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# Structure for a protocol

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# 1. BACKGROUND, POLICY PRACTICE AND EXISTING RESEARCH

## 1.1 Aims and rationale for review

Since the turn of the century, we observe an evident increase in the interest in innovation as a significant driver of development in low-income countries. In 2005, the UN World Summit stated that science and technology are vital for the achievement of the Millennium Development Goals (UN, 2005). Similarly, the UNESCO's 2005 Report indicated that indigenous development of science and technology and strengthening of regional networks for that purpose are essential for African development. This view was echoed in the 2005 Report of the UK Commission for Africa, which stated the need to identify opportunities arising from innovation and to develop effective policies in areas such as science and trade (Commission for Africa 2005; 137). Similar views were expressed by the African Union Commission and the New Partnership for Africa's Development (NEPAD). Both regional institutions acknowledged the need to promote science, technology and an innovation as instruments for sustainable development, including employment (NEPAD, 2006).

The evident interest in innovation and technological change as drivers of development and employment growth is a welcome step in the right direction. However, the relationship between innovation, growth and employment is quite complex. First of all, there is the issue of what kind of innovation is conducive to employment creation. For example, Acemoglu (1998 and 2002) has demonstrated that skill-replacing innovation of the late-eighteenth and nineteenth centuries was conducive to job creation whereas the skill-complementary or skill-biased innovation of the twentieth and early twenty-first centuries was not. Secondly, there is the issue of time horizon. As Harrison et al (2008) have observed, innovation and employment growth went hand in hand in developed countries for centuries, but the evidence on the short-run relationship is not clear-cut. Finally, the relationship between innovation and the level of competition may not be linear (Aghion et al, 2004). This issue had been detected much earlier by Schumpeter (1934), who pointed out that innovative firms require 'rents' that can be used as insurance against the riskiness of the investment in innovation. Under this condition, innovation may be necessary but not sufficient for growth and employment creation. This is because innovative firms may acquire market power and as such may maximise profits by increasing prices rather than output and employment.

Given such potential complications in the relationship between innovation and employment, there is an evident case for synthesizing the evidence that would

inform the policy and academic debate on the innovation-employment relationship. This systematic review aims to make a contribution in that direction by synthesizing the evidence on the experience of low-income countries (LICs).

Two aspects of the current debate justify the focus of the review on LICs. On the one hand, there is an evident policy preference for encouraging innovation as a driver for development and employment creation in LICs. This orientation may be justified by the historical experience of the developed countries, which suggests that the relationship between innovation and job creation is a positive one in the long term (Acemoglu, 2003). However, the implications for LICs may not be clear-cut as the evidence base tends to relate to developed or middle-income countries. Therefore, there is an evident need to cast a wide net in terms of time period and different measures of innovation with a view to uncover the work on the innovation-employment relationship in LICs; and to synthesize its findings in a systematic manner. This systematic review aims to address this need by including all research work produced since 1970. In addition, it will include work that examines the employment effects of innovation not only in manufacturing sectors but also in agriculture and services. Finally, it will include work examining the employment-effects of different types and measures of innovation - including product and process innovations that are new to the firm or the market, input and output measures of innovation, technology adoption and imports, and technological change in general. (See, NEPAD, 2006; World Bank, 2008; Pianta, 2004; Piva, 2003; and Mitra, 2009).

This systematic review aims to: (a) synthesize the **empirical evidence** on the innovation-employment relationship with a view to support evidence-based policy making; (b) identify the **strengths and shortcomings** of the existing work on LICs; and (c) point out potential **avenues for further analytical and empirical research**. In doing this, we will pay special attention to the synthesis of the evidence on the innovation-employment relationship in the context of **low-income countries**, but we will also synthesize work on lower middle income countries (LMICs) that were low-income countries in the past.

Unlike healthcare or social policy research, where systematic reviews constitute a well-established method of synthesizing research findings, systematic reviews in economics in general and international development in particular are a new development. In addition, the nature of the data and data collection methods poses additional challenges to systematic reviews in economics. Studies in economics in general (and those on the innovation-employment relationship in particular) may draw on cross-sectional data, panel data or time-series data. In addition, the sample, the estimated model, the estimation methods, and the quality of the data may differ from one study to the other.

The proposed review will address these challenges and maximise the reliability of the synthesis by drawing on the mixed methodology proposed by Harden and Thomas (2005). The mixed method to be used in this review includes the following:

1. Providing a **narrative synthesis** of the theoretical/analytical explanations of the innovation-employment relationship;
2. Conducting a **meta-analysis** of the evidence from all empirical studies to be selected in accordance with pre-specified inclusion/exclusion criteria;
3. **Clustering (nesting)** the empirical studies on the basis of common characteristics such as innovation and employment measures and estimation methods used;
4. Comparing and conducting sensitivity analysis of the findings in (2) and (3) by **controlling** for estimation methods, publication type, and country groups; and
5. **Mapping** the meta-analysis of empirical evidence with the narrative synthesis of the theoretical/analytical studies, with a view to provide a better evidence base for policy making and further research.

## 1.2 Definitional and conceptual issues

### *1.2.1 Innovation and employment: definition and measurement*

The OECD's *Oslo Manual* (2005: 46) defines innovation as follows:

> An **innovation** is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.

In this review, we will adopt the definition above as a working definition that allows for inclusion of studies that examine product, process, marketing or organisational innovations at firm level; and import or adoption of technology at the sectoral, regional or national levels. The *Oslo Manual* states that innovation data must refer to *implemented innovation* rather than measures of innovative capacity such as research and development (R&D) expenditures and patents. This emphasis on implementation is compatible with the type of evidence that is more likely to be available and relevant for LICs. The existing literature indicates that R&D and patents data is usually lacking for LICs and even where it exists it tends to have a short time dimension – usually beginning after 2000.

The other aspect of the OECD definition is that it considers an activity as 'innovative' whether it is 'new' to the firm or to the market or both. This aspect implies that an innovative activity does not have to be 'new to the world' to qualify as innovation. As such, the definition is compatible with the type of innovation usually observed in LICs.

Firms usually introduce innovation as a strategic response to developments in product and labour markets. Hence, the level of competition in the product/services markets, the patterns of shifts in the demand for products and services, changes in market size, evolution of wages and labour market institutions and changes in the supply of labour and its skill composition play a significant role in shaping the innovative activities of the firms. More importantly, however, these factors also determine the effect of innovation on output and employment growth. The aim of this systematic review is to synthesize the qualitative and quantitative evidence on how innovation impacts on employment and how this impact is mediated through various displacement and compensation mechanisms at work in the product and labour markets. Stated differently, we treat innovation as a 'proxy' for 'intervention' that, in turn, affects employment as an 'outcome' variable.

ILO (2000) defines employment rate as the proportion of economically-active persons (usually, aged 15-64) who were in paid or self employment for a specified period at the time when data is compiled. Studies examining the impact of innovation at sectoral, regional or macro levels use employment statistics compiled in accordance with ILO definition and guidelines, but adherence to these guidelines is known to be uneven – depending on capacity and traditions of the national statistical offices (Inter-Secretariat, 1993). On the other hand, studies examining the effect of employment at the firm level utilise employment data reported in firm-level surveys.

The impact of innovation on employment can be positive or negative. Therefore, the employment effect of innovation must be analysed by paying attention to the contextual factors and causal mechanisms at work. Innovation can affect employment *directly* by changing the mix of the productive factors – capital and labour – used it the production process. However, it may also affect employment indirectly through its effects on product differentiation, prices, product and service quality, and the marketing mix. The direction of these effects can be positive or negative – depending on the structures of the product and labour markets, openness to international trade, and factor endowments (Conte and Vivarelli, 2007).

Given this complexity of the innovation-employment relationship, it is essential to have appropriate measures of innovation that are good enough to measure the

extent of innovative activities, the type of innovation implemented, and the link between the former and employment as the outcome variable. Chennells and Reenen (2002) provide a good summary of the kinds of innovation measures used in micro-level studies on the innovation-employment relationship in developed countries. They report that the most often used measures are R&D expenditures (i.e. inputs into the knowledge production function) and number of patents (i.e. outputs of the knowledge production function). However, such measures are less appropriate for LICs and even for lower middle income countries (LMICs). This is because these countries are far from the technology frontier. Secondly, firms in LICs and some LMICs do not necessarily patent all innovations they implement – either because of capacity/resource constraints or because of the weaknesses of the institutions of the national innovation systems (Piva, 2003).

Therefore, it would be more appropriate to identify innovation measures that satisfy two conditions: compatibility with the range of measures implied by the innovation definition of the *Oslo Manual*; and data availability for LICs. The *Oslo Manual* recommends that innovation surveys should aim to capture the following range of innovative activities: new concepts for products, processes, marketing methods and organisational changes; purchase of technical information, acquisition of licences, patents, and know-how; human skills development through tacit or informal learning; and purchase of capital goods or intermediate inputs that embody innovative inputs from third parties (OECD, 2005: 36). Fortunately, the literature we reviewed so far suggests that studies on the innovation-employment relationship in LICs tend to draw on data that satisfy these conditions.

For example, Piva (2003), Conte and Vivarelli (2007), and Mitra (2009) suggest that imports of capital goods, machinery and technical equipment; licensing and foreign direct investment (FDI) inflows are used as proxies for innovation. Value of imported capital goods can be taken as proxy for innovation because it contributes to capital upgrading (Xu and Wang, 2000; Eaton and Kortum, 2001). Also Mayer (2000) reports a significant association between the ratio of machinery imports to GDP and the ratio of GDP to domestic investment. Stated differently, higher levels of imported capital goods are associated with higher levels output per unit of investment. Similarly, Conte and Vivarelli (2007) use skill-enhancing technology import (SETI) as an innovation indicator because SETI comprises the value of trade flows from high-income to low-income countries that incorporate technological upgrading. SETI is also appropriate because high-income countries produce the most advanced technologies whereas low-income and lower-middle-income countries have a negligible level of R&D expenditures and their main channel of technological upgrading is through SETI from high-income countries.

Licensing as a measure of innovation involves the contractual transfer of knowledge and technology between firms. Licensing contributes to local firm knowledge more directly than FDI. Therefore, developing countries such as Brazil, India and Mexico have favoured licensing to FDI (De Ferranti et al., 2002). From the perspective of this review, licensing is also preferable to FDI for two reasons. First, FDI data is aggregate and as such it represents investment not only in new technology but also overall investment in fixed assets and operating capital. Therefore, FDI inflow data (which is the most commonly used measure of FDI) does not provide a reliable measure of FDI's *direct* contribution to innovation either in the local subsidiary or in the host country in general. True, FDI can be associated with technology transfer and spill-overs in general. However, technology transfers or spill-overs from FDI are known to vary greatly between subsidiaries, host countries and sectors (for a systematic review, see Havranek and Irsova, 2010). In contrast, licensing data is specific and provides a direct measure of imported technology or know-how. For these reasons, this review will include studies that use expenditures on licensing but not those using FDI data as a determinant of employment. A systematic review of the latter-type studies may well be justified and relevant, but such a review would be appropriate for a question on the relationship between FDI and employment – not for addressing a question on the relationship between innovation and employment.

A third measure of innovation can be the capital-labour ratio (as proposed by Berman and Machin, 2002) or capital-GDP ratio (as suggested by Robbins, 1996). These measures assume that technology is embodied in capital goods. They are also informed by the observation that the capital-labour or capital-GDP ratio has increased in middle-income countries and that there are cross-country correlations between changes in capital-labour and capital-GDP ratios of both developed and developing countries. This review will include studies that use the capital-labour or capital-GDP ratio as a proxy for innovation, provided that the study also estimates or analyses the association between changes in capital intensity and the level of employment.

