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The State of STEM Labour Markets in Canada Literature Review

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The State of STEM Labour Markets in Canada Literature Review^{*}

Natalia Mishagina[†]

Résumé/abstract

In this paper we summarize views presented in recent literature regarding the state of the Canadian labour market for science, technology, engineering, and mathematics (STEM) professionals. To a large extent, this market is affected by trends in the global market for high technology products and services. These global trends have been well-studied in the literature but mostly with respect to their effects on the United States, China, and India, whereas Canadian STEM labour market has received little attention. We propose topics of future research based on identified literature gaps and discuss issues related to data to make this research possible.

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Section 1. Introduction and key findings

The importance of the science, technology, engineering, and mathematics (STEM) workforce has been widely accepted because of its critical role in the knowledge-based economy. Regardless of its small share in the nation's total workforce, its impact on society is tremendous. The first goal of this report was to survey recent literature and to summarize views expressed by various authors about the current state of Canadian STEM labour market and main tendencies in the country and abroad affecting Canadian demand and supply of STEM workers. The second goal was to identify literature gaps, to propose topics of future research, and to suggest data needed to make these studies possible. The sections of this report are primarily based on publications in peer-reviewed journals and analytical reports. Due to delays in data availability and the publication lag common to economics journals, analyses of most recent events are not widely covered in peer-reviewed publications. Therefore, this literature review has been supplemented where possible with materials found in conference proceedings, discussion and working papers, government reports, and newspaper articles.

Key findings:

1. Technological growth facilitates globalization of markets for new technologies, as well as products and services previously thought immune to globalization. For the same reason, labour markets for professionals who create and use these technologies have also become increasingly international.
2. The balance of power in the world has changed due to the rapid growth of Asia, Eastern Europe, and Brazil, accompanied by the economic slowdown in OECD countries. Thanks to this shift of power, traditional roles of countries have been noticeably shifting in terms of both technology flows and labour flows:
 - a) Traditional source countries of foreign students, China and India, are now increasingly able to produce large numbers of quality graduates in STEM fields, thus contributing not only to the stock of skilled labour in their countries but also decreasing a flow of potential workers to developed countries.
 - b) OECD countries, and especially USA, are seen as less attractive options to work and study for foreign high skilled labour. Some studies report increasing return flows of educated Asians to their home countries.
 - c) Traditional receivers of offshored low-skill jobs, China and India, are now increasingly exporting high-skilled goods and services such as information and communication technologies (ICT), research and development (R&D) in fields like pharmaceuticals, and many business services. Moreover, these countries have been continuously producing their own R&D, with their share of high quality publications and patents rising.
3. Unlike the USA or the UK, which traditionally have been offshore outsourcing their ICTs, Canada has been acting as both a sender and a receiver of outsource offshoring ICTs and services

(ranking closely with Ireland and India). However, appreciating Canadian dollar has made the country's exports of ICT products less attractive. American multinational corporations (MNCs) have reportedly shifted their growing operations to other countries. Canada has also started relocating its R&D to lower cost areas like Eastern Europe and Asia.

4. The effects of these global tendencies on the Canadian economy and its labour market have been found to be mainly small and insignificant. However, opinions have been expressed that in the future the effects will be more pronounced. Global factors examined in the studies have mainly resulted in temporary job uncertainties, delays in securing entry jobs for new graduates, and skill mismatches in some areas. In many cases authors report gradual adjustments on the labour market due to high mobility and adaptability of professionals affected by these tendencies. Employers have approached their difficulties with skill mismatches by tapping into the global supply of labour. The future effects of these imbalances are forecasted to be more pronounced as they will affect the relative attractiveness of STEM professions for new generations. As a result, more massive labour imbalances are possible in the future. Some signs of these imbalances can already be seen from reduced enrolment rates and decreased inflows of foreign trained labour in some fields.

Global tendencies outlined above have been analyzed primarily with respect to the US economy and its labour market, whereas Canadian studies of STEM markets date back to the mid-2000s. The only area that is well presented in recent publications is the effect of offshore outsourcing on Canadian labour markets. It is possible that due to the publication lag common to peer-reviewed journals in economics new studies will appear in a few years. Lags with data availability would contribute in a similar fashion. However, on a number of topics Canadian data is either not collected, is inadequate, or is unavailable to researchers due to restricted access.

The following literature gaps are identified and proposed as areas of future research:

1. Analysis of the economic behaviour of STEM professionals on the labour market. The effects of economic shocks to labour supply cannot be properly evaluated without understanding the mechanisms of individuals' career choices. A large portion of skills acquired during education is applicable in occupations other than STEM. Therefore, career changes are possible in response to worsening economic opportunities on STEM labour markets. By now, supply responses in the form of emigration are analyzed. However, career changes may be seen as a less costly alternative to emigration. In fact, as will be shown in the report, the number of individuals with STEM degrees employed outside STEM occupations is quite substantial. Therefore, careers changes exist, and they are costly for the society since education is largely financed by public funds, especially at the graduate level.

