity of goods exported, and the effect of export-induced learning on productivity is larger the larger is the foreign R&D capital stock. A positive θ_5 implies that the effect of capital goods exports weighted foreign R&D capital stock on domestic productivity is larger the greater is the quantity of capital goods exported, and the effect of capital goods exports-induced learning on productivity is larger the larger is the foreign R&D capital stock. Finally, a positive θ_6 implies that the effect of non-capital goods exports weighted foreign R&D capital stock on domestic productivity is larger the greater is the quantity of non-capital goods exported, and the effect of non-capital goods exports -induced learning on productivity is larger the larger is the foreign R&D capital stock.

I also control for the effects of human capital measured as the average years of school completed. The quality of human capital may have both direct effects and indirect effects on productivity. In particular, a quality workforce may facilitate the transformation of new ideas into improved intermediate inputs or new intermediate inputs that would ultimately enhance firm level efficiency and productivity across the economy. I also control for strength of a country's intellectual property rights protection measured

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[37] Please see appendix B for the definitions and sources of variables used in the study.

as an index of patent protection. Patent protection may also raise productivity directly and indirectly by providing incentives to firms to invest more in R&D, (Coe, Helpman and Hoffmaister(2008)).

The specifications (0.24) differs from that used by (Coe, and Helpman(1995)) in three ways: First, I focus on exports induced foreign R&D spillovers. The relationship between exporters and their foreign purchasing agents have been suggested as possible channels of knowledge diffusion. Second, I emphasize capital goods exports non-capital goods exports rather than total exports which is more consistent with the theory and does a better job empirically, (Coe, Helpman and Hoffmaister (1997)). Finally, I also control for patent protection.

3.2 Data.

The study results are obtained using pooled data for 19 OECD countries over the period 1990-2004. This time period was selected because disaggregated data on exports for OECD countries was only available from 1988 and some countries did not have complete data for 1988 and 1989. Table 3.0 summarizes data for all countries in the sample[38].

Table 3.1 compares total factor productivity in 2004 with the level in 1990. There is striking variation in total factor productivity across countries and also over time. In

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[38] Variable sources and definitions have been discussed in appendix B.

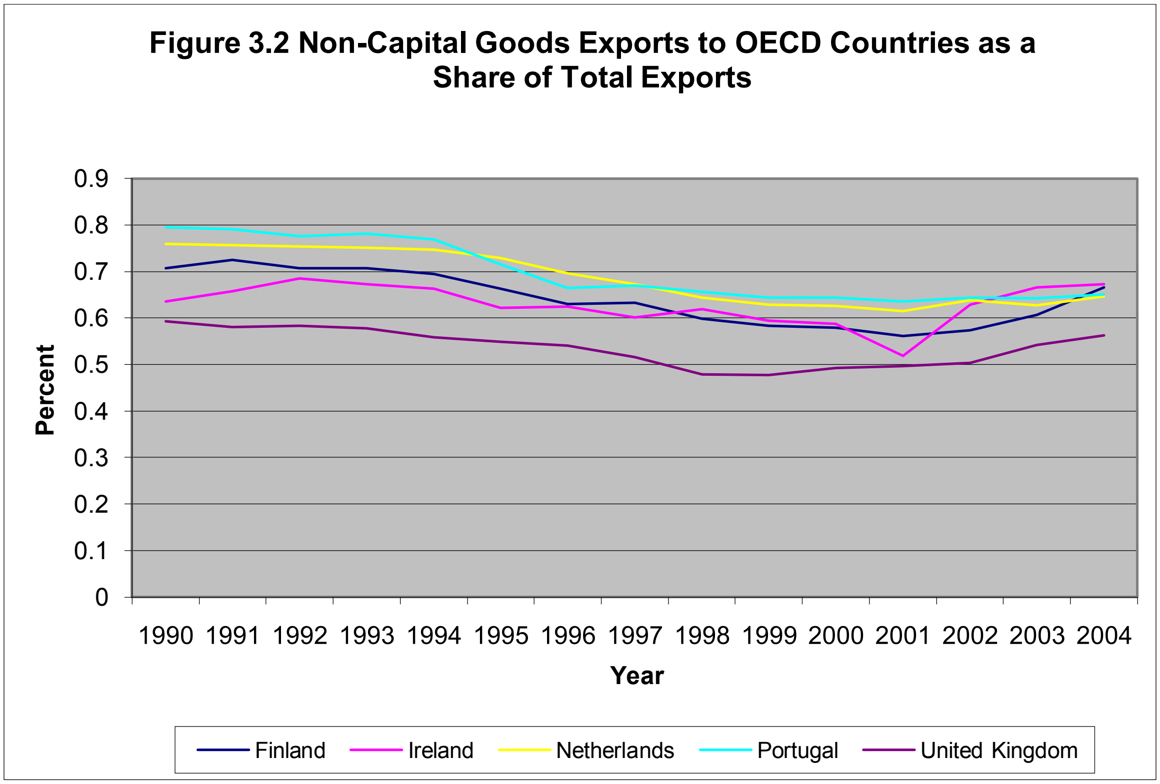
particular, while total factor productivity in 2004 for Switzerland, Spain and Italy was not very different from the level in 1990, it increased by an average of about 10-20% in 2004 for ten of the 19 OECD countries. In Australia, Finland, Ireland, Norway, Sweden and U.K, total factor productivity increased on average between 26-70% in 2004. Total factor productivity increased by about 22% and 16% for all the 19 countries and G7 countries respectively.