The review team and DFID policy leads agree that TFP is related to innovation, and although this relationship may differ between countries and/or industries, TFP is one measure of innovation and its impact on employment will be a central part of the review. In the Report (the outcome document), the review team will synthesize the evidence on the TFP-employment relationship in addition to the relationships between other measures of innovation and employment – subject to availability of studies and their compliance with the eligibility criteria specified in the Protocol.

In addition to these macro- or sector-level indicators, we will also include studies that draw on firm-level innovation data. At this level of analysis, innovation

measures capture the introduction of new products or processes. New products (or processes) can represent 'breakthrough innovation (new to the world), incremental innovation (new to the market) or imitation (new to the firm). Product innovations increase the quality and variety of goods and may open up new markets – leading to higher demand for labour. However, new products can simply replace old ones produced by the innovative firm or its competitors, leading to destruction of old jobs. Hence, the effect of product innovation on employment must be established empirically (Pianta, 2001). On the other hand, process innovation occurs at the intensive product margin and is usually associated with employment-saving effects (Edquist et al, 2001). This review will include studies that examine the employment effects of both types of innovation at the firm or industry level. These innovation measures are usually captured by innovation surveys through questions on whether the firm has introduced new products or process in the last year; or through breakdown of firm sales into revenue from sale of new and old products.

The strengths and shortcomings associated with each measure of innovation (including TFP) will be discussed in the Report, which will have a section that will guide the reader about how innovation may affect employment (i.e., a section that addresses issue 5 above).

Compared to measures of innovation, employment measures are less varied in the existing literature. However, we identified at least two measures: change in the level of employment and change in the composition of the wage bill. For the employment level, studies use national statistics compiled largely in accordance with the ILO guidelines referred to above. Firm-level data, however, is based on firm-supplied information in innovation and employment surveys. Whether it is macro- or firm-level, the employment measure also distinguishes between demand for total labour and demand for skilled and unskilled labour. In this review, we will include studies that examine the impact of innovation on both types of labour as well as total employment. However, we will not include studies that examine the impact of innovation on the composition of the wage bill only. For example, Berman and Machin (2000) examine the impact of innovation on the components of the wage-bill in developing countries. They conclude that technological change is a significant determinant of demand for skills. Such studies will be included in this review only if they examine the impact of technological change on the demand for skilled (or unskilled) labour *in addition to* the impact on the composition of the wage bill. This is because shares of skilled and unskilled labour in the wage bill depend not only on the change in the quantity of labour in both categories, but also on the change in their wages. Given these sources of change, it is impossible to establish whether the change in the wage bill shares is due to change in employment or wages or both.

The review question also requires an examination of the innovation's effect on the demand for labour with respect to gender. The literature we have examined so far does not provide estimates of the gender-related effects. However, our search terms will include gender with a view to capture relevant studies.

Finally, there is the issue of sector coverage. The literature review by Piva (2003) suggests that the large majority of existing work tend to examine the impact of innovation on employment in the manufacturing sector. This is due to both data availability and the implicit assumption that innovation is more prevalent in manufacturing industries. This 'bias' limits the evidence base on low-income countries severely. In this group of countries, the weight of manufacturing is lower than agriculture in terms of both employment and value-added. To circumvent this limitation, we will search for studies that examine the impact of innovation on employment in agriculture and non-farm rural labour markets. We have established that there are a significant number of studies in this area, produced in the 1970s and 1980s. Examples include Morawetz (1974), Raju (1982), Bisaliah (1978), Singh (1972), Barker et al (1972), and Manning (1988).

The Review Team and DFID policy leads discussed the importance of providing a clear, accessible and informative section in the Report on how/why and to what extent innovation may affect employment. A summary of the channels and causal mechanisms through which innovation may affect employment is provided in section 1.2.2 and Table 1 below. The review Report will have a special section providing background on the relevant body of growth theory and dedicated to explaining how, given this framework, innovation may affect employment, through which channels in the production process, and with what causal mechanisms. This section will provide tables and/or diagrams to elucidate the narrative.

Measures of innovation we propose in the review (TFP growth, product innovation, process innovation, and imports of technology) and other proxies that will be captured in search (mechanization, technological change, etc.) are derived from the existing literature. However, each measure has certain strengths and weaknesses. The quality issue has been discussed with DFID policy leads and the Report will provide a detailed assessment of the data/measures with respect to relevance and reliability. By 'relevance' we refer to what the measure 'measures'; by reliability we refer to data quality/accuracy.

### *1.2.2 The innovation-employment relationship: channels and causal mechanisms*

Since the Industrial Revolution, the relationship between employment and innovation has been the subject of intense debate. Over the last three decades, the debate has intensified once again because of the stagnation in employment creation in developed countries and due to concerns about whether this stagnation has been related to skill-biased technological change and innovation (see, OECD, 2004). The debate has acquired a new dimension in the context of international development – especially with reference to Millennium Development Goals and the role of innovation in achieving the goals of poverty reduction.

In the long-term, the impact of innovation on employment is clearly positive. For centuries, industrialisation and innovation went hand in hand not only with higher levels of employment but also with greater variety of jobs. Nevertheless, the effect of innovation on employment in the short run remains uncertain due to misalignments caused by market rigidities and information asymmetries (Benavente and Rodolfo, 2008). In the short run, innovations can reduce the amount of labour for a given level of output. The absorption of excess labour would depend on the prevailing production technology and on substitutability between factors, as well as the nature of the technological change itself.

At the firm or industry level, innovations can create or destroy jobs, depending on whether it is mainly process or product innovation; or whether the new technology is capital- or labour-augmenting. It also depends on strategic behaviour of the firm – i.e. on the extent to which firms decide to maximise returns on innovation by increasing output or prices or both. If productivity gains due to innovation are reflected into lower prices and higher output, the demand for innovative firm's product increases and so does the firm's demand for labour. However, even under this condition, the industry- or macro-level effect of innovation on employment would depend on the extent of complementarity or displacement between the products of innovative and non-innovative firms.

**Table 1: Effects of innovation on employment: Levels, channels and causal mechanisms**

| | Displacement channel | Compensation channel | Overall short-run effect |
|---|---|---|---|
| **Firm-Level Process innovation** | Effect through productivity: less labour for a given output. Effect through skill-bias: higher demand for labour with matching skills; lower demand otherwise. | Effect through product prices; positive effect if product prices fall; negative effect otherwise (assuming price-elastic demand) | Uncertain: Depends on skill bias and strategic firm behaviour |
| **Firm-Level Product innovation** | Effect through productivity differences: lower demand for labour if job destruction in old product lines is greater than job creation in new product lines; higher demand otherwise. | Effect through market power: lower demand for labour if firm acquire market power and increase prices; higher demand otherwise. | Uncertain: Depends on product displacement and competition. |
| **Industry-Level Process innovation** | Effect through productivity: less labour for a given output. Effect through skill-bias: higher demand for labour with matching skills; lower demand otherwise. | Effect through industry prices; positive effect if product prices fall; negative effect otherwise (assuming price-elastic demand) | Uncertain: Depends on skill bias and strategic industry behaviour |
| **Industry-Level Product innovation** | Effect through productivity differences: lower demand for labour if job destruction in non-innovative firms is greater than job creation in innovative firms; higher demand otherwise. | Effect through market power: lower demand for labour if firms exercise market power and increase prices; higher demand otherwise. | Uncertain: Depends on displacement of non-innovative firms and competition. |
| **Macro-level innovation** | Substitution between capital and labour: higher labour demand if innovative technologies are labour-augmenting; lower demand if they are capital-augmenting. Substitutions between skill-levels: higher demand for skilled, lower demand for unskilled labour if innovation is skill-biased. | Effect through total factor productivity (TFP): Higher TFP - higher output growth - higher demand for labour. Effect through lower prices and higher incomes: higher innovation - higher productivity - lower prices - higher incomes – higher demand for labour. Compensation through investment: higher innovation - higher profits - higher investment - higher demand for labour. | Uncertain: depends on lack of demand constraints; labour market and governance institutions; and macroeconomic conditions. |

Table 1 above provides a summary of the channels through which innovation affects employment and the causal mechanisms at work. Informed by the existing literature, Table 1 identifies two main channels: displacement and compensation. The causal mechanisms at work are varied, but this variation can be explained easily and coherently by taking into account the fact that the demand for labour is derived demand. Whether innovation leads to higher or lower demand for labour depends on the nature/type of innovation, how firm respond to costs and incentives associated with innovation, and on the nature of labour market institutions that determine the extent of wage flexibility as a nominal adjustment mechanism.

Thus, the causal mechanisms at work within the displacement channel consist of product substitution, factor substitution and skill substitution mechanisms. As innovation increases the productivity of innovative firms and industries, the costs (and possibly the prices) of the latter fall, leading to an increase in the demand for goods and services they produce. This product-market-effect leads to higher demand for labour by innovative firms and industries. However, this increase in employment can be associated with reduced employment in non-innovative firms and industries as the higher-price and lower-quality products of the latter are substituted with lower-price and higher-quality products of their innovative competitors. Hence, even when we focus on the product substitution mechanism only, the effect of innovation on employment remains uncertain.

The uncertainty about innovation's effect on employment is confounded by factor substitution and skill substitution mechanisms. Factor substitution refers to the extent to which innovation induces firms to substitute capital for labour; whereas skill substitution refers to the extent to which innovation induces firms to substitute skilled for unskilled labour. The higher the rate of capital-labour substitution associated with innovation, the lower is the demand for labour – or vice versa. The extent and duration of this labour displacement effect depends on wage flexibility and the elasticity of demand for both innovative and non-innovative products and services. On the other hand, the employment effect through skill substitution is even less clear-cut. Even if innovation is skill-biased, it can change the skill composition of the labour force without significant job destruction. However; it can also lead to overall reduction in employment if the rate of job destruction for unskilled segments of the labour force is greater than the rate of job creation for the skilled segment.

At the macro level, the product substitution mechanism is less relevant. However, the factor and skill substitution mechanisms remain at work and their implications for employment may be exacerbated by international trade. At the macro-level, international trade may exacerbate factor or skill composition for both exporters and

importers of innovative technologies. Given that technology imports are main source innovation in LICs, trade liberalization can increase the rate of job losses and wage inequality in these countries if the imported technology is skill-biased and/or requires substitution away from labour. However, if imported technology is skill-neutral or if it is conducive to the absorption of unskilled labour, international trade may reinforce the job-creation effects of innovation.

To what extent can compensation mechanisms compensate for the adverse effects that result from the substitution mechanisms? Neo-classical economists tended to argue that compensations mechanisms are strong enough to override the adverse effects through product, factor or skill substitution (Hicks, 1932; Harrod, 1939; Myres, 1929). The assumptions here are that product markets are usually in equilibrium, any deviation from equilibrium is temporary, and that there are no demand constraints. However, both Kaldorian approaches by Pasinetti (1981) and Boyer (1988) and eclectic work by Acemoglu (1998, 2003) and Vivarelli (1995) demonstrates that innovation-induced deviations from equilibrium exist and can last for decades. Therefore, the speed and extent of the compensation mechanisms must also be verified in the light of empirical evidence.