2. Contribution of foreign students to creation of knowledge in Canada. Currently, foreign students in Canada have been seen as a source of income to the country in the form of higher tuition fees and other expenditures. However, education abroad is often seen as a secure and

successful immigration path. To our knowledge, there is no study that evaluates student-to-resident transition rates and labour market outcomes for international students. Existing studies of the foreign-born primarily concentrate on immigrants who either never acquire a Canadian degree or acquire a degree post-landing.

3. Career outcomes of doctorate recipients. The literature on American higher education institutions emphasizes that the number of contingent faculty has been increasing. These findings are troublesome since work arrangements of contingent faculty undermine the main factors that make the profession attractive: job security and academic freedom. It is possible that these structural changes in academic faculties are specific to the USA which experienced budget cuts to universities in the 1980s and 1990s, accompanied by enrolment spurts and an increase in awarded doctorate degrees. It is also possible that being a small open economy, Canada has been affected by this problem differently by simply losing PhDs unmatched to jobs to the USA and other countries. It is difficult to answer this question without a thorough analysis of the data. No study on faculty structure dynamics is available for Canadian universities and colleges, although there is a dataset that can be potentially used to answer these questions: An administrative data set of university teachers is collected by Statistics Canada but it is not available for researchers. Two other surveys collected in the USA but not in Canada which could shed light on the issue are the Survey of Doctorate Recipients and the Survey of Graduate and Postdoctoral Students. The first survey follows a subset of PhDs trained and residing in the USA in terms of their career advancement. The second survey covers graduate students and junior researchers. Having similar data in Canada is important to understanding the issue discussed in this paragraph and many other questions.

4. Returns of Asian immigrants to home countries. The recent economic slowdown in the USA, an increasing backlog for green cards, and caps on work permits have lessened the attractiveness of the USA as a host-country for thousands of Asian specialists. A number of studies report increasing outward migration of Asian-born high skilled labour from the USA, with a primary destination - "home". Two aspects of this migration are relevant to Canada. First of all, it would be interesting to know whether Canada is among the desired destinations for these migrants. There has been anecdotal evidence that Canada has been benefitting from this migration by directly attracting immigrants and by converting temporary workers in Canada employed by American MNCs to permanent residents. Second, it would be interesting to know if similar trends are observed for the Asian-born living in Canada. As was emphasized in the studies cited above, not only better economic opportunities at home but also proximity to family and preferences to different lifestyle are among main reasons for returns. Asian living in Canada may have come to Canada for similar, that is economic, reasons. Are their employment options still attractive? Are these individuals similar to their American counterparts in the sense that their elderly parents are still in China, that they have been having difficulties integrating, and they prefer the culture and lifestyle of their home countries to those of Canada? And finally, do they intend to migrate (or have they already migrated) back home?

The report is structured in the following fashion: Although factors affecting the labour market are tightly intertwined, it was decided to present supply and demand factors separately. In addition, often the authors reviewed concentrated on one particular side or segment of the market, which in turn dictated the approach. The next chapter describes the current stock of STEM professionals and provides comparisons with other OECD countries where data was available. Next, market dynamics are analyzed with respect to factors affecting primarily the supply of STEM labour. Domestic as well as international tendencies are compared. The following chapter concentrates on the demand side of the market. It similarly studies the domestic demand for STEM workers in Canada and the international demand, which has been separated into the demand for STEM workers directly and the demand for Canadian STEM products and services that in turn affects the labour market. The final section draws conclusions and indicates possible areas of future research.

Section 2. Supply of STEM workers

The size of the STEM workforce can be estimated either based on the total number of holders of STEM degrees, or on the total number of individuals employed in STEM occupations. According to Desmond and Gellatly (2006) who use the second method, about 14% of the Canadian labour force were employed in STEM occupations. However, total STEM degree holders in Canada outnumbered those employed in STEM occupations by a ratio of 2.2 to 1. Out of the total STEM labour force, there was 242,680 full-time equivalent personnel engaged in R&D, roughly two-thirds of which worked in the private sector. The predominant group of R&D workers (61%) were researchers, or a ratio of 8.8 researchers per 1,000 employed (a ratio that has been stable since 2005). For comparison, the ratio of researchers per 1,000 employed in OECD countries in 2008 ranged from 3.8 in Italy to 10.6 in Japan and Sweden.

Canadian STEM labour force is similar to that of the US in terms of its relative size. However, its distribution over economic sectors is different. For example, in Canada, the sector of professional, scientific, and technical services employed a larger share of STEM workers than in the USA. Conversely, the manufacturing sector in the USA was more S&E-intensive than in Canada. Two-thirds of all Canadian R&D personnel were employed in the private sector, followed by the sector of higher education (26%) and government (8%).

The stock of STEM workers in Canada evolves in a dynamic environment: new STEM workers are added every day through training and immigration, while current STEM workers leave by changing professions, emigrating, or retiring. What follows describes the main aspects of the evolution of the STEM supply in Canada that were actively discussed in the literature.