Table 3.1 also compares the bilateral export weighted foreign R&D capital stocks for a sample of 19 OECD countries in 2004 to the level in 1990. Columns 3, 4, and 5 show that bilateral export weighted foreign R&D spillovers increased dramatically in all 19 countries in 2004. Since domestic R&D capital stocks were weighted by bilateral exports, bilateral capital goods exports and bilateral non-capital goods exports, changes in the foreign R&D capital stock variable reflects changes in the exports of the three categories of goods from the 19 OECD countries. However, Figure 1 and 2 show that the share of capital goods exports in total exports for Finland, Ireland, Netherlands and Portugal increased from 1990-2004 whiles the share of non-capital goods in total exports over the same period declined.

Table 3.1 Total Factor Productivity and Bilateral Export Weighted Foreign R&D Capital Stocks

Country	$\frac{F_{2004}}{F_{1990}}$	$\frac{Texp_{2004}}{Texp_{1990}}$	$\frac{Cap_{2004}}{Cap_{1990}}$	$\frac{Noncap_{2004}}{Noncap_{1990}}$
Australia	1.294	1.741	1.694	1.720
Belgium	1.156	1.857	1.607	1.959
Canada	1.198	1.738	1.587	1.864
Denmark	1.178	1.633	1.769	1.563
Finland	1.411	1.775	1.678	1.801
France	1.163	1.680	1.576	1.735
Germany	1.120	1.933	1.962	1.864
Greece	1.188	1.682	1.642	1.707
Ireland	1.697	2.371	2.716	2.201
Italy	1.050	1.664	1.778	1.601
Japan	1.143	1.575	1.565	1.625
Netherlands	1.100	1.723	1.645	1.718
Norway	1.497	1.770	1.759	1.784
Portugal	1.202	1.634	1.994	1.450
Spain	1.003	1.341	1.508	1.247
Sweden	1.262	1.853	1.545	2.177
Switzerland	1.013	1.835	1.935	1.781
United Kingdom	1.270	1.855	1.769	1.913
United States	1.167	1.505	1.662	1.366
Average	1.216	1.746	1.757	1.741
Maximum	1.697	2.371	2.716	2.201
Minimum	1.003	1.341	1.508	1.247
G7 Average	1.159	1.707	1.700	1.710

Table 3.2 reports the average ratios of total exports, capital goods exports and non-capital goods exports as a percentage of GDP for all 19 countries from 1990-2004. The results show a striking variation in the ratio of total exports to GDP. In particular, average the ratio from 1990-2004 was less than 10% in Greece, the United States, and Australia. However, the ratio was over 50% in Belgium and Ireland.



For another 13 countries, the average ratio of total exports to GDP from 1990-2004 was in the range from 12-34%. The average ratio of capital goods to GDP from 1990-2004 also follows a similar pattern although none of the 19 countries had a ratio exceeding 50% of GDP.

However, the ratio varied from 0.007 in Australia to 0.209 in Ireland. Similarly, the ratio of non-capital goods to GDP for all 19 countries varied from 0.009 in Japan to 0.388 in Belgium. Human capital measured as average years of school completed by people who are 25 years or older also ranged from 6.752 in Italy to 12.186 in the United

States. Australia, Canada, Denmark, Norway, Sweden, Switzerland and the United States had averages exceeding 10. Values of the patent protection index were relatively similar.

Table 3.2 Ratio of Exports as a percentage of GDP

	Average 1990-2004				
Country	**Ratio of Total Exports to GDP**	**Ratio of Capital Goods Exports to GDP**	**Ratio of non-Capital Goods Exports to GDP**	**Human Capital**	**Patent Protection**
Australia	0.066	0.007	0.058	10.428	3.988
Belgium	0.565	0.178	0.388	8.634	4.560
Canada	0.280	0.115	0.165	11.194	4.282
Denmark	0.224	0.067	0.157	10.052	4.468
Finland	0.204	0.074	0.130	9.944	4.270
France	0.146	0.061	0.086	8.122	4.468
Germany	0.170	0.091	0.078	9.576	4.282
Greece	0.049	0.003	0.046	8.248	3.624
Ireland	0.559	0.209	0.350	8.870	4.023
Italy	0.132	0.051	0.081	6.752	4.424
Japan	0.048	0.039	0.009	9.564	4.427
Netherlands	0.343	0.108	0.236	9.058	4.535
Norway	0.267	0.027	0.240	11.650	3.851
Portugal	0.178	0.054	0.124	4.720	3.368
Spain	0.123	0.055	0.068	6.892	4.137
Sweden	0.240	0.103	0.137	10.976	4.368
Switzerland	0.211	0.088	0.123	10.254	4.207
United Kingdom	0.140	0.065	0.075	9.164	4.502
United States	0.041	0.023	0.019	12.186	4.835
Average	**0.210**	**0.075**	**0.135**	**9.278**	**4.243**
Maximum	**0.565**	**0.209**	**0.388**	**12.186**	**4.835**
Minimum	**0.041**	**0.003**	**0.009**	**4.72**	**3.368**
G7 Average	**0.137**	**0.064**	**0.073**	**9.508**	**4.460**