As can be seen in Table 1, the compensation mechanisms involve prices, total factor productivity (TFP), investment and income. The assumption that underpins the compensation mechanisms is that innovation is conducive to productivity or TFP growth. Based on this assumption, it can be demonstrated that innovation can lead to higher consumer demand, increased firm profitability, higher wage incomes, and higher investment. All of these are conducive to job creation as firms increase investment to respond to increased demand for their products and services. However, the theory of imperfect competition suggests that the expected compensation mechanisms may not deliver the expected outcome of increased employment if firms increase prices rather than quantities and/or if labour unions do not adjust wages down. This further source of complication reinforces the need to resolve the uncertainty through empirical investigation.

The analysis above demonstrates that the effect of innovation on employment differs at different levels of aggregation. From a policy perspective, the overall effect at the macro level is the most relevant outcome. This has been confirmed during our deliberations with DFID policy leads. However, the Review can synthesize the macro-level evidence only to the extent that this is provided in original studies. Therefore, we will first synthesize the evidence separately for three different levels - firm, industry/sector and macro levels. This level-specific evidence can inform level-specific policies. Then, we will pool the level-specific evidence together to establish the strength and direction (positive or negative) of the partial correlation between

innovation and employment in general. In this, we will control for the level of analysis to demonstrate how innovation at firm, industry/sector or macro levels contribute to the overall correlation coefficient.

DFID policy leads have also pointed out the need to differentiate between effects of innovation on employment in the formal and informal sectors. To address this need, we will run a new search to capture studies that may be missed in the search we had completed. However, we think the number of such studies is likely to be small because the original search did not have any restriction on the type of employment (i.e., on whether employment effects are in the formal or informal sectors). The new search results will be documented. More to the point, special attention will be paid to the effects of innovation on employment in the informal sector – subject to study availability and quality.

## 1.3 Policy and practice background

The economic growth literature indicates that economies can grow either by accumulating capital, labour and other factors of production with a given technology; or thorough technological deepening driven by innovation. Growth, in turn, is the main source of job creation in the long run. However, the relationship between innovation, growth and employment has been studied mainly in the context of developed countries – with some notable exceptions concerning the impact of technology adoption on growth and employment in agriculture in the 1970s and the role of FDI in technology diffusion in the 1980s and 1990s. Hence, the role of innovation and technological change in LICs has remained largely outside the immediate attention of researchers, policy makers and practitioners for a long time. The technology gap between LICs and developed countries and the relative lack of data for the former have exacerbated the developed-country-bias of debate within policy and academic communities. This neglect, however, appears to have come to an end thanks to efforts by a mixture of actors, including international organisations, international donors, and policy makers in LICs. The common denominator of these efforts is to bring innovation into the centre of the policy debate on development and job creation in LICs.

The year 2005 appears to constitute a turning point in this context. First, the Gleneagles Summit of G8 countries in July 2005 resolved to intensify cooperation with Sub-Saharan Africa in the areas of research, science and technology. Almost in a parallel fashion, the UN World Summit of September 2005 stated that science and technology are vital for the achievement of the Millennium Development Goals (UN, 2005). Similarly, the UNESCO's 2005 Report indicated that indigenous development

of science and technology and strengthening of regional networks for that purpose are essential for African development. This view was echoed in the 2005 Report of the UK Commission for Africa, which stated the need to identify opportunities arising from innovation and to develop effective policies in areas such as science and trade (Commission for Africa 2005; 137). Similar views were expressed by the African Union Commission and the New Partnership for Africa's Development (NEPAD). Both regional institutions acknowledged the need to promote science, technology and an innovation as instruments for sustainable development, including employment (NEPAD, 2006).

In 2008, the World Bank (2008) published a comprehensive report on technology diffusion in developing countries. The report stated that technology is a 'critical determinant of sustainable growth and poverty reduction' and presented a methodology for measuring the extent to which countries use technological inputs and produce technological outputs. Although the report indicated that the rate of technology diffusion in developing countries is high, the technology gap for LICs is still very large and it is increasing for some of them. In 2010, the Department for International Development (DFID) of the UK government began to support research on innovation, technological diffusion and economic growth. The aim is to develop a better understanding of how innovation and technological change affect growth and the level and composition of employment.

This systematic review aims to contribute to the existing knowledge and evidence base concerning the relationship between innovation and employment. It will address the causal mechanisms at work and synthesize the quantitative and qualitative evidence, drawing on best practice and state-of-the-art methods developed by the systematic review community.

The review team will expand the range and composition of the potential users by following a two-pronged strategy. On the one hand, we will draw on the University of Greenwich's research and publicity infrastructure to disseminate the review findings through press releases, Greenwich-based workshop presentations, and web presence on the University of Greenwich website. On the other hand, we will liaise with the University of Greenwich Director for International Partnerships, who works closely with higher education institutions in developing countries. The aim here is to present the findings of the review and elicit debate through workshops open to the faculty of partner institutions, civil society organisations, and local/national policy-makers in the host country. We will organise 2 overseas workshops – one in India and one in Nigeria. The choice of these countries is informed by two considerations. First, these countries have graduated from low-income to lower-middle-income country status recently. Secondly, they have been noted by the UNESCO and World

Bank for their performance with respect to innovation and technology adoption in both manufacturing and non-manufacturing sector. However, we will also consult with our Advisory Board, 3ie, DFID and MAER-NET with a view to refine and finalise our strategy of dissemination and user-involvement.

We will revise and update the review in the light of the feedback given and comments raised in the workshops at Greenwich at our partner institutions in Ethiopia and Bangladesh. We aim to publish the review report as a journal article, with a view to make the findings available to a wider range of audience and elicit debate on how systematic reviews can add value to the conventional literature reviews in economics in general and development economics in particular.

## 1.4 Research background

### *1.4.1: Theoretical and empirical research on innovation-employment relationship: an overview*

The relationship between innovation, growth and employment is a well-established area of research. However, the mainstream literature reflects a developed-country focus and a relatively greater emphasis on the relationship between innovation and growth rather than employment.

Nevertheless, there is a critical mass of research on the innovation-employment relationship in LICs, encompassing 3 types work. First, there is an emerging body of work using aggregate measures of innovation such as technology import to estimate the effect on employment (Conte and Vivarelli, 2007; Mitra, 2009). Secondly, there is a long tradition of work on the relationship between technology adoption and employment in labour-intensive sectors such as agriculture or standard-technology sectors such as textiles other consumer goods industries (see, for example, Sing, 1972; von Braun, 1989; and Spielman et al, 2009). Finally, there is what is referred to as 'grey literature' and we prefer to describe as 'below-the-radar' literature in the form of conference proceedings, country reports or policy background papers produced in or for LICs (see, for example, Economic Growth Centre, 1974; Schumacher, 1972; King, 1986).

In short, the literature on innovation-employment relationship in the context of developing and/or low-income countries is well-developed to warrant a systematic review for three reasons. First, we have a well-developed theoretical/analytical framework for understanding the causal mechanisms in the innovation-employment relationship. Secondly, there are well-developed measurement/estimation methods

and a wealth of empirical evidence on the innovation-employment relationship. Finally, existing studies provide both convergent and divergent findings and as such they call for a systematic evaluation. The proposed systematic review will address this need by providing a global meta-synthesis accompanied with: (a) cluster-synthesis based on different research set-ups, estimation methods, publication types, country compositions, levels of analysis (macro-, sector-, and firm-levels), and type of innovation; and (b) a narrative synthesis of the theoretical/analytical information that will be mapped with the meta-analysis.

In what follows, we will summarise the main findings of the literature and explain how the proposed systematic review will synthesize the findings with a view to: (i) provide verifiable and reproducible estimates of the employment impact of innovation; (ii) contribute to development of evidence-based policies; and (iii) enable researchers and policy-makers alike to identify the need or potential for further research.

The debate on the relationship between innovation and economic performance goes back to Schumpeter (1934), who coined the term 'creative destruction' to analyse the relationship between innovation, growth and competition. The work gathered a new momentum with the advent of endogenous growth theory, which examines the role of the so-called Solow residual in growth equations – i.e., the variable that captures technology, skills, institutional quality, etc. The pioneering work is that of Romer (1986), while Aghion and Howitt (1992) incorporate the role of innovation, and Bardhan (1995) provides a comprehensive review of the work in the first decade of the related work.

One approach to the innovation-employment relationship focuses on 'innovation efforts' of firms in addition to capital formation and investment analysed in the exogenous growth theory. Here, innovation is the 'engine' of growth and it is usually measured/proxied by technology adoption, learning, educational variables, or by input variables such as research and development. The other approach is that of labour economists, who explain changes in employment (and other labour market outcomes such as wages) by labour force demography, macroeconomic factors, wage costs, labour market institutions; and innovation variables.

Pianta (2004) and Spiezia and Vivarelli (2002) provide good reviews of the body of both types of literature, albeit the latter tends to focus on developed countries in Europe and North America. Piva (2003), on the other hand, provides a review of the literature on innovation-growth-employment nexus in developing countries.

The existing literature tends report four main conclusions:

1. Type of innovation matters. While product innovation generally has a positive effect on employment, process innovation tends to have a negative effect. (See, for example, Edqhuist, 2001; Benavente et al, 2006; Jaumandreu, 2003).

2. Innovation-trade interactions matter. Technological change is conducive to job losses, particularly among unskilled workers. However, this is not the whole story: interaction between innovation and trade qualifies the impact of innovation on competitiveness, growth, and labour market outcomes. (See, Entorf and Pohlmeier, 1990).

3. National innovation systems matter. This is because countries' technological opportunities and innovating capabilities are embedded in the characteristics of their national innovation systems. Therefore, strengths, orientation, and priorities of the national innovation systems are likely to bear upon the innovation-employment relationship. (See, Hall et al, 2007).

4. Labour market institutions matter. Employment outcomes of innovation and technological change are mediated through national labour market institutions that affect wages, training, and labour market flexibility. (See, Beneventa et al, 2006).

These findings tend to hold across reviewed studies, but there are also significant differences between findings depending on estimation methods, specific sectors/industries, and country groupings. In addition, the reviews tend to be 'biased' in favour of developed countries - partly due to better data availability. Yet, evidence on innovation in agriculture and/or developing countries does exist – albeit such studies tend remain 'below the radar' of most reviews. In this category, studies on innovation and employment in developing/low-income countries include, Ansal and Karaomerlioglu (1999, 2000), Conte and Vivarelli (2007), Mayer (2000), Piva (2003), Robins (1996), and Spielman et al (2009). Studies on technology adoption and employment in agriculture include Basant (1987), Doss et al (2003), Feder et al (1985), Knowler and Bradshaw (2007), and von Braun and Webb (1989).

The proposed systematic review will contribute to our understanding of the innovation-employment relationship in three ways.

First, it will combine all main-stream studies with what we describe as 'below-the-radar' micro studies that examine the impact of innovation on employment in agriculture or non-farm employment in developing countries.

Secondly, it will draw on the innovation definition provided in the *Oslo Manual*, but it will interpret the definition widely to include a wider set of innovation indicators relevant to developing and low-income countries. We will differentiate between product and process innovations; and we will examine not only the employment impact of conventional innovation measures (e.g., R&D expenditures, patents, new products, etc.), but also that of non-conventional measures such as new technology adoption, new process adoption, and new delivery or working methods.