2.1. Inflows of STEM workers

Inflows of STEM workers through training

Building brains rather than buying them through immigration or sharing them through outsourcing has been suggested in many studies as a cost-effective way to create the STEM labour force (Mueller 2006 citing Helliwell 2005, Freeman 2010). The significant development of Canadian universities since the 1970s has allowed Canada to rely on its own research and graduate training and provide educational services on the international market (Helliwell, 2006). The total number of students graduating from Canadian universities rose from 169,000 in 1992 to 242,000 in 2007. The growth of the number of graduates was not stable over time experiencing periods of rapid spurts (1992-1994 and 2002-2007) and periods of stagnation (1995-1999). The UNESCO report on sciences predicts a possible slowdown in future graduation rates by demonstrating that undergraduate enrolment in Canadian universities in the 2006/2007 academic year rose only by 0.9%, the smallest rate since 2000.

The report also notes that of some concern is a persistent disaffection among undergraduate students for the natural sciences and mathematics: In recent years, enrolment has fallen in several areas, including mathematics and computer and information sciences, where enrolment fell by almost 25% since 2002/2003. Auriol (2007) uses multiple data sources to study graduation rates and compositions of PhD graduates in OECD countries. The author reports that the number of PhDs awarded in Canada was stagnating between 1998 and 2006. In comparison, the overall growth of PhD awards in OECD grew by 40% during the same period. More recent data (post-2008) that would be interesting to analyze due to the economic crisis of 2008 are not yet publicly available.

The effects of graduation rates on the labour market are traditionally studied using dynamic supply and demand models also known as “cobweb models”. These models allow understanding how the supply of new graduates responds to policy incentives like changes in R&D-to-GDP ratio and others. Majumdar and Shimotsu (2006) developed a cobweb model for engineers and scientists in Canada and estimated it for the period between 1986 and 1998. The authors found that the relative employment of engineers was sensitive to the share of R&D expenditures in GDP, particularly after 1997. They then used the estimates to develop a dynamic impulse response function. Looking at the impact of a permanent increase in R&D-to-GDP ratio, they found that the adjustment process was relatively smooth, and the market adjusted in 2 to 8 years to roughly 80% of the final steady state. For a one-time improvement in R&D allocation, it was found that under rational expectations, there was an initial increase in the number of science graduates which later fell below the steady state value and remained there for a long period as the initial increase worked its way through the market. It would be interesting to repeat this exercise using more recent data.

An important feature of modern STEM education systems in the OECD countries is the presence of foreign undergraduate and graduate students. The choice of study locations (e.g., home vs. abroad, if abroad, where exactly) depends on the perceived relative availability and quality of education in each location. Moreover, education abroad may offer an opportunity to stay in the country after graduation for work and possibly immigration. Therefore, relative employment opportunities and immigration regimes in different countries may matter as well. Depending on why students choose Canada and what they do after graduation will define how changes in STEM education and immigration policies worldwide will affect the Canadian STEM labour force. There are no analytical studies on the behaviour of foreign students in Canada after graduation, or on student-to-resident transition patterns, or on the reasons to choose Canada as a place to study.

A few statistical reports shed light on the current stock of foreign students, their composition, and their current impact on the economy. According to the Canadian Bureau of International Education, in 2008 there were over 178,000 foreign students in Canada, nearly twice the number of 1999. Half of these students came to study in universities. Not only their absolute number but also their share in the total university enrolment in Canada grew from 4.8% in 1999 to almost 8% in 2008. Roughly half of all international students were from Asia, and the numbers of Asian students were among the

highest growing since 1999: 6.5 times for China and 5.5 times for India. The highest growth (among countries with non-negligible number of students in 1999) was exhibited by Saudi Arabia: almost a 10-fold increase. The distribution of international students in Canada over fields of study is somewhat similar to the USA but not exactly the same. For example, international students were less represented in humanities, social sciences, education, and law, but were more numerous in business and public administration, mathematics and computer sciences, and architecture, engineering, and related technologies. In 1992, a relatively larger share of international student compared to Canadians was enrolled in physical and life sciences, but by 2008 their shares have equalized.

Currently, the Canadian share in the worldwide market for education is about 5% at the undergraduate level and under 5% at the graduate level. A report by RKA, Inc. finds that direct financial gains from international students' expenditures on tuition and accommodation in Canada in 2008 reached \$6.5 billion, more than the total revenues of exporting coal or lumber in the same year (\$6.07 billion and \$5.1 billion, respectively). However, foreign students (at least in graduate programs) also contribute to innovation by doing research.¹ They also have a potential impact by remaining in the country and contributing to the Canadian labour force, innovation, and prosperity growth.² However, neither of these contributions have been acknowledged and evaluated in the literature.