Tables 3.3 and 3.4 report the average shares of non-capital goods and capital goods exports in total exports respectively. The results in table 3.4 show that the average share of capital goods exports in total exports varied widely from 7.6% in Greece to 81% in Japan. In all, nine out of the nineteen OECD countries had average shares exceeding 40% of the total exports to OECD countries from 1990-2004. The shares for G7 countries varied from 41% to 81%. In contrast, non-capital goods exports are larger in the smaller OECD countries than the G7 countries. For example, Japan's average share of capital goods exports from 1990-2004 is the highest, but as Table 3.3 shows, its average share of non-capital goods exports is the lowest at 19.33% while Greece which has the lowest average share of capital goods exports recorded one of the highest non-capital goods exports share at 92.4%. Other G7 countries had less average share of non-capital goods exports in total exports when compared with the smaller OECD countries. In

3.3 Empirical Results

3.3.1 Panel Unit Root and Co-integration Results

The study sample comprises 19 OECD countries over the period 1990-2004[39]. All regressions are obtained using OLS and dynamic OLS (DOLS). The DOLS regression results are my preferred results because OLS estimation has non-negligible bias in finite samples. This bias is due to endogeneity in variables. The bias in the OLS parameters implies that the corresponding t-statistics do not have the usual t-distribution, Kao and

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[39] The study period starts from 1990 because of data constraints.

Chiang (1999). In contrast to the OLS, the dynamic OLS (DOLS) estimator includes lead and lags terms of the first differenced explanatory variables to correct the nuisance parameter in order to obtain coefficient estimates with well-behaved limiting distribution (Kao and Chiang (1999)).

Before estimating regression results however, I first examined the relevant variables to determine whether they are stationary or non-stationary and also whether they are co-integrated. That is, although all the variables may be individually non-stationary, there exists a linear combination of these variables such that the regression containing these variables has a stationary error. Following the literature, I applied the (Im, Pesaran and Shin (IPS) (2003)) panel unit root test. The null hypothesis of the IPS test is unit root for each country i. The IPS test is a group mean test that treats rho as heterogeneous among countries under both the null and alternative hypothesis. The results of the panel unit root test are reported in Table 3.5. With the exception of the index of patent protection, all the variables are unit root or I(1). That is, all the relevant variables in the regressions except the index of patent protection are non-stationary.

To test whether the variables have a long-run relationship, I applied four different cointegration tests proposed by (Phillips-Perron, Dickey-Fuller and Kao (1999)). The null hypothesis of the fours tests is no cointegration. The (Kao (1999)) ADF test treats rho as heterogeneous among countries under both the null and alternative hypothesis. The results of the panel cointegration tests are reported in Table 3.6. The results show that, with the exception of the Phillips Perron rho test for equation (2), the null hypothesis of no cointegration is strongly rejected. Therefore, the long-run relationship among variables for all equations is supported. In the next section, I apply OLS and dynamic OLS to data from 19 OECD countries over the period 1990-2004 to estimate the long-run relationship between the co-integrated variables.

3.3.2 Regression Results

My interest is to examine the relationship between export patterns and international R&D spillovers. That is, I seek to test the hypothesis that the relationship between local exporters and their foreign purchasing agents leads to the accumulation of knowledge and thereby improves the manufacturing process and hence productivity of firms in the exporting country. My main goal however, is to examine which categories of exported goods bear the greatest learning effects and thus explains a country's level of productivity. Consequently, I distinguished between capital goods and non-capital goods exports. For the sake of comparison and robustness checks, I also constructed export weighted foreign R&D spillovers variable and included that in my regression equations.

Table 3.7 reports the estimation results using OLS. All regressions include unreported individual country –specific effects. In addition to the foreign R&D spillovers through total exports, capital goods exports and non-capital goods exports, I also control for domestic R&D capital stock, human capital measured as the average years of school completed by people who are 25 years or older, and index of patent protection which range from 1(low) to 5.

Table 3.7 reports results of four regressions which are variants of equation (7). All four estimated regression equations include domestic R&D capital stock, human capital and index of patent protection. The coefficient of domestic R&D capital stock (DRD) in all the four specifications is positive and statistically significant. The results are consistent with earlier studies that showed that investments in domestic R&D capital stocks enhances productivity, (Coe and Helpman(1995), Funk (2001), Xu and Wang(1999), Zhu and Jeon (2007)). Specifically, 1% increase in domestic R&D capital stock raises domestic productivity from 0.225 to 0.231%. The coefficient of the patent variable was also positive for four regression equations and statistically significant. However, the coefficients of human capital had the wrong signs and were not statistically significant.

The column labeled total exports reports results of regression equation (0.24) that includes total exports weighted R&D spillovers. The coefficient of the total bilateral exports weighted foreign R&D spillovers is positive and significantly different than zero This indicates that bilateral total exports weighted foreign R&D capital stocks enhances domestic productivity through the relationship between local exporters and their foreign purchasing agents. The size of the coefficients is comparable to the coefficients of similar studies in the literature. For example Funk (2001) had a coefficient of bilateral export weighted foreign R&D capital stock of 0.1.

The column labeled capital goods exports reports results of regression equation (0.24) while controlling for capital goods exports weighted R&D spillovers. The coefficient of the bilateral capital goods export weighted foreign R&D spillovers is positive and significantly different than zero implying that bilateral capital goods exports weighted R&D capital stocks enhances domestic productivity through the relationship between local exporters and their foreign purchasing agents. Thus, (Grossman and

Helpman(1991)) hypothesis is supported. The coefficient of capital goods exports weighted R&D spillovers is larger than the coefficient of total exports weighted foreign R&D capital stocks. The size of the coefficients is consistent with the range of coefficients considered reasonable by (Grilliches (1988)).