Finally, it will cluster the original estimates into 15 nests, each of which is defined by given metrics for innovation and employment. In other words, the original estimates that will be combined/synthesized as fixed-effect or random-effect weighted means will be nested such that they have common metrics for the intervention (independent) and outcome (dependent) variables. The nests/clusters will be defined by 5 measures of innovation (technology import, product innovation, process innovation, product and process innovation mixed, and TFP growth); and 3 measures of employment (at firm, sector, and macro levels). Depending on the number of studies and reported estimates, the *technology import* measure may be broken down into two components: licensing fees and import of technology embodied in capital goods. Similarly, the employment measure may be broken down into 'white collar', blue colour' and 'female employment' if data availability allows.

We estimate to include around 80 studies for meta-analysis and narrative synthesis. These studies will be screened and selected from a larger set of search results, the methodology of which is explained in the 'Methodology' section below.

### *1.4.2: Reviews of the literature and potential evidence base*

Although original studies provide literature review of varying length and scope, comprehensive reviews of the literature are few and have emerged in the last decade. Of these, Pianta (2004) reviews the empirical literature on the innovation-employment relationship in developed countries. Piva (2003), on the other hand, reviews the literature on developing countries. The scope of this review, however, goes beyond innovation and employment to include studies on the relationship between innovation, productivity and income distribution too.

In the developed country context, Pianta (2004) classifies the literature into three categories – based on the level of analysis. At the firm level, he reports that the overall employment impact of innovation tends to be positive. Firms that innovate in products as well as process tend to grow faster and are more likely to create jobs.

This result holds for companies with different sizes and within different industries. However, firm-level studies cannot capture the overall effects of innovation at industry or macro levels because employment creation by innovative companies may be obtained at the expense of job destruction in non-innovative firms.

The implications of the displacement mechanisms at the firm level are addressed by industry-level studies. These studies report mixed findings, which depend on the industry type (manufacturing, services and their sub-sectors) and the type of innovation. Innovation tends to have a positive effect on employment in industries that enjoy high product demand and engage in both product and process innovation. Industries engaged mainly in process innovation tend to experience job losses.

As indicated in Table 1 above, even industry-level evidence may not capture the full effect of innovation on employment. A full view can be obtained from macro-level estimates that take account of all direct and indirect effects through which innovation impacts on employment. However, differences in model specification and data availability tend to limit the extent to which macro-level estimates can be generalised. Bearing this caveat in mind, the macro-level evidence available points to positive effects; but the latter depend on macroeconomic conditions, institutional factors, and product prices.

The review by Piva (2003) indicates that the relationship between innovation and employment in developing countries has not been studied as widely as developed countries. Therefore, she focuses on studies that examine the impact of innovation on the skill composition of the labour force – rather than the impact on total demand for labour. It is not clear whether this focus is dictated by the lack of studies that examine the impact on total employment; or whether the review's aim is to highlight the innovation's effect on skill composition of the labour force. The literature review we conducted in preparation for this protocol suggests that the second reason may be the case. We have identified a significant number of studies examining the effect of innovation on employment in developing/low-income countries. These include Ansal and Karaomerlioglu (1999, 2000), Conte and Vivarelli (2007), Mayer (2000), Piva (2003), Robins (1996), and Spielman et al (2009). In addition, we have identified a significant number Studies on technology adoption and employment in agriculture, including: Basant (1987); Doss et al (2003); Feder et al (1985); Knowler and Bradshaw (2007); von Braun and Webb (1989); Morawetz (1974); Raju (1982); Bisaliah (1978); Singh (1972); Barker et al (1972); and Manning (1988). The latter group of studies examine the impact of innovation on employment in agriculture and non-farm rural labour markets. In addition, these studies cover either low-income countries as currently defined or developing countries that could be considered as LICs at the time of the research.

### *1.4.3: The rationale for a systematic review: intellectual and policy relevance*

The evident concentration of the research effort on developed or middle-income countries can be considered as both a challenge and an opportunity for this systematic review. It can pose a challenge for the obvious reason that existing studies may be inadequate in terms of quantity and/or quality. However, it can also provide an opportunity to look for studies that have remained 'below the radar' of the research community for two reasons.

First, there appears to be a disconnect between earlier studies conducted in 1970s and 1980s; and later studies conducted in 1990s and 2000s as part of the revival of interest in the innovation-employment relationship in developed countries. For this reason, recent studies tend to refer to contemporaneous studies on developed or middle-income countries rather than earlier studies on low-income countries and/or 'low-technology' sectors such agriculture, food processing or textiles. The second reason relates to the evident neglect of innovation as a driver for growth and employment in LICs until the turn of the twenty-first century. It is only after 2000 that international donors, developed-country governments, and policy makers in developing countries have begun to focus on innovation and technological change in LICs. This 'low ranking' of the innovation issue in the policy agenda of the major actors may have caused a 'selection bias' in the mainstream outlets for publications – leading to consignment of relevant studies to outlets for 'grey literature' such as national/regional journals, conference proceedings, or specialised databases.

Given this state of affairs, we will pay special attention to sources of grey literature and manual searches. Our list of databases (30 in total) includes 12 sources of working papers, reports, and policy documents. These include specialised databases such as Africabib, British Library Development Studies database, FAOBIB, International development Abstracts database, KIT Rural Innovation Systems database, and ILO library; and general sources such as NBER working papers, RePec repository, OECD Library, and World Bank databases. (For the full list and content description, see **Table A1** in the ***Appendix***).

In addition, we will attend the Fifth Conference on Micro Evidence on Innovation in Developing Economies, organised by UNU-Merit (United Nations University Maastricht Economic and Social Research on Innovation and Technology). This conference will have special sessions on the innovation-employment relationship in developing countries. The papers to be presented to this conference and the

additional information that we will obtain through networking will be added to the information that we already have on possible avenues for manual search.

Stated briefly, we aim to transform the challenge posed by the relatively small number of studies published in mainstream sources into an opportunity to build a comprehensive inventory of eligible studies for review. This exercise will enable us to address not only the need of the policy-makers for reliable and verifiable evidence, but also that of the research community interested in future avenues for research on an issue that has moved up the policy-makers' agenda in the last decade.

The rationale and strategy summarised above suggest that the policy and intellectual relevance of this systematic review are intertwined. This is generally the case in systematic reviews, but it is especially important in the context of the innovation-employment relationship in LICs, the increased policy-relevance of which is likely to encourage new research.

## 1.5 Objectives, Scope and Milestones

This systematic review addresses the following question: ***What is the impact of higher rates of innovation (measured by faster TFP growth, product innovation, process innovation, and imports of technology) on employment in LICs? How does this vary by gender?***

To address this question, we will cluster the work into 15 nests characterised by a unique pair of innovation and employment measures. As such, studies within each nest will share a common measure for the intervention (independent) and outcome (dependent) variables. Clustering/nesting will allow meta-analysis and synthesis of the empirical evidence reported by studies within the same nest. The nests/clusters will be defined by 5 measures of innovation (technology import, product innovation, process innovation, product and process innovation mixed, and TFP growth); and 3 measures of employment (at firm, sector, and macro levels). Depending on the number of studies and reported estimates, the *technology import* measure may be broken down into two components: licensing fees and import of technology embodied in capital goods. Similarly, the employment measure may be broken down into 'white collar', blue colour' and 'female employment' if data availability allows.

The scope of the study consists of mapping the meta-analysis of the empirical/quantitative evidence with qualitative evidence on causal mechanisms at work in the innovation-employment relationship. The existing work reviewed in Sections 1.4.1 and 1.4.2 above indicates that there is a wealth of empirical and

theoretical/analytical information on this relationship. Yet, there is also an evident need to make a systematic assessment of the findings and a critical evaluation of the implications for future research – as stated in Section 1.4.above.

The existing work indicates that innovation may affect employment in different ways in different contexts; and as such, it points out the need to classify and synthesize these effects and the channels through which they unfold. Therefore, the proposed systematic review will consist of three sections:

1. Section 1 synthesizes the theoretical explanations of the innovation-employment relationship - by drawing on the narrative synthesis methodology proposed by Popay et al (2006) and Rogers et al (2009). We will also draw on the meta-narrative method used by Greenhalgh et al (2005) in a systematic review on diffusion of innovation.

2. Section 2 synthesizes the empirical evidence on innovation-employment relationship – using meta-regression analysis methodology that draws on relevant work in economics, such as Mitchell et al (2005); Doucouliagos and Paldam (2009); Stanley and Jarell (1989); and Stanley and Doucouliagos (2007);

3. Section 3 maps the meta-synthesis with narrative synthesis, with a view to derive policy implications and identify the scope/need for further research – drawing on 'mixed methods synthesis' proposed by Harden and Thomas (2005).

The combination of meta-analysis and narrative synthesis is both necessary and appropriate for this review because of the complexity of the causal mechanisms in the innovation-employment relationship, the variations in the measures of innovation and employment, and the significance of the context-related factors.

The **milestones** in the review process are as follows:

| **Project activity (milestone)** | **Start date** | **End date** |
|---|---|---|
| Starting date | 1 April 2011 | |
| Submission of draft protocol | 8 April 2011 | 9 May 2011** |
| Review of protocol | 12 May 2011 | 13 June 2011* |
| Final protocol | 15 June 2011 | 4 July 2011** |
| Literature search | 13 May 2011 | 13 June 2011 |
| Uploading of studies to EPPI-Reviewer | 14 June 2011 | 20 June 2011 |
| Screening on the basis of title/abstract information | 23 June 2011 | 25 July 2011 |
| Critical evaluation – stage 1 | 22 August 2011 | 19 Sept. 2011 |
| Critical evaluation – stage 2 | 22 Sept. 2011 | 3 Oct. 2011 |
| Data extraction | 4 Oct. 2011 | 21 Oct. 2011 |
| Narrative Synthesis and Meta-Analysis | 24 Oct. 2011 | 14 Nov. 2011 |
| Writing of Draft Report | 15 Nov. 2011 | 20 Dec. 2011 |
| Submission of Draft report | | 21 Dec. 2011** |
| Review of Draft Report | 27 Dec. 2011 | 6 Feb. 2012* |
| Writing and Submission of the Final Report | 13 Feb. 2012 | 12 March 2012** |
| Policy brief and Website Text | 14 March 2012 | 20 March 2012 |
| Submission of Final Report, Policy Brief and Website Text | | 26 March 2012** |

** Indicates key **delivery dates** for the review team.

* Indicates key **return dates** for external reviewers.

# 2. REVIEW METHODOLOGY AND PROCEDURES

## 2.1 User involvement and impact

Our starting point in the process of identifying potential users of the review has been the review specifications drafted by the Department for International Development (DFID) of the UK government. DFID is a major actor with strong interest in international development in general and international aid in particular. The Department considers the production and dissemination of systematic reviews as an important means for strengthening the policy-makers' capacity to design and implement policy interventions. (http://www.dfid.gov.uk/R4D). This systematic review has been conducted in response to the objectives identified by DFID in its program for systematic reviews, one of which is to support the '... creation and dissemination of systematic reviews as public goods'.

To develop a better understanding of DFID's goals and benefit from the insights of potential users, we have also consulted with 2 DFID staff (Nicola Crissel of the Systematic Reviews Unit and Nirosha Gaminiratne of the Growth Unit); and DFID Consultant Professor Chris Heady. The consultations have contributed to clarification of the review question, extended the range of innovation indicators to be considered, and demonstrated the importance of looking for evidence on innovation's employment implications for women as well as informal sector jobs.