Canada's position on the global education market is currently affected by two tendencies: the growth of education systems in traditional source countries (China and India), and changes in policies regarding the foreign-born in OECD countries. According to Freeman (2010), in the past 25 years virtually every country in the world has expanded its education system by creating new universities. India has tripled the number of post-secondary institutions (from 6000 to 18000) between 1990 and 2006. Asia-Pacific in-country training has increased from 9 to 19% and among middle income countries from 16 to 27%. If in 1975 China produced virtually no PhDs in S&E, by 2004 the country graduated 23,000 PhDs, 63% of them in S&E. The author predicts that based on current enrolment rates in PhD programs, by 2010 China would have produced more S&E PhDs than the USA. These numbers are expected to grow even further. According to the UNESCO science report, by 2017 India's enrolment rates are planned to increase by 21%. This will be achieved by establishing 30 more universities, 14 of which are planned to be innovation universities. RKA (2009) has already reported a decrease in the Canadian share on the global education market by 1 percentage point between 2000 and 2004, which were the years to take advantage of the USA tightening its visa requirements to foreign students after the events of 9-11. This decrease could be the first indicator that the competition on the global market for foreign students is getting fiercer and the main

¹ According to Statistics Canada, a substantial number of researchers in the sector of higher education are doctoral students.

² See, for example, Hunt and Gauthier-Loiselle (2008) for the analysis of the contribution of foreign scientists to innovation in the USA.

competitors on the market have changed from OECD countries to Asia. In 2006, Canada was ranked 14th in the global ranking of education destinations, a fall from its 5th position (RKA, 2009, citing a report by the Conference Board of Canada). Considering the growing demand for international education (projected growth from 1.9 million to 7.2 million students by 2025), the loss can be substantial (RKA 2009).

The second process affecting the potential inflow of foreign students to Canada is current and forecasted changes in the immigration policies and policies regarding foreign students in other OECD countries. Prior to the economic slowdown, OECD countries were aiming their immigration policies at highly skilled labour, following the Canadian model. For example, the Skilled Migrant Program in the United Kingdom resulted in an increase in admissions from 1,197 in 2002 to 21,939 in 2006. Recently replaced by the Tier 1 (General) program, it allowed highly skilled individuals who scored the required points to immigrate to the United Kingdom without the sponsorship of an employer. Japan increased the number of skilled temporary workers admitted from 30,000 in 1990 to 169,800 in 2005 (Science and Engineering Indicators, 2010). Increasingly, international students were seen as a valuable source of these skilled migrants. The ability of countries to attract and retain international students was recognized as an important component of meeting countries' future labour market needs. Since 2006, Australia has admitted 99% of its former international students as long as they could pass the physical examination. These applications were processed within three weeks if the student was already in Australia at the time of application (Hawthorne, 2008). Germany instituted a new immigration law in 2005 that allowed students to work 180 half days per year and apply for the new Highly Skilled Program after graduation.

However, after 2008-2009 the economic prospects in OECD countries have substantially changed: the economic slowdown substantially affected employment of the native population in these countries so that public concerns have turned towards protecting existing employment for countries' citizens. Tightening of immigration policies has been already being enacted or discussed as a possibility. For example, in May 2011 France has adopted a new rule known as *La Circulaire Guéant*, aimed at restricting the inflow of foreign students into the country and limiting their opportunities after graduation. Regardless of the protests of university communities in the country, the government refused to withdraw *La Circulaire Guéant*. The UK has tightened its Points Based System, increasing skill and wage thresholds. It also increased the period during which the jobs should be advertised nationally before being opened to non-EU residents. The minimum salary for a job to be classified as skilled went up by 17.5%, and the duration of employment in MNCs before eligibility for transfers to other immigrant categories was also increased. The US fiscal stimulus package makes it more difficult for beneficiary firms to hire high-skilled foreign workers, although this may make little practical difference given how over-subscribed quotas for such visas are. Australia has cut its skilled permanent migrants quota for 2009 by 20% against the target initially announced. Italy has announced that it will cut its quota for non-seasonal workers from 150,000 in 2008 to zero for 2009. Spain has cut its quota for non-seasonal "Contingente" workers from 15,000

in 2008 to 900 in 2009 (OECD, 2009a). So far, Canada has broadly maintained its immigration policies making slight changes at the margin. The loss of these countries with respect to foreign students and specialists can become Canada's gain.

Inflows through access to global labour markets

In his study of the American supply of S&E workforce, Freeman (2006) evaluated whether America would suffer a shortage of scientists due to demographic reasons, a problem that equally concerns Canadian policy-makers. He found that since the US is an open economy, domestic imbalances of supply on the S&E labour market will be immediately resolved by tapping in the world-wide market for professionals. He provides the following evidence: Since the early 1990s, China, India, and the former Soviet countries nearly doubled the global labour force when they opened and began their economic growth. The STEM labour force in China is reaching that of the USA and Europe (each country now employs 20% of the world scientific labour force). Adding Russia (7%) and Japan (10%) results in a group of nations that employs 75% of all researchers in the world, while accounting only for 35% of all world population. China alone produced 6 million bachelor's graduates thus expanding the coverage of university education from 5% to 22% among 18-22 year-olds. Most of these graduates were in S&E fields. In fact, in 2005 China produced 5 times as many engineers as the USA.³ Even the number of PhDs granted worldwide has expanded dramatically. In 2004, the European Union granted 78% more degrees than the USA. Based on the UN demographic data, the population of the working age in these countries (mostly in China and India) will massively increase by 2050. This global labour force will provide more than ample supply for developed countries that face decreasing growth rates of their population. Freeman adds that the quality of the growing global labour force is increasing due to improving domestic education systems so that neither the quantity nor the quality of the world labour force should be a concern for employers in developed countries.