The column labeled non-capital goods exports reports results of regression equation (0.24) while controlling for non-capital goods exports weighted R&D spillovers. The coefficient of the bilateral non-capital goods export weighted foreign R&D spillovers is positive and significantly different than zero implying that bilateral non-capital goods exports weighted R&D capital stocks enhances domestic productivity through the relationship between local exporters and their foreign purchasing agents. Thus, (Grossman and Helpman(1991)) hypothesis is also supported for non-capital. The coefficient of non-capital goods exports weighted R&D spillovers is also larger than the coefficient of total exports weighted foreign R&D capital stocks but lower than capital goods exports weighted foreign R&D spillovers. The results thus far suggest that capital goods bear the greatest learning effects and best explains a country's level of productivity.

The last column in Table 3.7 reports results of equation (0.24) while controlling for capital goods exports and non-capital goods exports weighted foreign R&D capital stock. The coefficients for both variables were positive but only the capital goods exports weighted foreign R&D capital stock variable was significant. This supports the earlier conclusion that capital goods exports bear the largest learning effects and best explains a country's productivity. However, the coefficient of this variable is lower than when it was introduced separately into regression equation(0.24).

Since OLS estimates are generally biased due to endogeneity in variables, (Kao and Chiang (1999)) suggest that it is unwise to place too much confidence in the estimated OLS results. In particular, (Kao and Chaing(1998)) found that the limiting distribution of OLS estimators are normally distributed but have non-zero means while the dynamic OLS(DOLS) estimators are asymptotically normal with zero means. Therefore, following (Kao and Chiang (1999)), I re-estimated the equation (0.24) using the dynamic OLS (DOLS) estimation technique first suggested by (Saikkonen (1991)). It has gained wide acceptance in the economics literature due to its simplicity and more importantly because , the DOLS estimator include lead and lag terms of first differenced explanatory variables in the regression equation that corrects the nuisance parameter in order to obtain coefficients with well-behaved limiting distribution ,(Kao and Chiang(1999))[40]. I first, re-wrote equation (0.24) as a single equation framework of the form:

$$Y_{it} = c_i + X_{it}'\beta + u_{it} \tag{0.25}$$

where i = 1, 2, …, N denotes countries and t = 1, 2, …T denotes time period, Y_{it} is the dependent variable, c_i captures individual specific effects, Z_{it} represent (K × 1) vector of regressors. The regressors are assumed to be I(1) and not co-integrated. I also assume a

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[40] The review here is based on the work of Breitung and Pesaran(2005). Interested readers should consult this source and several for further details.

homogenous co-integration relationship. That is, the coefficients for all cross-section units are the same. The DOLS estimator proposed by (Saikkonen (1991)) is based on the error decomposition[41]:

$$u_{it} = \sum_{k=-\infty}^{\infty} \Omega_k \Delta X_{it} + v_{it} \tag{0.26}$$

where v_{it} is orthogonal to all leads and lags of ΔZ_{it}. Inserting (0.26) into (0.25) yields:

$$Y_{it} = c_i + X_{it}'\beta + \sum_{k=-\infty}^{\infty} \Omega_k \Delta X_{it} + v_{it} \tag{0.27}$$

The infinite sums are usually truncated at some small numbers of leads and lags; (Kao and Chiang (2000), Mark and Sul (2003)). In this study, I truncated the infinite sum at three lags and three leads because lags and leads beyond three did not improve the fit of the regression equation[42].

Table 3.8 reports the estimation results based on the DOLS estimation technique. I again controlled for domestic R&D capital stocks, index of patent protection and human

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[41] See Breitung and Pesaran(2005), Kao, Chiang and Chen(1999) for a detailed discussion.

[42] Interested readers should consult Breitung and Pesaran (2005) for a good review of OLS, FM-OLS and DOLS. Kao and Chaing(1999) also explain how to apply these approaches empirically.

capital. These variables are among the commonly included variables in foreign R&D and productivity studies, (Coe, Helpman and Hoffmaister (2008), Park and Lippoldt(2005)). The coefficient of domestic R&D capital stocks are still positive and statistically significant implying that a 1 percent increase in domestic R&D capital stocks would raise productivity by an average of about 0.105% in all 19 OECD countries. This elasticity is consistent with similar estimates in the literature. In particular, studies of industrial countries typically find elasticities in the range of 0.06 to 0.10, (Grilliches (1988)).

The elasticity estimates for domestic R&D capital stock using the DOLS estimation technique are well below estimates using OLS reinforcing the general perception that the OLS estimates are bias. In particular, the estimated elasticity of total factor productivity with respect to domestic R&D capital stock using OLS were in the range of 0.225 to 0.231. That is more than twice the coefficients of domestic R&D spillovers obtained from DOLS estimation techniques. The coefficients of total exports, capital goods exports and non-capital goods exports were all positive and significantly different than zero. These results are thus consistent with the OLS estimation results. However, the coefficients of all three of all three variables were smaller when estimated with the DOLS estimation techniques. These results thus provide support for the conclusions of (Kao and Chiang (1998, 1999)). The DOLS coefficients are also comparable to estimates in the literature.