We aim to expand the scope for user involvement in and potential impact of this review by following a two-pronged strategy. On the one hand, we will consult with members of the advisory board we set up for the review. The board includes Professor Mario Pianta of Urbino University and Mr Ian Shemilt of the University of Cambridge. Professor Pianta is a leading contributor to the literature on innovation and employment, in addition to his work on innovation analysis and innovation and inequality. Mr Shemilt has extensive experience systematic review methodology and is a leading contributor to the development an economics perspective into evidence-based decision making. In addition to his work at Cambridge (and University of east Anglia until recently), he has also acted research coordinator of the Campbell & Cochrane Economics Methods Group (CCEMG). We will draw on the extensive knowledge and experience of the board members to ensure the quality of this review and disseminate it within the research and policy communities.

On the other hand, we will draw on the University of Greenwich's research and publicity infrastructure to disseminate the review findings through press releases, Greenwich-based workshop presentations, and web presence on the University of Greenwich website. We will also liaise with the University of Greenwich Director for

International Partnerships, who works closely with higher education institutions in developing countries, including India and Nigeria. We aim to present the findings of the review and elicit debate through workshops open to the faculty of partner institutions, civil society organisations, and local/national policy-makers in the host country.

## 2.2 Review Stages and Methodology: The Pre-Analysis Phase

In this section, we explain the methods and procedures that will guide the **first 4 steps** in the review process. These are:

1. Searching and Search Criteria;
2. Initial Screening on the basis of title/abstract information;
3. Critical appraisal and applying Inclusion/Exclusion Criteria on the basis of full-text information; and
4. Data/Information Extraction

The final phase, which consists of the synthesis and writing up, and the synthesis methods to be used are explained in Section 2.3 below.

**Step 1: Search and search criteria**

Our search strategy consists of 2 components:

a. Database selection; and
b. Concept/keyword specification, searching, and storing/documenting the search results.

### *2.2.1(a): Databases*

We will search 30 Databases for studies on the innovation-employment relationship. The list (**Table A1** in ***Appendix***) is drawn on the basis of our research experience, recommendations by EPPI-Reviewer staff at the Institute of Education, and Librarians at the University of Greenwich. Our list of databases includes 12 sources of working papers, reports, and policy documents. These include specialised databases such as Africabib, British Library Development Studies database, FAOBIB, International development Abstracts database, KIT Rural Innovation Systems database, and ILO

library; and general sources such as NBER working papers, RePec repository, OECD Library, and World Bank databases. (For the full list and content description, see **Table A1** in the ***Appendix***). In this review, we pay special attention to sources and databases specialised in the so-called 'grey literature', which consists of working papers, reports, and policy papers not published or due to be published in journals or edited books.

The emphasis we place on grey literature databases is due not only to the usual need to minimise the risk of publication bias. It is also driven by the need to cast the net wide in order to capture the maximum number of studies on LICs. The existing reviews suggest that innovation-employment studies on LICs are smaller in number compared to those on middle-income or developed countries. Therefore, it is important to include unpublished studies or studies published in 'below-the-radar' sources or on industries such as agriculture, food processing textiles, sales, etc. that may not be major innovators in a developed country context, but may be significant innovators and employers in LICs. Although casting a wide net is appropriate for this review, we must also ensure that studies by the same author(s) and using the same data set should be considered as duplicates even if their titles differ. This is likely to be the case when a working/discussion paper version of the study is published later as a journal article or book chapter. In addition, grey literature or 'below-the-radar' studies must be subject to the same quality assessment and critical evaluation criteria as published/mainstream studies.

### *2.2.1(b): Manual search and citation search*

In addition to database searches, we will conduct manual search after the title/abstract screening stage. The manual search will aim to locate unpublished studies, grey literature not indexed on databases, and to identify any study that may not be captured by the electronic search. Our manual search will be guided by the recommendations of JBI (2008) and CRD (2009), which include:

- Manual search in the reference lists of studies included for the full-text screening stage;
- Contacting governmental and inter-governmental agencies and relevant think-tanks not included in the list above; and
- Consulting the advisory board members major contributors to the work included in the final sample.

In addition, we will use Google Scholar and ISI citation search in Web of Knowledge to conduct citation searches for seminal studies on the relationship between innovation and employment in LICs or LMICs.

The results from hand search and citation search will be subject to the same selection and inclusion/exclusion criteria used for studies obtained through electronic search.

### *2.2.1(c): Search criteria, database searches and storing search results*

Searches in databases will be conducted as 'Title', 'Abstract', 'Keyword', and 'Text' searches. The search procedures are based on recommendations provided in the **EPPI Workshop** held at the Institute of Education and the text mining method suggested in CRD (2009); and will be driven by the following specifications:

**Search 1: Key word -** Innovation

**Synonyms:** Innovation OR "New Technique*" OR "New Technolog*" OR "Factor Intensity" OR "Total Factor Productivity" OR "New Product*" OR "New Process*" OR "New Method*" OR "New Service*" OR "Techn* Progress" OR "Techn* Change" OR "Modern Method" OR "Green Revolution" OR Mechanisation OR "Knowledge Transfer" OR "Technolog* Diffusion" OR "Technolog* Choice" OR "Technolog* Adoption" OR "Technolog* Import" OR "Import of Technolog*" OR TFP OR "Purchase of Technology" OR "Technolog* Transfer" OR "Capital Goods Import"
**(Use in 'Title' 'Abstract' and 'Keyword' search)**

**Search 2:** Keyword - Employment

**Synonyms:** Employment OR Unemployment OR "Labo*r composition" OR Labo*r Demand OR "Factor Demand" OR "Substitution Effect*" OR "Substitution Mechanism*" OR "Labo*r mobilization" OR "Job Creation" OR "Job Destruction" OR "Demand for Labo*r" OR "Labo*r Demand" OR "Demand for Skill" OR "Skill demand" OR "Skill-bias*" OR "Skill Bias" OR "Compensation Effect*" OR "Compensation Mechanism*" OR "Female Labo*r" OR " Women Employment"
**(Use in 'Title' 'Abstract' and 'Keyword' search)**

Added: Informal employment (upon DFID recommendation)

**Search 3:** Keyword - Low-income countries

**Synonyms:** "Low* income countr*" OR "Low-income countr*" OR LIC OR LICs OR LMIC* OR "Low* Middle Income Countr*" OR "Developing countr*" OR

"Less developed country" OR "Less* developed countries" OR "Low* income econom*" OR "Low* Middle Income econom*" OR "Underdeveloped country" OR "Underdeveloped countries" OR Africa OR Asia OR "Latin America" OR "third world" OR "low and middle income" OR "lower middle income"; names of LICs or LMICs in World Bank list (Appendix, Table A2).
**(Use in 'Text' search)**

**Combine Search 1, 2 and 3 results with 'AND')**

**Time period:** January 1970 – May 2011.

**Language:** Open

Initially, we will search in 'Title', 'Abstract' and 'Keyword' for Keywords 1 and 2, and their synonyms. Then, we will carry out a 'Text' search, using the 'Low-income countries' (Keyword 3) and its synonyms. Finally, we will use the 'Combine' command to combine the search results. This exercise will yield studies that have all specified keywords and their synonyms in 'Title' OR 'Abstract' OR 'Keyword' AND 'Text'. An extract from the search in IBSS database is provided in **Table A3** in the ***Appendix.***

The search will be conducted by a research assistant, who is trained in search methodology and in use of the *EPPI Reviewer*. The research assistant will upload the search results to *EPPI Reviewer.* The search and uploading process will be monitored by 2 members of the review group: Denise Hawkes and Mehmet Ugur.

We will use *EPPI Reviewer* as our management tool for documenting the screening results pursuant to the PIOS framework (Step 2 below), the inclusion/exclusion decisions based on the inclusion/exclusion criteria (Step 3 below), and data extraction codes (Step 4 below).

We will provide a search summary for each round of the search process described above. The summary will be obtained automatically from the 'Search' facility of each Database.

**Step 2: Initial screening on the basis of title/abstract information: establishing relevance**

The titles and abstract of all search results will be screened to assess ***the relevance of the studies for the review question***. During screening, we will draw on the PICOS framework recommended by the Centre for Reviews and Dissemination (CRD) of the

University of York (CRD, 2009). Although PICOS has been developed for systematic reviews in health care, the framework can be adopted to this systematic review.

The PICOS framework requires screening with respect to: (i) **P**opulation; (ii) **I**nterventions; (iii) **C**omparators; (iv) **O**utcomes; and (v) **S**tudy design. We revise this framework by dropping the 'Comparator' criteria as the research on the innovation-employment relationship is not based on controlled trials. We will also rename the intervention variable as 'Independent variable' that is assumed to influence the outcome. Thus, the resulting framework can be described **PIOS Framework** - referring to "**Population"**, "**Independent Variable",** "**Outcome Variable"** and "**Study Design".** The PIOS framework will inform the decisions of the reviewers at two stages of study selection:

1. Stage of **title/abstract screening** for establishing relevance
2. Stage of **full-text assessment** for establishing eligibility

At the title/abstract screening stage, we will ascertain study relevance by interrogating each study with 4 questions derived from the PIOS framework. The questions and their relationship with the PIOS framework are as follows:

a. With respect to **Population:**

   - Is the study relevant for understanding the innovation-employment relationship in **low-income countries** (or synonyms)?

b. With respect to **Independent variable:**

   - Is innovation (or synonyms) **independent** rather than outcome variable in the study?

c. With respect to **Outcome variable:**

   - Is employment (or synonyms) **outcome** rather than independent variable in the study?

d. With respect to **Study design**

   - Is the study **original** and NOT a review of original studies?

The PIOS criteria tested with these questions will be coded in EPPI Reviewer – our main data storage and management platform. The selection/de-selection decisions will be taken in accordance with the following rule:

- Studies **satisfying the 4 PIOS criteria** will be **selected** for the next stage
- Studies **failing to satisfy any of the PIOS criteria** will be coded accordingly and will be **de-selected** from the review.

Three reviewers (Denise Hawkes, Arup Mitra and Mehmet Ugur) will apply the PIOS criteria to each study independently. However, before independent screening, we will conduct a pilot of 10 studies listed in search results. The aim here is to test whether the proposed selection criteria can be interpreted reliably and consistently; and whether they are effective in classifying studies for selection or de-selection. Any discrepancies between reviewer decisions will be discussed, and both the discussion and the basis of *ex-post* agreement will be documented. This is in line with CRD (2008: 24) recommendations, which indicate that piloting and independent screening increases the chance of selecting all relevant studies and ensures that the selection procedure can be repeated by third parties, if necessary.

This procedure will ensure that a study selected for the next stage will be compatible with the objective of the review. Despite this precision, the methodology is not restrictive. This is because a study satisfying the PIOS criteria can be selected even if it may have some inadequacies in terms of estimation methodology or data quality or country coverage. Similarly, a study has equal chance of being selected, irrespective of the magnitude or measures of the innovation and employment variables it utilizes. These qualities will help in reducing the risk of omitting relevant studies.

At the end of the screening stage, we will document the selection / de-selection decisions given. This information will be provided in a table that summarises:

- The total number of **selected** studies
- The total number of **de-selected** studies
- A Breakdown of the **de-selected** studies, based on the number of PIOS criteria NOT satisfied.

The information for this table will be generated from the PIOS codes recorded in *EPPI Reviewer* for each study. Hence, the basis for selection/de-selection decisions will be verifiable.