Not every country saw its growth in STEM employment proportionally match the growth in their GERD. Although post-2008 numbers are not yet available and one cannot judge how severe the change in pull-push factors has been, systematic imbalances in R&D funding and investment in human resources can influence global migration flows for years to come. For example, Russia continues to invest in STEM fields but fails when it comes to R&D funding, which can be noted from the country's decrease in global scientific output measured with patents and publications. At the same time other countries do not have adequate human resources to support their expanding investments. The global competition for skilled migrants has substantially intensified as more countries recognize the need to supplement their domestic workforces with technologically advanced workers from abroad.

³ Freeman reports statistics by regions in general and for the USA specifically. No numbers were reported for Canada.

Similarly to the USA, tapping into the global market for S&E labour is an immediate option for Canada. The economic slowdown and the immigration backlog in the USA and the crisis in the Euro zone have been currently affecting thousands of temporary workers, students near graduation, and other categories of the S&E workforce in the USA and Europe. Although there have been no studies or statistical reports directly related to this issue, newspapers often publish interesting stories regarding this new trend. For example, in 2009, *Maclean's* publishes an article that suggests that Canada can become a brain-gainer of thousands of foreign highly skilled workers in the US with expiring work permits and no prospects of green cards, difficulties finding jobs, and facing caps on H-1B visas. The article cites speeches by Bill Gates and Michael Bloomberg asking to prevent the loss of highly skilled labour to other countries, including Canada. Some companies like Microsoft opened "development centers" in Canada, where they could keep their employees while they are waiting for visas. Companies that already have offices in Canada use them as temporary bases for their employees awaiting visas. Oftentimes, such employees stay in Canada for a year and become eligible for category L visas (intracompany transfers) instead of H-1B since category L has no cap. Another variation of this practice, called "parking", includes assigning employees to Canadian branch offices but having them spend most of their time in the USA. The article reports that Canadian immigration lawyers have already taken advantage of this situation by directly contacting these individuals and offering them an accelerated process of acquiring permanent immigrant status. For some, this seems like an attractive option, especially for those who spent years waiting for the permanent resident status in the USA. The article also suggests that difficulties with obtaining visas may be the problem of the past, and the new trend for outmigration from the USA is the lack of jobs rather than visas.

In addition to luring foreign-born brains from the USA, Canadian labour market can gain by encouraging returns of Canadians who left to study and/or work in the USA. Ferrall and Mishagina (2011) study first job locations of doctorates trained in the USA between 1957 and 2005. In particular, the authors analyzed decisions to stay in the USA versus returning to Canada with respect to demographic characteristics and economic and political factors in both countries in the year of graduation. The decisions to locate to Canada or remain in the USA are studied separately for Canadian citizens, American citizens, and third country nationals. In addition to demographic variables expectedly affecting home bias (i.e., older age and being married), doctorates' mobility was found sensitive to political events. For example, the draft years during the Vietnam War pushed both American and Canadian doctorates towards Canada (the effect held strong even for Canadians on temporary visas who were ineligible to be drafted). Another example is the period post-9-11, when Canadians and nationals of Muslim countries were more likely to locate in Canada. Although tightening visa requirements could explain the mobility of doctorates of Muslim origin, the decision of Canadians to return home could be explained by changes in their political attitudes. Although this mobility could instead be the result of the innovation-intensive policies in Canada in the early 2000s, the authors control for relative R&D expenditures (a proxy for demand for doctorates) and find no

effect of the latter variable on mobility. These findings also support the story featured in *Maclean's* that Canada could capitalize on the current American economic and political situation to lure away foreign nationals and to persuade Canadians to return home.

2.2. Outflows of STEM workers

Outflows of Canadians (primarily to the USA) have been extensively studied in the literature on “brain drain” and have been a much-discussed issue in the late 1990s and the early 2000s. The extent of the brain drain, however, especially with respect to historic migration trends has been questioned. The interest to the topic was generated by higher expected and observed outflows of Canadians to the USA following the introduction of NAFTA. The examples of brain drain studies are DeVoretz (1999), Emery (1999), Finnie (2001), Iqbal (2000), Wagner (2000), and Frank and Belair (1999). The main determinants of such migration were mostly economic: better career opportunities and better returns to skill south of the border. For example, Hunt and Mueller study Canadian mobility to the USA between 1995 and 2001 and find that higher taxes in Canada are a substantial motivator for Canadians to move the USA. At the same time, their findings are contradicted by Wagner (2000) who finds the effect of taxes on migration to be very small. Analyzing earnings of PhDs in both countries in 2001, Auriol (2010) demonstrated that in Canada male doctorates made on average 76% of their counterparts employed in the USA and women made 83%. These differences were especially impressive for business sector employees (57.6% for both men and women). The earnings differences were less pronounced early in a career but the gap grew as careers progressed. The study also noticed that in the United States, doctorates were paid more in non-research positions compared to research, whereas in Canada this was not the case. In addition, in the United States, private sector salaries were the highest, followed by the government salaries, and academic salaries being the lowest. In Canada, the situation was the other way around. Iqbal (2000) also reports primarily economic reasons for migration and notes that the availability of public healthcare and welfare systems in Canada carries no weight for high-skilled migrants: First, due to their high income, they are ineligible for most benefits of the welfare system and act more as contributors to the system’s revenues. Second, the costs of their healthcare in the USA are covered primarily by their employers, and it comes at better availability and higher quality than in Canada.