I also investigate the impact of foreign R&D capital stock through total exports, capital goods exports and non-capital goods exports on total factor productivity. Table 3.9 therefore reports the estimated elasticities of total factor productivity with respect to foreign R&D capital stock through total exports, capital goods exports and non-capital goods exports based on the regression results in Table 3.8. In particular, the elasticities are estimated by multiplying the coefficients of total exports, capital goods exports and non-capital goods exports weighted foreign R&D spillovers from table 3.8 by their respective ratios of total exports, capital goods exports and non-capital goods exports to GDP.

The estimated impact of foreign R&D capital stocks increased from 1990-2004 for most countries. On average, a 1 percent increase in bilateral export weighted foreign R&D capital stocks results in about 0.0010% and 0.0012% increase in domestic productivity for 1990 and 1992 respectively. a 1 percent increase in capital goods exports weighted foreign R&D capital stocks results in about 0.0021% and 0.0029% increase in domestic productivity for 1990 and 2004 respectively. Finally, a 1 percent increase in non-capital goods export weighted foreign R&D capital stocks results in about 0.0015% and 0.0018% increase in domestic productivity for 1990 and 2004 respectively. The results thus show that the impact of export weighted foreign R&D spillovers on domestic productivity was higher in 2004 than in 1990. Second, capital goods exports have the largest impact on productivity than both total exports and non-capital goods exports. Finally, Grossman and Helpman's hypothesis that idea exchange and thus productivity would increase with the size of exports is supported. The smaller OECD countries benefited more from R&D spillovers than large countries. Similar results were obtained by (Coe and Helpman(1995), Kao and Chiang(1999)).

The average impact of foreign R&D spillovers on productivity from 1990-2004 for all 19 countries are similar to these results. In particular, a one percent increases in bilateral exports weighted foreign R&D stocks results in about 0.0011% increase in domestic productivity for all 19 countries from 1990-2004. Similarly, a one percent increase in bilateral capital goods exports weighted foreign R&D stocks results in about 0.0028% increase in domestic productivity in all 19 countries from 1990-2004. Finally, a one percent increase in bilateral non-capital goods exports weighted foreign R&D stocks results in about 0.0018% increase in domestic productivity in all 19 countries from 1990-2004.

3.4 Conclusion

In this study I tested the hypothesis that the relationship between local exporters and their foreign purchasing agents may lead to the exchange of ideas that may improve the manufacturing process and thus enhance productivity. This hypothesis was first tested by (Funk (2001)) using aggregated data. However, Funk admits that the level of aggregation in his data may lead to biased results and thus recommended the use of disaggregated. My approach differs from (Funk (2001)) in that I test the hypothesis using disaggregated data. Disaggregated data is more consistent with Grossman and Helpman's hypothesis and has been found to perform better empirically, (Xu and Wang (1999)). Moreover, disaggregated data enabled me to examine the categories of exports that bear the greatest learning effects and thus best explain a country's level of productivity as recommended by (Chuang(1998)) in his conclusion. I also controlled for domestic R&D capital stocks, human capital and index of patent protection.

I find empirical support for the hypothesis that the relationship between exporters and their foreign purchasing agents may lead to the exchange of ideas that enhances the manufacturing process and thus raise domestic productivity. In particular, a one percent increase in bilateral exports weighted foreign R&D stocks results in about 0.0011% increase in domestic productivity. Similarly, a one percent increase in bilateral capital goods exports weighted foreign R&D stocks results in about 0.0028% increase in domestic productivity. Finally, a one percent increase in bilateral non-capital goods exports weighted foreign R&D stocks results in about 0.0018% increase in domestic productivity. The results thus show that capital goods exports generate the greatest learning effects and thus best explains a country's level of productivity.

Finally, I have shown that the relationship between exporters and their foreign purchasing agents may enhance the manufacturing process and productivity in the exporting country. However, strong exports may be due to strong productivity. This may therefore give rise to endogeneity problem. The current study does not address this potential endogeneity problem.

Appendix 3.A

Table 3.0

		Mean	max	min	Stdev
F	Total Factor Productivity	0.952348	1.11061	0.64325	0.074651
TEXP	Total Export weighted R&D spillovers	495227.6	2261397	161927.9	385645.3
CAP	Capital Goods Exports weighted R&D spillovers	550594.3	2299677	145471.9	411899
NCAP	Non-Capital Goods Exports weighted R&D spillovers	467759.2	2239564	179998.6	375527.2
E0	Ratio of total exports to GDP	0.209873	0.698635	0.033351	0.149591
E1	Ratio of capital goods exports to GDP	0.074655	0.305249	0.002207	0.054472
E2	Ratio of non-capital goods exports to GDP	0.135218	0.49461	0.007291	0.103032
H	Human capital	9.278105	12.306	4.33	1.807279
PP	Patent Protection	4.243113	4.875	1.6657	0.494497