**Step 3: Inclusion criteria with full-text information: establishing eligibility**

At this stage, we assess the ***eligibility of the studies for inclusion in the systematic review*.** Full text of selected studies will be read in order to assess the extent to which the study satisfies the PIOS criteria. Three reviewers (Denise Hawkes, Arup Mitra and Mehmet Ugur) will apply the PIOS criteria to full-text studies independently. However, before independent screening, we will conduct a pilot of 10 studies listed in search results. The aim here is to test whether the proposed inclusion criteria can be interpreted reliably and consistently; and whether they are effective in identifying studies for inclusion/exclusion. Any discrepancies between reviewer decisions will be discussed, and both the discussion and the basis of *ex-post*

agreement will be documented. This is in line with CRD (2008: 24) recommendations, which indicate that piloting and independent screening increases the chance of selecting all relevant studies and ensures that the selection procedure can be repeated by third parties, if necessary.

The PIOS criteria for inclusion/exclusion at the full-text stage are specified as follows:

**Table 2: PIOS criteria for inclusion/exclusion with full-text information**

| PIOS Heading | Inclusion/Exclusion Criteria | Question | Decision |
|---|---|---|---|
| Population | 1**. Data/evidence including low-income countries and/or LMIC** | 1. **Does the study use data including 'low-income countries' or LMIC its synonyms?** | Yes -Include<br>No -Exclude |
| Independent Variable | 2.Documented/recognised innovation data/evidence source | 2. Does the study use a documented/recognised data/evidence source for innovation? | Yes -Include<br>No –Exclude |
| Outcome | 3. Employment is a main outcome variable, measured with recognised/documented data/evidence | 3. Does the study report innovation effects on employment rather than other labour market outcomes such as wages only? | Yes -Include<br>No –Exclude |
| Study Design | 4. Valid study design | 4.<br>Does the study have a clearly set out theoretical framework linked to quantitative or qualitative evidence?<br>OR<br>Does the study have a clearly set out empirical framework tested with quantitative evidence? | Yes–Include and code as Theoretical/analytical (TA)<br>No –Exclude<br>Yes–Include and code as empirical (EM)<br>No –Exclude |

**Decision rule:** a study will be included for critical evaluation if it satisfies 4 criteria/questions.

At the end of the full-text assessment stage, we will document the inclusion / exclusion decisions given. This information will be provided in a table that summarises:

- The total number of **included** studies
- The total number of **excluded** studies
- A Breakdown of the **excluded** studies, based on the PIOS criteria NOT satisfied.

This procedure will ensure that a study selected for the critical evaluation stage is compatible with the objective of the review and eligible for inclusion in a systematic review aiming to provide a meta-analysis of the empirical evidence, combined with a narrative synthesis of the causal mechanisms at work in the innovation-employment relationship.

During the full-text evaluation stage, we will also conduct manual search for seminal cited in the included studies but not captured by the electronic search. We will also conduct citation search, using Google Scholar and ISI citation search in Web of Knowledge. The citation search will be conducted for seminal/important studies identified during full-text evaluation.

**Step 4: Critical evaluation / quality assurance: validity, reliability and applicability**

At this stage, selected studies will be read independently by three reviewers, who will evaluate the studies with respect to **validity, reliability and applicability (VRA)**. In this review, **validity** refers to methodological rigour that would minimise the risk of bias; **reliability** refers to the extent to which the findings of the study are re-producible; and **applicability** refers to the extent to which the findings can be generalised/applied to low-income countries.

**Validity** determines whether a study has a valid 'construct' and a valid 'method'. The construct consists of concepts, notions and hypotheses that postulate the relationship between innovation and employment; whereas the method involves the kind of evidence and analysis used to test the hypotheses for the innovation-employment relationship. An empirical and/or theoretical/analytical study will be considered to satisfy the *construct validity* requirement if it is based on a coherent set of arguments on why innovation can be expected to affect employment, and if these arguments are clearly related to existing literature. It will be considered to satisfy the method validity criterion if its evidence/data is documented and its method of analysis is clearly defined.

**Reliability** of a study is the extent to which study results can be regarded as consistent over time and across countries; or they are open to be verified in the light of new evidence. The reliability criterion requires that the evidence used is collected on the basis of a clear methodology and the results, given the method of analysis, can be replicated. We will consider a study to satisfy the reliability criterion if its evidence base is documented, the evidence is related to postulated causal mechanisms at work in the innovation-employment relationship, other relevant variables that impact on employment are controlled for, and the findings are discussed in the light of existing literature.

Finally, **applicability** refers to the extent to which the findings of the study can be applicable to low-income countries. The applicability of a study to LICs can be established on theoretical and/or empirical grounds.

To establish validity, reliability and applicability (VRA), we interrogate each study with the set of questions listed in **Table 3** below.

**Table 3: Validity-Reliability-Applicability (VRA) criteria for final inclusion**

| | VRA Criteria | Question | Decision |
|---|---|---|---|
| **1.** | **Validity of construct** | Is innovation-employment relationship theorised/modelled coherently and in the light of existing literature? | Yes -Include<br>No -Exclude |
| **2.** | **Validity of method** | Is the method of analysis informed by existing theory/theories? | Yes -Include<br>No –Exclude |
| **3.** | **Reliability of data/evidence (1)** | Is data/evidence documented and its reliability discussed? | Yes -Include<br>No –Exclude |
| **4.** | **Reliability of data/evidence(2)** | Is the evidence related to causal mechanisms postulated in the innovation-employment relationship? | Yes–Include<br>No –Exclude |
| **5.** | **Reliability of estimation** | Are other relevant variables that impact on employment controlled for? | Yes–Include<br>No –Exclude |
| **6.** | **Reliability of findings(1)** | Are the findings tested for robustness? | Yes–Include<br>No –Exclude |
| **7.** | **Reliability of findings(2)** | Are the findings related to relevant methodological or theoretical/analytical literature? | Yes–Include<br>No –Exclude |
| **8.** | **Applicability to LICs** | Are the findings applicable to low-income countries on theoretical or empirical grounds? | Yes -Include<br>No -Exclude |

A study will be included for meta-analysis and/or narrative synthesis if it satisfies 6 out of 8 VRA criteria – provided that it satisfies at least one of the two 'data/evidence reliability' and 'findings reliability' criteria. In other words, a study will be included if it satisfies criteria 1, 2, 3, and 6; and one of 4 or 5 and one of 7 or 8. We will provide a breakdown of included and excluded studies, and the latter will also be broken down with respect to the number of criteria they failed to satisfy.

Inclusion/exclusion criteria at the full-text critical evaluation stage will be implemented by three reviewers - Denise Hawkes, Arup Mitra, and Mehmet Ugur. The reviewers will first conduct a pilot study consisting of 10 studies selected randomly. The decisions on the pilot sample will be compared and convergent/divergent decisions will be noted. Agreement on divergent decisions will be sought through consensus based on prior discussion. The same method will be applied to the critical evaluation of the whole sample.

**Step 5: Data/information extraction**

Data extraction is the process through which we obtain findings from included studies and information about study characteristics. Data extraction will be linked with the evaluation/critical appraisal process, and we will follow the methodology proposed by Stanley (2010) and Doucouliagos et al (2001) for coding each estimate extracted from the original studies. D. Hawkes and M. Ugur will extract information and data from all empirical studies (EM); and Arup Mitra will extract information and data from all theoretical/analytical studies (study type **TA**). This division of labour will be facilitated by the fact that studies coded in ***EPPI Reviewer*** with these codes can be sorted on that basis easily. Mehmet Ugur will conduct additional checks on all extracted data/information to minimise the risk of errors and/or omissions.

Data/information extracted from each study will be coded systematically to allow for flexible retrieval and, more importantly, to be able to conduct meta-analysis and narrative synthesis in a coherent manner. **Table A4** in the ***Appendix*** provides a list of study and data/information characteristics that will be coded in EPPI-Reviewer. The codes will enable us to nest studies on the basis of study types, innovation and employment measures, country types, estimation methods, or data types – depending on the number of studies and reported estimates. The codes will enable us to capture the following information:

a. Bibliographical information about the study: including record no. in EPPI Reviewer, author(s), date of publication, mid-point of observation period, etc.

b. Study characteristics information: including study design, study type, type of data used (time-series, cross-country or panel data), and units of measurement for dependent (outcome) and independent variables.

c. Analytical/estimation methods used: including type of analysis (mathematical/verbal) for study type **TA**, method of estimation for study type **EM** or **EM2** (including fixed- or random-effects regression, linear or non-linear modelling, interaction terms, etc), and number of countries/years in the sample.

d. Outcomes/results reported: theoretical/analytical conclusions about casual mechanisms and channels in the innovation-employment relationship (for **TA** studies), estimated parameters for all independent variables including interaction terms (for **EM** and **EM2** studies), standard errors of estimated parameters (for **EM** and **EM2** studies), causality/endogeneity test results (for **EM** and **EM2** studies), etc.

In this review, we will include all estimates of innovation's effects on employment reported in empirical studies, irrespective of the econometric method through which the estimates are obtained. However, each estimate will be coded systematically to indicate whether the underlying estimation is instrumented and what kind of estimation method (OLS, 2SLS, 3SLS or GMM) is used in the original studies. In addition, the effect estimates will be with respect to the measure of employment – i.e., with respect to firm-, industry- and macro-level as well as skill type and male-female employment.

The alternative would have been to choose an aggregate statistic that summarizes the study-specific estimates (e.g. the average or median of the reported estimates) or an estimate chosen from the reported set on the basis of significance or sample size or degrees of freedom. However, reliance on single estimates has two major shortcomings. First, it prevents the use of all available information. Secondly, the selection criterion is highly likely to have a subjective dimension. Therefore, we will include all reported estimates and use the appropriate weighting method (fixed-effect weighting for within-study estimates and random-effect weighting for cross-study estimates).

## 2.2 Methodology of narrative synthesis and meta-analysis

Methods of synthesis can be classified into 2 broad categories: methods for synthesizing quantitative/empirical evidence such as meta-analysis; and methods for synthesizing qualitative evidence, such as narrative synthesis. In this review, we will use both methods and map the findings systematically, as suggested by Harden and Thomas (2005). We will combine meta-analysis with narrative synthesis because the causal mechanisms at work in the innovation-employment relationship are quite complex (see **Table 1** above). In addition, the demand for labour is a 'derived demand' in the sense that it is related not only to wages (i.e., the cost of labour), but also to price and quantity changes in the product market, to labour market institutions, and macro-economic environment. Hence, when innovation is introduced as an 'intervention', its effect on the demand for labour will be felt through a complex set of displacement and compensation mechanisms at work in different markets and at different levels of analysis. As a result, it is necessary to complement the meta-analysis results with a narrative synthesis of the causal mechanisms at work and the level .

### 2.2.1. The narrative synthesis

As Harden and Thomas (2005) have observed, synthesizing both quantitative and qualitative findings strengthens the systematic review for two reasons. First, the qualitative synthesis can compensate for the relative lack or weakness of the contextual information associated with quantitative meta-analysis. Secondly, the synthesized effect size may be a reliable indicator of how innovation may affect employment under certain conditions, it does not provide adequate information about how the effect materializes and whether it can be generalized. Therefore, the mixed methods enable the reviewer to relate the effect to different contexts and to verify the extent to which theoretical/analytical or qualitative evidence is supported by empirical evidence from the meta-analysis.