The attention to the topic has substantially subsided in the media and academic literature by mid-2000s. Finnie (2006) explains that the decreased interest was due to the empirical evidence that the problem has been overestimated and with the effectiveness of Canadian policies aimed at retaining educated Canadians at home (including the policy to increase expenditures on R&D). He also provides evidence that in addition to decreasing departures to the USA, there were increasing flows of returns to Canada. Similarly, Mueller (2006) wrote that the outlook in mid-2006 on the brain drain was quite different than it was in the 1990s. He believed that “with the appreciating Canadian dollar and worries that the US has been living beyond its means (via its large trade deficit and the declining value of the US dollar), these worries [brain drain] are largely behind Canada.” He also listed

increasing expenditures on innovation, education and healthcare and the strong economy in Canada versus the USA as key factors affecting the reduction of Canada-USA migration.

However, a set of essays issued by the C.D. Howe Institute one year earlier presents a different picture (and mood) about the migration of skilled Canadians (Easton et al, 2005). The authors suggest that the brain drain is ongoing and it happens in the fields that are directly related to knowledge economy and are most important. They suggest that previous studies have overlooked the gravity of the phenomenon because aggregate data masked the shift in the type of labour flows occurring at the time. For example the definition of “skilled workers” as “anyone with a college degree” is questionable because not all degrees are equivalent, and the field of study should be considered together with the type of occupation held by a migrant. Also questionable is the argument that the inflow of skilled labour to Canada through immigration programs more than offsets the outflow from Canada because Canadian immigrants have difficulties finding jobs matching their education and experience obtained in home countries whether due to its low applicability to Canadian standards or discrimination (Imai et al, 2011). Schmitt and Soubeyran (2005) also argue that even though Canada attracts talented scientists, it does not attract the best of them, since they prefer to go the USA.

Another reason for underestimating the brain drain is concentrating on Canadians going to the USA for work. One of the essays in Easton et al (2005) by Gibson reports a different kind of mobility, namely, mobility to study in the USA. The size of this previously overlooked flow is quite substantial and highly asymmetric: the author estimated that “six times as many Canadians obtain their education in the United States as Americans study in Canada even though our southern neighbour has eleven times Canada’s population”. Gibson also notes that Canadians studying abroad are primarily in graduate programs, compared to immigrants in Canadian universities who are in undergraduate programs. This type of migration presents a “delayed” brain drain because, at least at the level of graduate degrees, education in the USA is often followed by remaining to work in the USA. Finn (2010) reports that stay rates of Canadian PhDs in the USA are fairly high: 55% of Canadian citizens receiving doctorates in the USA in 2002 were still in the USA in 2007. The average stay rate for all foreign-born doctorates in the cohort of 2002 was 62%. The stay rate of this cohort of Canadians slightly decreased between 2002 and 2006 from 65% to 52% but then went up again in 2007, suggesting that some graduates returned to Canada sometime after graduation (between 2002 and 2006) but then went back to the USA. Finn (2010) also reports 5-year stay rates for cohorts graduating between 1987/1988 and 2002. His results for Canada indicate a gradual increase from 32% for the class of 1987/1988 to 62% for the class of 1994/1995 and a gradual decrease to 55% for the class of 2002.

Although there have not been any studies comparing scientists remaining in Canada versus those migrating to the USA (directly for work or indirectly for education), Ioannidis (2004) presents some indirect evidence that allows to shed light on this question. The author studied origins of 1,500 highly cited scientists in a variety of fields. He found that 63% of highly cited Canadian-born scientists

worked outside their country of origin, making Canada among 6 countries that served as top sources for highly cited scientists working abroad. For comparison, only 2% of highly cited Americans and 20% of highly cited Japanese, French, and Swedish scientists worked abroad.