Table 3.3 Average Share of Non-Capital Goods Exports

	MEAN	MAX	MIN	STDEV
Australia	0.890	0.922	0.866	0.016
Belgium	0.686	0.714	0.656	0.019
Canada	0.590	0.637	0.552	0.021
Denmark	0.701	0.734	0.667	0.025
Finland	0.642	0.725	0.562	0.057
France	0.588	0.628	0.549	0.028
Germany	0.465	0.505	0.426	0.026
Greece	0.924	0.966	0.864	0.030
Ireland	0.630	0.686	0.519	0.043
Italy	0.616	0.637	0.596	0.011
Japan	0.193	0.211	0.175	0.013
Netherlands	0.686	0.759	0.615	0.057
Norway	0.896	0.929	0.854	0.019
Portugal	0.699	0.794	0.636	0.064
Spain	0.555	0.579	0.535	0.011
Sweden	0.573	0.609	0.533	0.025
Switzerland	0.581	0.613	0.560	0.016
United Kingdom	0.537	0.593	0.478	0.040
United States	0.450	0.481	0.411	0.022

Table 3.4 Average share of capital goods exports in total exports from 1990-2004

	mean	max	min	stdev
Australia	0.110	0.134	0.078	0.016
Belgium	0.314	0.344	0.286	0.019
Canada	0.410	0.448	0.363	0.021
Denmark	0.299	0.333	0.266	0.025
Finland	0.358	0.438	0.275	0.057
France	0.412	0.451	0.372	0.028
Germany	0.535	0.574	0.495	0.026
Greece	0.076	0.136	0.034	0.030
Ireland	0.370	0.481	0.314	0.043
Italy	0.384	0.404	0.363	0.011
Japan	0.807	0.825	0.789	0.013
Netherlands	0.314	0.385	0.241	0.057
Norway	0.104	0.146	0.071	0.019
Portugal	0.301	0.364	0.206	0.064
Spain	0.445	0.465	0.421	0.011
Sweden	0.427	0.467	0.391	0.025
Switzerland	0.419	0.440	0.387	0.016
United Kingdom	0.463	0.522	0.407	0.040
United States	0.550	0.589	0.519	0.022

Table 3.5 Panel Unit Root Test Results

Variable	Im, Pesaran and Shin Test
Log(Total factor productivity)	3.777 (0.9999)
e_0* Log(Total exports weighted foreign R&D spillovers)	-0.176 (0.4300)
e_1*Log(Capital goods export weighted foreign R&D spillovers)	-0.102 (0.7252)
e_2*Log(Non-capital goods export weighted foreign R&D spillovers)	0.088 (0.4648)
Human Capital	-0.936 (0.1746)
Log(Patent Protection)	-25.058*** (0.000)
Log(domestic R&D capital stock)	4.928 (1.000)

e_0, e_1 & e_2 are the ratio of total exports, capital goods exports and non-capital goods exports as a percentage of GDP. Numbers in parenthesis are p-values. Patent Protection is an index which range from 1 (low) to 5. The null hypothesis of unit root is rejected if the test statistic is significant.

Table 3.6 Panel Cointegration Results

	Total Exports	Capital Goods Exports	Non-Capital Goods Exports
PP-rho	2.467* (0.0190)	1.632 (0.1053)	2.511* (0.0171)
PP	-4.719*** (0.0000)	-7.186*** (0.0000)	-3.450** (0.0010)
ADF	-3.968*** (0.0002)	-6.023*** (0.0000)	-2.967** (0.0049)
Kao	-2.099* (0.0179)	-2.118* (0.0171)	-2.219* (0.0132)

Numbers in parenthesis are p-values. The null hypothesis of no co-integration is rejected if the test statistic is significant. *, **, *** denotes the level of significance at 10%, 5% and 1% respectively. PP-rho, PP and ADF report the Philips-Perron rho & t-tests and the augmented Dickey-Fuller tests.

Table 3.7 Results of OLS Estimation of International R&D Spillovers through Exports

	Total Exports	**Capital Goods Exports**	**Non-Capital Goods Exports**	**Capital & Non-capital Goods Exports**
Log (domestic R&D)	0.225*** (9.922)	0.231*** (9.992)	0.226*** (10.003)	0.227** (9.859)
Log(Patent Protection)	0.084** (2.679)	0.068* (2.034)	0.101** (3.016)	0.077* (2.292)
Human Capital	-0.008 (-1.037)	-0.008 (-1.106)	-0.006 (-0.864)	-0.008 (-1.085)
e_0 x log (Texp-spillovers)	0.021** (3.330)			
e_1 x log (cap-spillovers)		0.041** (2.703)		0.030* (1.722)
e_2 x log (Noncap-Spillover)			0.025** (2.981)	0.014 (1.500)
R^2	**0.80**	**0.80**	**0.79**	**0.80**
$\bar{R}^2$	**0.78**	**0.78**	**0.78**	**0.78**
Panel observations	**285**	**285**	**285**	**285**

Note: The dependent variable is Log(Total factor productivity). Numbers in brackets are t-statistics. LOG(Texp-Spillover) refers to total bilateral export weighted R&D spillovers, LOG(Cap-Spilloverp) refers to capital goods exports weighted R&D spillovers, LOG(noncap-Spillover) refers to non-capital goods export weighted R&D spillovers. E0, E1& E2 refers to the ratio of total exports, capital goods exports and non-capital goods exports to GDP respectively. All regressions include unreported country fixed effects. *, **, *** denotes the level of significance at 10%, 5% and 1% respectively.