Our narrative synthesis methodology draws on research findings and practical guidelines in Popay et al (2006) and CRD Guidance (2009). The methodology is designed to enable reviewers to strike an optimal balance between the need for reflecting variations in terms of theorisation and explanation on the one hand and the need for deriving cross-cutting and generalizable conclusions on the other. To extract the necessary data for the narrative synthesis, we will use 8 key identifiers for **thematic (vertical)** and **content (horizontal)** issues.

The thematic (vertical) issues consist of innovation type, including product innovation, process innovation, 'mixed' innovation, and innovation embodied in

imported capital goods. Our reporting of the narrative synthesis will follow a sequence determined by the thematic (vertical) issues. Using an analogy, types of innovation will be used as 'pillars' around which the narrative synthesis is built. The content (horizontal) issues, on the other hand, consists of the effects of innovation on employment (negative, positive, non-linear); the levels at which the effects are estimated (firm, industry/sector, macro levels); the causal mechanisms at work (nature of displacement and compensation mechanisms); and the role of 'state variables' such as country characteristics, institutional factors, skill types, and gender. Following the same analogy above, data/information on the content (horizontal) issues can be viewed as the 'bricks' that complete the structure laid out by the thematic (vertical) issues.

### 2.2.2 Meta-analysis: partial correlations, elasticities and meta-regression analysis

The meta-analysis of the reported estimates of the innovation's effect on employment consists of 4 stages. In stage 1, we will provide fixed-effect weighted means of the estimates reported by each original study. The averages will be based either on **partial correlation coefficients** or **elasticities** – depending on the type of estimates and sample data reported by original studies. In stage 2, we will cluster the original estimates into 15 nests, defined by 5 innovation measures/metrics and 3 measures of employment (see, section 1.4.1 above). In this stage, we will provide random-effect weighted means of the estimates clustered within each nest. In stage 3, we will provide random-effect weighted means for all of the estimates pooled together. Finally, in stage 4, we will provide multi-variate meta-regression results for estimates reported stage 2 and stage 3 – provided that the number of observations within each nest is adequate for regression analysis. If the number of observations within each nest in stage 2 is thin, we will conduct meta-regression analysis for pooled estimates we synthesize in stage 3.

We are aware of the limitations/constraints we may encounter when we cluster the original study estimates into 15 nests. The main limitation/constraint is data availability. Indeed, we may have no or very few observations in some nests. In such cases, we will not be able to conduct meta-regression – either for testing for genuine effect or for identifying the sources of variation/heterogeneity between original estimates. In addition, even if we have sufficient number of observations within a particular nest, the large majority of the estimates may originate from a single study. In such cases, we run against the risk within-study dependence due to non-random character of the underlying data. This problem can be ameliorated by using clustered data analysis to correct the standard errors. However, the dependence on a single source or few sources remains as a limitation when the cluster-adjusted standard errors remain sufficiently low to return statistical significance.

Despite these limitations, we do not want to rule out the use of clusters/nests at the Protocol stage because the problems posed by clustering/nesting are 'empirical' in nature. In other words, their occurrence or severity cannot be established *ex ante*. In addition, clustering/nesting will enable us to test whether the theoretical/analytical predictions about different employment effects at different levels (firm, industry and macro levels) or with different innovation types (process versus product innovation) are borne by empirical evidence. Given this advantage, we propose to calculate random-effect weighted means and conduct meta-regressions within clusters/nests – provided that the original estimates are rich enough and distributed evenly so as to make the exercise viable. Otherwise, we will calculate weighted means for clusters/nests, but we will run the meta-regression (including the funnel asymmetry and precision-effect tests) with full sample data.

The original estimates from empirical studies will consist of regression estimates for partial effect of innovation on employment, controlling for other factors. Formally, the estimated regression model is likely to be a variant of the following model:

$$L_{ti} = \beta_{0ti} + \theta Inv_{ti} + \beta_k CV_{kti} + u_{ti} \qquad (1)$$

Where $L_{ti}$ is employment in firm/industry/country i at time t; $Inv_{ti}$ is innovation in firm/industry/country i at time t; $CV_k$ is the kx1 vector of control variables that are derived from the theory on the demand for labour; $u_{ti}$ is the error term. The coefficients are defined as follows: $\beta_0$ = constant term; $\theta$ = the partial effect of innovation on growth; and $\beta_k$ is the kx1 vector of coefficients representing the partial effects of the control variables on employment. The main estimate of interest for us is the estimate of $\theta$ – and the standard error (or the t-statistic) associated with it.

The major challenge for meta-analysis of regression estimates such as $\beta$ is that the metrics used for the dependent and independent variables (i.e., employment and innovation) usually differ between studies – and even between model specifications within each study. This measurement problem can be overcome if the dependent and independent variables are measured in natural logarithms, where the estimate of $\beta$ is the **elasticity** of employment with respect to innovation. In such cases, $\beta$ represents the percentage change in employment in response to 1% change in innovation – irrespective of the unit of measurement. Therefore, our preferred estimate for synthesis will be the elasticities – provided that these are reported by original studies or the original studies contain sufficient information to enable us to calculate elasticities.

If neither condition holds, we will calculate partial correlation coefficients for individual estimates, cluster of estimates within a particular nest, and all estimates within the study sample. The partial correlation of coefficient shares 2 common features with elasticity. First, it is comparable across studies irrespective of the underlying unit of measurement for innovation or employment. Secondly, it measures the association between innovation and employment, controlling for other factors affect employment in the estimated model. However, unlike elasticity, it provides information only about association – and not about the effect size. In other words, the partial correlation coefficient does not provide an estimate of how much employment change in response to a given change in innovation – it merely summarises the extent and direction of partial correlation between the two. Despite this limitation, the partial correlation coefficient is widely used in meta-analysis of econometric studies (see, for example, Doucouliagos et al, 2011). In line with this tradition, we will calculate partial correlation coefficients at study, cluster/nest and all-sample levels. In addition, we will calculate fixed-effect and random-effect weighted means for the partial correlation coefficients at the same levels of analysis.

The partial correlation coefficient and its standard error will be calculated in accordance with the following formulae:

$r = \frac{t}{\sqrt{t^2 + df}}$ (partial correlation coefficient); and (2)

$Se = \sqrt{\frac{1-r^2}{df}}$ (standard error) (3)

Partial correlation coefficients have been used in economics by Doucouliagos (1995) and Djankov and Murrell (2002). Doucouliagos et al (2011) use the partial correlation coefficient as a substitute for effect size in a meta-analysis of the relationship between executive pay and firm performance.

The weight in the **study-based** fixed-effect estimators (FEEs) is the inverse of precision-squared ($1/SE_i^2$), where $SE_i$ is the standard error of each estimate reported in the study. The weighted mean calculated with this method will tend to be lower the lower is the precision (i.e., the higher is the standard error) of the original estimates (Stanley, 2008; Stanley and Doucouliagos, 2007; and de Dominicis et al, 2008). The FEE of reported effects is calculated as follows:

$$\Omega = \frac{\sum (1/SE_i^{\,2}) * \theta_i}{\sum 1/SE_i^{\,2}} \quad (4)$$

Where $\Omega$ is the weighted mean of the reported effects; $\theta_i$ is the series of reported effects (elasticities of partial correlation coefficients) ranging from 1 to N; and $1/SE_i^2$ is the inverse of the squared standard error associated with each estimate.

In addition to FEEs, for each study we will also calculate confidence intervals and precision levels associated with each FEE. This set of synthesis will enable us to establish the extent of convergence or divergence between the study-based estimates, whether the average estimate is statistically different than zero, and the level of precision it is associated with. The study-based summary measures will be ranked on the basis of precision.

The **cluster-based** or **full-sample** random-effect estimates (REEs) are efficient when the original estimates are drawn from different populations (Stanley, 2008; Stanley and Doucouliagos, 2007; and de Dominicis et al, 2008). This condition is not usually satisfied in country-based econometric studies because the 'country population' is fixed. However, the REE has the added advantage of accounting not only for within-study variation (as the FEE does) but also for between-study variation. It is calculated using $[(1/(SE_i^2 + \sigma^2)]$ as weight, where $SE_i$ is the standard error of each original estimate and $\sigma^2$ is the variance of the distribution of all estimates reported by studies in a specific nest/cluster. It is calculated as follows:

$$\Psi = \frac{\sum[1/(SE_i^2 + \sigma^2)] * \theta_i}{\sum[1/(SE_i^2 + \sigma^2)]} \qquad (5)$$

Where $\Psi$ is the weighted-mean of reported effects; $\theta_i$ is the series of reported effects (elasticities or partial correlation coefficients) ranging from 1 to N; and $1/(SE_i^2 + \sigma^2)$ is the weight. The weight is the inverse of the sum of two variances: the square of the standard error ($\boldsymbol{SE_i^2}$) associated with the reported effect (i.e., the measure of within-study heterogeneity); and the variance ($\sigma^2$) for the set of reported estimates (i.e., the measure of between-study heterogeneity) within a nest/cluster.

The REE will provide a summary measure for the innovation's effect on employment, given the evidence reported by a number of studies nested together. We will not calculate confidence intervals or precision levels for the REEs. Instead, we will conduct meta-regression analysis (MRA) in order to establish: (a) whether the synthesized evidence can be taken as indicator of genuine effect; (b) if publication bias exists; and (c) the sources of variation/heterogeneity between original estimates.

The multi-variate meta-regression model is a weighted-least-squares (WLS) model that allows testing for statistical significance of the intercept and slope coefficients. It can be stated as follows:

$$t_i = \beta_0 + \beta_1(1/SE_i) + \sum \mu_k (MV_k / SE_i) + \varepsilon i \qquad (6)$$

Here ($t_i$) is the t-statistic and ($1/SE_i$) is the precision of the elasticities reported in original studies (or the precision of the partial correlation coefficients to be calculated); MV is vector of moderating variables that affect the heterogeneity between reported estimates; and ($\varepsilon i$) is the error term. (For discussion on the properties of the model in (6), see Stanley, 2010 and Doucouliagos et al, 2011). Some of the moderating variables are indicated in table A4 in the Appendix. However, the full list of these variables will be completed during the critical evaluation stage, when develop a deeper understanding of the study characteristics.

The meta-regression model in (6) enables us to carry out a number of tests. One of these is the funnel-asymmetry test (FAT) that detects publication bias. The test specification is indicated in (7) below and rejection of the null-hypothesis should be interpreted as evidence of publication bias.

$$\begin{aligned} H_0: &\quad \beta_0 = 0 \\ H_1: &\quad \beta_0 \neq 0 \end{aligned} \qquad (7)$$

Yet, this test is known to have low power – i.e., the test has low probability of rejecting the null hypothesis when the latter is actually false. This increases the probability of committing Type II error and as such implies higher risk of not detecting bias when the latter exists.

Against this weakness, the model specified in equation (6) has the advantage of identifying genuine empirical effect regardless of bias. In other words, it allows testing for $\beta_1$ separately. If the test for $\beta_1$ rejects the null-hypothesis, it implies that there is genuine effect beyond publication bias or small study effect. (Stanley, 2008: 108). This requires testing the hypothesis in (8) below. Rejection of the null hypothesis indicates that innovation has a genuine effect on employment (or the association between innovation and employment is statistically different than zero).

$$\begin{aligned} H_0: &\quad \beta_1 = 0 \\ H_1: &\quad \beta_1 \neq 0 \end{aligned} \qquad (8)$$

Finally, estimating the meta-regression model in (6) also allows for identifying the sources of heterogeneity/variation between estimates reported in original studies. This is achieved by testing for the statistical significance of the coefficients of the moderating variables (the range of $c_k$'s). The size and sign of those coefficients that are statistically significant will provide an indication of whether the relevant moderating variable has a positive or negative effect on the original estimates.