All studies described above were concerned primarily with the Canadian-born. However, there is also a potential for the outward migration of the foreign-born who came to Canada to study or work. The regular concerns about the implications of brain drain apply to this category of migrants as well: a) many of them obtained a degree in Canada which was publicly funded, and b) many of them are in S&E fields and could contribute to the Canadian knowledge economy. Their outmigration is mainly overlooked but it is of big concern as this group is more internationally mobile than their Canadian-born counterparts: they have weaker ties with Canada than the Canadian-born, and they had already paid the initial psychological costs of migration when they left their home countries. In addition, their experience in Canada further increased their mobility: they have obtained education and work experience that are recognized worldwide, they have acquired language skills, and many of them have become Canadian citizens which should facilitate their mobility at least to the USA. In addition, compared to the Canadian-born, this category of potential migrants has an option of returning home if economic opportunities there become relatively more attractive. Finally, similarly to the USA, the foreign-born population accounts for a substantial part of the STEM workforce in Canada.

China and India deserve a special place in this report. Initially, these two countries mainly served as sources of highly skilled labour for Canada and other OECD countries through three distinct streams of migrants: students, temporary workers, and immigrants, and they still account for large shares in all three categories. The events during the last decade or so substantially affected “pull” and “push” factors that are known to determine migration: Labour market opportunities, in particular in high technology industries and higher education, have been on the rise in China and India, whereas OECD countries have been experiencing an economic slowdown. The economic growth in turn improved the living standards and the quality of life. These changes in the balance of power may affect Canadian STEM labour markets through four channels: a) STEM workers of Chinese and Indian origin already present in Canada may want to return to their home countries; b) Chinese and Indian potential migrants may choose to remain in their home countries thus affecting the future inflow of STEM professionals in Canada; c) potential migrants from other countries may choose to work in China and India rather than come to Canada; and d) STEM workers of Canadian or third-country origin may choose to leave Canada for China and India. Due to the relative size of India and China, the size of these flows may be quite substantial.

We begin with a review of national return policies in China and India, as their success to a degree promoted the growth of high technology industries and the higher education sector in these countries. For decades, China and India have been interested in repatriating their citizens who left to study or work abroad. The two countries have introduced special national policies aimed at repatriating and professionally integrating highly skilled expatriates. Jonker (2008) surveys literature on the history of

these policies. Three types of policies are identified: “migrant network policies”, “temporary return programs”, and “permanent return programs”. As can be clearly seen from the names of the last two programs, they are directly aimed at stimulating return migration of highly skilled labour to their sending countries. Temporary return programs facilitate financial and entrepreneurial ties of migrants with the sending countries while maintaining their residence abroad. Favourable tax regimes, introduction of dual citizenship or special visa status, and temporary research/teaching appointments are examples of temporary return policies. Permanent return policies create favourable conditions to work and invest in sending countries by offering competitive salaries and research grants, and creating attractive work environment (e.g., attracting international conferences or funding travel to conferences), and creation of research and high technology parks.

The reasons for outward migration of the highly-educated from these two countries are different. Inadequate funding of research in India and its highly bureaucratic nature pushed highly skilled labour to the West. On the contrary, China encouraged its citizens to study abroad expecting them to return as part of the country’s development strategy since 1978. The return rates, however, were lower than expected due to more attractive employment opportunities and social freedoms abroad, and additional measures were taken to ensure returns. These measures were effective towards students funded by the Chinese government, but self-funded individuals (whose share in migration flows was growing) were more likely to stay abroad. That is why China began creating favourable conditions for returnees’ employment including free entrepreneurial zones (export oriented), development of intellectual property rights, waiver of fines in violations of the one-child policy, assistance with spouses’ employment, and others. Financial benefits were offered as well: fellowships and awards for young promising researchers, funds to top up salaries of faculty members, and grants to set up and furnish labs. The Two Bases program was established to allow Chinese scientists established abroad to spend parts of the year in laboratories and universities in China without losing their main base abroad. These “circulating scientists” were more likely to have foreign citizenship, and since formally China does not permit dual citizenship, multi-entry visas were introduced to facilitate such back-and-forth mobility. Lifting barriers to regional relocations was another policy to encourage return mobility. Since research does not develop well in isolation, the migration of star-scientists was followed by so-called “chain re-migration” when colleagues and younger faculty followed their leaders.

The effects of these return policies on the stock of STEM workers in North America have not been evaluated. However, the outflows of the foreign born from the US received attention with connection to the recent economic slowdown. Two new studies by Wadhwa et al (2009a) and Wadhwa et al (2009b) show that the USA is no longer seen as the land of opportunity by Asian scientists and students. The study surveyed 1,200 students in 2008, that is, before the financial crisis of 2008 had unfolded. Most respondents were from India, followed by China, and Western Europe. The students were asked about their intentions to stay in the USA after graduation and their perceptions of employment opportunities in the USA versus their country of origin. While most students reported

positive educational experience and would recommend USA education to their friends, they were less inclined to remain and work in the USA after graduation. Fifty-two percent of Chinese students felt that their home-country currently provides better opportunities for both employment and entrepreneurship, compared to 32% of Indians, and 26% of Europeans. Seventy four percent of Chinese students and 86% of Indian students believed that future employment opportunities at home will also remain better than in the USA.