Table 3.8 Results of Dynamic OLS Estimation of International R&D Spillovers through Exports

	Total Exports	**Capital Goods Exports**	**Non-Capital Goods Exports**
Log (domestic R&D)	0.105*** (4.513)	0.107*** (4.113)	0.079** (3.293)
Log(Patent Protection)	0.476*** (4.679)	0.471*** (4.356)	0.529*** (5.130)
Human Capital	0.255 (0.938)	0.230 (0.709)	-0.206 (-0.633)
e_0 × log (Texp-spillovers)	0.016** (3.152)		
e_1 × log (cap-spillovers)		0.038** (3.102)	
e_2 × log (Noncap-Spillover)			0.013* (1.680)
R^2	0.95	0.96	0.96
$\bar{R}^2$	0.93	0.95	0.94
Pooled observations	152	152	152

Note: The dependent variable is Log(Total factor productivity). Numbers in brackets are t-statistics. LOG(Texp-Spillover) refers to total bilateral export weighted R&D spillovers, LOG(Cap-Spilloverp) refers to capital goods exports weighted R&D spillovers, LOG(noncap-Spillover) refers to non-capital goods export weighted R&D spillovers. E0, E1 & E2 refers to the ratio of total exports, capital goods exports and non-capital goods exports to GDP respectively. All regressions include unreported country fixed effects. The DOLS regressions include three leads and three lags of the differenced regressors. *, **, *** denotes the level of significance at 10%, 5% and 1% respectively.

Table 3.9 Average Elasticity of Productivity With Respect to Foreign R&D Stocks through Total Exports and Capital Goods Exports (1990-2004)

	Total Exports		Capital Goods Exports		Non-Capital Goods Exports	
	1990	**2004**	**1990**	**2004**	**1990**	**2004**
U.S	0.0003	0.0003	0.0008	0.0008	0.0003	0.0002
U.K	0.0009	0.0009	0.0020	0.0020	0.0010	0.0009
Japan	0.0007	0.0006	0.0017	0.0015	0.0001	0.0001
Germany	0.0015	0.0018	0.0035	0.0043	0.0011	0.0011
France	0.0008	0.0010	0.0019	0.0024	0.0011	0.0011
Canada	0.0012	0.0017	0.0029	0.0041	0.0015	0.0025
Italy	0.0007	0.0008	0.0016	0.0020	0.0009	0.00011
Australia	0.0001	0.0001	0.0002	0.0003	0.0009	0.0008
Belgium	0.0023	0.0032	0.0002	0.0075	0.0007	0.0064
Denmark	0.0010	0.0012	0.0024	0.0028	0.0021	0.0021
Finland	0.0007	0.0011	0.0016	0.0025	0.0013	0.0017
Greece	0.0000	0.0001	0.0001	0.0002	0.0008	0.0004
Ireland	0.0026	0.0026	0.0063	0.0062	0.0037	0.0044
Netherlands	0.0015	0.0022	0.0036	0.0052	0.0039	0.0032
Norway	0.0005	0.0003	0.0011	0.0008	0.0030	0.0034
Portugal	0.0006	0.0010	0.0015	0.0023	0.0020	0.0015
Spain	0.0006	0.0009	0.0014	0.0022	0.0006	0.0010
Sweden	0.0013	0.0019	0.0030	0.0045	0.0016	0.0019
Switzerland	0.0014	0.0014	0.0032	0.0034	0.0015	0.0019
Average	0.0010	0.0012	0.0021	0.0029	0.0015	0.0018
G7 Average	0.0009	0.0010	0.0021	0.0024	0.0009	0.0009

Appendix 3.B

Data Sources and Variable Definition

The dependent variable is in this study is total factor productivity of the business sector in the 19 OECD countries measured as a residual. Data for this variable is the same as the data used by (Coe, Helpman and Hoffmaister (2004)). The authors estimated total factor productivity as :

$$F = \frac{Y}{K^{\beta}L^{1-\beta}},,$$

Where Y is real value added in business sector, K is capital stock, L is labor input (defined) as business sector employment times average annual hours worked). All variables are from the OECD's analytical database or the OECD Economic Outlook database.

The total exports, capital goods exports and non-capital goods exports weighted foreign R&D spillovers variables were constructed (Coe and Helpman (1995)) approach.

Coe and Helpman (1995) measure import weighted foreign R&D capital stock of a developing country i as a weighted average of domestic R&D capital stock of the trading partner, where the weights are the bilateral import-share of a developing country.

$$S_{1i} = \sum_{j^{1}i} w_{ij} S_j^d$$

$$w_{ij} = \frac{M_{ij}}{\sum_{j \neq i} M_{ij}}, \qquad \sum_{j \neq i} w_{ij} = 1$$

where S_j^d denotes domestic R&D capital stock of trading partner j. I constructed the three export weighted R&D spillovers variables using the same approach. Howver, unlike Coe and Helpman, I use exports as weights to emphasize that fact that pure idea exchange between local exporters and their foreign purchasing agents increases with the size of the exports. The R&D expenditure for the business sector comes from OECD directorate of Science, Technology and industry, published in the Main Science and Technology Indicators. Total exports, capital goods exports and non-capital goods exports data were obtained from OECD Stan's bilateral trade in goods and services.

I used Coe, Helpman and Hoffmaister's dataset on domestic R&D capital stock to construct my foreign R&D capital stock variable. Coe, Helpman and Hoffmaister constructed the domestic R&D capital stock using the perpetual inventory method.: $S_t^d = (1-\delta)S_{t-1}^d + RD_{t-1}$. where δ = 0.05 is the depreciation rate. Data for business sector R&D expenditure was obtained from Directorate of Science Technology, and Industry published in Main Science and Technology Indicators. The initial R&D capital stock was obtained as

$$S_{1970} = \frac{RD}{d+g}$$

where g is the annual average logarithmic growth rate from 1970 -1985. That is:

$$g = \log\left(\frac{RD_{1985}}{RD_{1970}}\right)/15$$

The human capital and index of patent protection are from (Coe, Helpman and Hoffmaister (2008)).