Meta-analysis combined with multi-variate meta-regression has certain advantages over conventional literature reviews and/or descriptive summaries of research findings. One advantage is that current meta-analysis methods enable reviewers to establish the extent to which model specification errors exist in empirical studies and how these errors affect the variation among reported evidence. Another advantage is that meta-analysis provides tools for checking for publication bias through Funnel Asymmetry Tests (FAT). Thirdly, meta analysis, despite its shortcomings, is an objective and systematic method for synthesising diverse and often conflicting empirical findings in the literature. In fact, Doucouliagos and Stanley (2007) report that meta-analysis results contradict the verdicts of conventional literature reviews and inform more verifiable conclusions.

Given these advantages, meta-analysis of economic research findings has been used in several studies as new techniques have been developed to test for the significance of the reported results. For example, Mitchell (2005) uses meta-analysis to synthesize research evidence on the relationship between economic development and human rights. Doucouliagos and Paldam (2009) conduct a meta-analysis of the relationship between international aid and population size of the recipient countries, and whether this relationship differs between multilateral and bilateral donors. Havranek and Irsova (2009) examine the relationship between firm characteristics and the extent of vertical technology spill-overs generated by foreign direct investment (FDI). (For further studies, see Meta Analysis of Economic Research (MAER) Network website at http://www.hendrix.edu/maer-network/default.aspx?id=15088 ).

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# APPENDIX

## Table A1: Databases and Indexes

| Database | Description and Access |
|---|---|
| **Africabib.org** | http://www.africabib.org/africa.html |
| **Africa Development Bank** | http://www.afdb.org/en/documents/ |
| **Asian Development Bank** | http://ss.adb.org/?type=advanced |
| **BLDS (British Library for Development Studies)** | The British Library for Development Studies (BLDS) contains the largest collection of economic and social development materials in Europe, with over half originating from developing countries. http://blds.ids.ac.uk |
| **Business Source Premier (EBSCO - Business and Economics Databases)** | Very wide-ranging within the Business discipline, including marketing, management, accounting, finance, economics, *etc*. Largely full-text journal articles, plus market research reports, industry reports, country reports, company profiles and SWOT analyses. (University of Greenwich portal) |
| **CAB Abstracts** | A bibliographic database compiled by the Commonwealth Agricultural Bureau International (CABI). It covers the significant research and development literature in the fields of agriculture, forestry, human health and nutrition, animal health, and the management and conservation of natural resources, with particular attention to the needs of developing countries. |
| **Centre for International Development** | CENTRE FOR INTERNATIONAL DEVELOPMENT OF HARVARD UNIVERSITY http://www.hks.harvard.edu/centers/cid/publications |
| **DOAJ (Directory of Open Access Journals)** | A multi-disciplinary database of freely available, peer-reviewed full-text journals. (These may not be contained in any of the aggregate databases such as ABI/Inform or Business Source Premier.) |
| **EconLit** | Provides bibliographic citations, with selected abstracts, to the international literature on economics from 1969, plus full text for more than 400 journals. It provides indexing and full text for articles in all fields of economics, including […] country studies, and labour economics". (University of Greenwich portal) |
| **EThOS (Electronic Thesis Online Service)** | The British Library's repository of post-doctoral theses from participating UK universities (see: http://ethos.bl.uk/HEIList.do). |
| **ESE (Economics Search Engine)** | Contains "over 23,000 economics websites and utilizes yolink to mine results and retrieve actionable, keyword-rich content. Results can be saved to Google Docs, bookmarked or shared via major social networks. Each site is certified |

| Database | Description and Access |
|---|---|
| | by RFE". Available at: http://ese.rfe.org/ |
| **FAOBIB (UN Food & Agricultural Organization)** | On-line catalogue of documents and publications produced by FAO since 1945, books added to the library collections since 1976, and serials. http://www4.fao.org/faobib/index.html |
| **Google** | http://www.google.com |
| **Google Scholar** | Searches across many disciplines and sources: articles, theses, books, abstracts and court opinions, from academic publishers, professional societies, online repositories, universities and other web sites. http://scholar.google.co.uk/schhp?hl=en&tab=ws |
| **IBSS (International Bibliography of the Social Sciences)** | Contains references to journal articles and some books. Broad ranging coverage of the social sciences, including economics, demography, political science and sociology. International coverage. (University of Greenwich portal) |
| **Index of Conference Proceedings** | Lists conference proceedings newly acquired by the British Library and available for loan or document supply. The BL acquires the proceedings of all significant conferences held worldwide regardless of subject or language and currently holds the proceedings of over 450k conferences. |
| **Index to Theses** | References to higher degree theses accepted by universities in Great Britain and Ireland. (University of Greenwich portal) |
| **IngentaConnect** | Multidisciplinary collection of full-text articles and bibliographic citations. (University of Greenwich portal) |
| **International Development Abstracts (Elsevier)** | *International Development Abstracts* was founded in response to the need for a reference journal covering the growing literature on topics and issues relating to developing countries and remains the leading bibliographical reference source in the field. Papers are divided into 40 main headings including sections on agriculture and rural development; environment and development; industrial policy; social policies such as health, housing, and education; health, demography; gender and culture; aid, international relations and politics. (University of Greenwich portal) |
| **JSTOR** | References to journal articles. Full text available for the Business Collections (1 & 2). (University of Greenwich portal) |
| **KIT Information Portal Rural Innovation Systems** | This information portal provides access to free, full-text electronic documents on Rural Innovation Systems (RIS), both as an analytical concept and a development tool. It is also a unique entry point for all other Internet sources on RIS, including newsletters, discussion groups, websites, bibliographic databases, and directories of organizations and projects. http://portals.kit.nl/-/7587/KIT-Portals/Portal-Rural-Innovation-Systems |
| **Labordoc (ILO Library)** | Contains references to print and electronic publications, including journal articles, from countries around the world, on all aspects of work and sustainable livelihoods, and the work-related aspects of economic and social development and human rights. Available at: http://labordoc.ilo.org |

| Database | Description and Access |
|---|---|
| **NBER (National (U.S.) Bureau of Economic Research) Working Papers** | Full-text access to working papers, plus references to selected books/book chapters. (University of Greenwich portal) |
| **OECD iLibrary** | References to journal articles, book chapters and datasets. (Greenwich has limited access to some full-text resources.). (University of Greenwich portal) |
| **RePEc (Research Papers in Economics)** | Collaborative international project for the dissemination of economics literature. Contains full text and references to book chapters, journal articles and working papers. (Note that the working papers are also offered through EconLit.) Can be searched via the IDEAS interface at: http://ideas.repec.org/search.html |
| **SSRN** | The SSRN eLibrary consists of two parts: an Abstract Database containing abstracts on over 336,600 scholarly working papers and forthcoming papers and an Electronic Paper Collection currently containing over 272,800 downloadable full text documents in Adobe Acrobat pdf format. The eLibrary also includes the research papers of a number of Fee Based Partner Publications. http://papers.ssrn.com/sol3/DisplayAbstractSearch.cfm |
| **Web of Knowledge** | Includes the *Social Sciences Citation Index*, and *Conference Proceedings Indices* for *Science* and *Social Sciences and Humanities* |
| **World Bank e-Library** | Contains books, journal articles, working papers and other research publications. Full text is available only to subscribers. However, it is fully searchable at: http://elibrary.worldbank.org/search/advancedsearch |
| **ZETOC** | The British Library's multi-disciplinary Electronic Table of Contents service. Contains references to journal articles and conference papers. (British Library) |

**Table A2- 1: List of Low-Income Countries (LICs)**

| | | |
|---|---|---|
| Afghanistan | Guinea | Nepal |
| Bangladesh | Guinea-Bisau | Niger |
| Benin | Haiti | Rwanda |
| Burkina Faso | Kenya | Sierra Leone |
| Burundi | Korea, Dem Rep. | Solomon Islands |
| Cambodia | Kyrgyz Republic | Somalia |
| Central African Republic | Lao PDR | Tajikistan |
| Chad | Liberia | Tanzania |
| Comoros | Madagascar | Togo |
| Congo, Dem. Rep | Malawi | Uganda |
| Eritrea | Mali | Zambia |
| Ethiopia | Mauritania | Zimbabwe |
| Gambia, The | Mozambique | |
| Ghana | Myanmar | |

**Table A2- 2: List of Lower Middle-Income Countries (LMICs)**

| | | |
|---|---|---|
| Angola | India | São Tomé and Principe |
| Armenia | Iraq | Senegal |
| Belize | Jordan | Sri Lanka |
| Bhutan | Kiribati | Sudan |
| Bolivia | Kosovo | Swaziland |
| Cameroon | Lesotho | Syrian Arab Republic |
| Cape Verde | Maldives | Thailand |
| China | Marshall Islands | Timor-Leste |
| Congo, Rep. | Micronesia, Fed. Sts. | Tonga |
| Côte d'Ivoire | Moldova | Tunisia |
| Djibouti | Mongolia | Turkmenistan |
| Ecuador | Morocco | Tuvalu |
| Egypt, Arab Rep. | Nicaragua | Ukraine |
| El Salvador | Nigeria | Uzbekistan |
| Georgia | Pakistan | Vanuatu |
| Guatemala | Papua New Guinea | Vietnam |
| Guyana | Paraguay | West Bank and Gaza |
| Honduras | Philippines | Yemen, Rep. |
| Indonesia | Samoa | |

http://data.worldbank.org/about/country-classifications/country-and-lending-groups#Low_income

Table A3: Use of search terms and search results – The IBSS trial

**Search 1 – Innovation and Synonyms in Title, Abstract and Keywords (109638hits)**
ti(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR ab(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR tag(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion)

**Search 2 – Employment and Synonyms in Title, Abstract and Keywords (87373hits)**
ti(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR ab(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR tag(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization")

**Search 3 – LICs and Synonyms in All fields + Text (247281hits)**
"Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world"

**Search 4 – Combine Search 1, 2 & 3 with the Boolean operator "AND" (1022hits)**
("Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world") AND (ti(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR ab(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR tag(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization")) AND (ti(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR ab(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR tag(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion))

**Table A4: Data to be extracted and coded**

| **Information/Data Required** | **Components (to be coded in *EPPI Reviewer*)** |
|---|---|
| Bibliographical information | 1. Record no. in EPPI Reviewer<br>2. Author(s)<br>3. Year of publication<br>4. Average year for period covered |
| Study characteristics | 5. Study type (TA, EM, EM2)<br>6. Publication type (journal articles, book chapter, working paper, thesis, report, etc.)<br>7. Type of data used (time-series, cross-country or panel data)<br>8. Units of measurement for dependent (outcome) and independent variables |
| Analytical/estimation methods | 9. Type of analysis (mathematical/verbal) for study type **TA**<br>10. Method of estimation for study type **EM** or **EM2** (including fixed- or random-effects regression, linear or non-linear modelling, interaction terms, etc)<br>11. Number of countries/years in the sample |
| Outcomes/results reported | 12. Theoretical/analytical conclusions about casual mechanisms and channels in the innovation-employment relationship (for **TA** studies)<br>13. Estimated parameters for the innovation variable, including interaction terms (for **EM** and **EM2** studies)<br>14. Standard errors of estimated parameters (for **EM** and **EM2** studies)<br>15. Causality/endogeneity test results (for **EM** and **EM2** studies) |