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SUMMARY AND CONCLUSION

The question of whether returns to R&D investments in certain countries influence productivity in other countries has received significant attention since the development of endogenous growth models that established a framework linking productivity and innovation. Earlier empirical studies starting with the seminal work of Coe and Helpman (1995) identified trade as the main vehicle for knowledge diffusion. However, more recent studies using modern econometrics techniques have questioned the existence of any trade related learning effects.

In the first essay, I provide cross-country evidence of the link between productivity and trade induced learning effects from Sub-Saharan Africa. I also provide evidence of the role of institutions in explaining R&D spillovers for a sample of 17 Sub-Saharan African countries over the period 1980-2004. My estimates suggest that spillovers to Sub-Saharan African countries are substantial. In particular, a 1% increase in domestic R&D capital stock in the major OECD countries will increase productivity in a Sub-Saharan African country by about 0.0011% on average. However, the average elasticity of productivity in Sub-Saharan African country with respect to foreign R&D spillovers from OECD countries has declined consistently from 0.0015% in 1980 to 0.0009% in 2004 for all the 17 countries in the sample.

In terms of the sources of R&D spillovers, the estimates suggest that the United States is the major source of spillovers in Sub-Saharan African countries. In particular, a 1% increase in domestic R&D spillovers in the United States raised productivity by an average of 0.0004% for all the 17 countries in the sample[43]. This may be expected since United States accounts for over 40% of the World's R&D investments. The legal origin of the company law or commercial codes of Sub-Saharan African countries affect the degree of knowledge spillovers. In particular, Sub-Saharan African countries that adopted the English common law legal system benefit more from the R&D spillovers than countries under the French civil law. In particular, a 1% increase in domestic R&D capital stock in OECD countries raised productivity for English common law countries by an average of 0.0015% compared to 0.0008% for French civil law countries from 1980-2004. There is however a trend decline in benefits for both legal systems.

Finally, my estimates suggest that total spillover effects from major OECD countries may have increased output in the 17 Sub-Saharan African countries by $10 million 2004. This shows that, although developing countries do benefit from returns from investments in R&D capital stocks, such benefits and small and declining.

In my second essay, I examine alternative channels of knowledge diffusion. In particular, I investigate whether technical cooperation grants and overseas development assistance grants induce R&D spillovers in Sub-Saharan Africa. My estimates suggest that a 1% increase in domestic R&D capital stock in G7 countries would raised productivity on average by 0.0021% , 0.0033% and 0.0044% through technical cooperation grants, overseas development assistance grants and imports of intermediate

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[43] Canada was the least important as a source of foreign R&D spillovers for countries in the sample followed by Italy. Japan, France and Germany were also major sources of foreign R&D spillovers.

goods from 1980-2004. This evidence thus lends support to the hypothesis that international R&D knowledge spillovers are trade related. The evidence also supports the hypothesis that aid flow is influenced by colonial past. Aid flow also had the highest effects on productivity in countries with good policies and also by population. Aid induced R&D spillovers appear to have raised productivity more in smaller countries than larger countries[44].

The study findings have some implications for policy. First, donor countries may focus on technical cooperation grants and overseas development assistance grants and more broadly on grants that facilitates knowledge accumulation in developing countries if their desire is to improve productivity and growth in Sub-Saharan African countries. Second, the study also provides some empirical support to earlier claims that aid induced learning effects do raise productivity and hence growth in countries with good policies. Consequently, donor aid allocation may target Sub-Saharan African countries with good policies if their goal is to increase economic growth and reduce the widespread poverty in Sub-Saharan Africa.

In the third essay, I test the hypothesis that the relationship between local exporters and their foreign purchasing agents may lead to the exchange of ideas that may improve the manufacturing process and thus enhance productivity. This hypothesis was first tested by (Funk (2001)) using aggregated data. However, Funk admits that the level of aggregation in his data may lead to biased results and thus recommended the use of

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[44] There is no specific definition for a small or large population.

disaggregated. My approach differs from (Funk (2001)) in that I test the hypothesis using disaggregated data. Disaggregated data is more consistent with the theory and has been found to perform better empirically, (Xu and Wang (1999)). Moreover, disaggregated data enabled me to examine the categories of exports that bear the greatest learning effects and thus best explain a country's level of productivity as recommended by (Chuang(1998)) in his conclusion. I also controlled for domestic R&D capital stocks, human capital and index of patent protection.

I find empirical support for the hypothesis that the relationship between exporters and their foreign purchasing agents may lead to the exchange of ideas that enhances the manufacturing process and thus raise domestic productivity. In particular, a one percent increase in bilateral exports weighted foreign R&D stocks results in about 0.0011% increase in domestic productivity. Similarly, a one percent increase in bilateral capital goods exports weighted foreign R&D stocks results in about 0.0028% increase in domestic productivity. Finally, a one percent increase in bilateral non-capital goods exports weighted foreign R&D stocks results in about 0.0018% increase in domestic productivity. The results thus show that capital goods exports generate the greatest learning effects and thus best explains a country's level of productivity.