The news of changing intentions and expectations are in fact not that new. NSF data suggests that the proportion of Chinese and Indian PhD graduates from USA universities with definite plans to stay in the USA after their graduation decreased between 1998-2001 and 2002-2005. The drops were primarily among computer sciences and engineering (S&E) majors from India, and engineering majors from China. Booming Asian economies accompanied by the economic slowdown in the West began to push thousands of scientists of Chinese and Indian origin to return to their home countries. Back in 2005, average stay rates among foreign-born PhDs in the USA were about 67% (Finn, 2007). These rates were much higher for Chinese and Indian doctorates: 92% and 85%, respectively. The 5-year stay rates of PhDs from India have declined from 86% in 2003 to 81% in 2007.

Wadhwa et al (2009b) conducted another survey in 2008, this time of Chinese and Indians who had studied or worked in the USA and had returned to their home countries. They found that returnees are mostly recent graduates (average age: 30 for Indians, 33 for Chinese⁴), with graduate degrees (Chinese: 41% with a Master's degree, 51% with a PhD; Indians: 66% with a Master's degree, 12% with a PhD).⁵ A majority in both groups were in the USA on temporary visas (student and work), although 30% acquired permanent residence or citizenship while in the USA.

Among the main reasons to return: better quality of life at home, proximity to friends and family, and better career prospects. Recall that the survey took place in 2008, that is, before the financial crisis that cut many jobs in R&D. The authors explain that the issue was originated by tremendous backlogs in H-1B visas and green card applications. Although 76% of respondents said that their departure was not motivated by visa issues, the visa situation indirectly affected career options in the following way. By the end of 2006, over 1,000,000 skilled professionals and their families were on the waiting list for green cards, the annual cap on which is only 120,000. Many of them had been waiting for over a decade. It must be noted that during this wait, most applicants were on H-1B visas which imply immediate departure from the country once the engagement with the employer specified on the visa is terminated. Moreover, applications for green cards were initiated and sponsored by

⁴ This observation of young age of migrants is consistent with another study that finds that among OECD doctorates, it's the younger ones that are more likely to work outside their country of origin and/or education. (Auriol 2007)

⁵ It is very likely that the authors surveyed a sample of returnees from the cohorts that left during the periods studied by the National Science Foundation.

employers. Both facts implied tremendous power of employers over their employees, which resulted in slow earnings growth and poor career advancement.

Career opportunities were mentioned as major reasons to come to the USA (93.5% for Indian and 91.6% of Chinese returnees), in addition to expected quality of life (67.4% of Indian and 69% of Chinese returnees). Therefore, it is no surprise that when their expectations were not realized they turned their attention to their home countries, which, they believed, offered better employment opportunities (84% of Chinese and 79% of Indians). The quality of life is also expected to be better at home. Proximity to friends and family, caring for ageing parents, better education for children were among the components of quality of life mentioned by responders. Problems like language barriers, and difficulties to culturally assimilate were also mentioned.

The study by Wadhwa et al (2009b) surveyed individuals who have already returned and spent some time back home (compared to students who reported their expected actions and perceived opportunities back home or abroad). It was interesting to note that returnees demonstrated some career advancement compared to their situation in the USA: for example, the proportion of Indians holding senior positions back home versus the United States increased from 10% to 44%, and for Chinese these numbers were 9% and 36%, respectively. Professional recognition was found to be favorable back home by roughly half of respondents, whereas about one fifth found it better in the USA. Similar numbers apply to the reaction to compensation after adjusting for the costs of living. Overall, Wadhwa predicts that over 100,000 Indian expats will return home in the next five years.⁶

To our knowledge, no study has been done in Canada to evaluate outward mobility of the foreign-born, and no data has been collected that would permit such a study.

⁶ Mattioli D, With Fewer U.S. Opportunities, Home Looks Appealing to Expats, Wall Street Journal, December 17, 2009, available at <http://online.wsj.com/article/SB10001424052748704869304574595831070819244.html>

Section 3. Demand for STEM workers

This section presents views expressed in the literature regarding factors affecting the demand for STEM workers, and their current and potential effects on the STEM labour market in Canada. These factors are split into two groups: those affecting demand at home, and those affecting global demand.

3.1. Domestic demand for STEM workers

Demand for STEM employees come from three main sectors: private sector, government sector, and the sector of higher education. What follows describes literature concerned with the effect of globalization of services, ICT, and R&D in the private sector. It also describes the situation with personnel in the sector of higher education, which traditionally has been the primary job market for doctorates.

Increasing importance of services and ICT in the Canadian economy

The Canadian economy is increasingly based on knowledge and information. The growing need for knowledge codification and transmission through communication and computer networks calls for workers with specific skills and the ability to continuously adapt to quickly evolving ICTs. Around 40% of all R&D expenditures by the Canadian business sector in 2010 were spent on ICT, with an annual growth of 6.8% between 1994 and 2005. According to the Information and Communication Technology Council (ICTC), in 2010 approximately 4% of employed Canadians worked in ICT occupations. Most of them (60%) were employed in the industry, and the remaining 40% worked for companies, public sector institutions, or organizations that use ICT products and services as inputs into their business operations. Domestic demand for ICT comes from large companies that directly hire ICT professionals and companies that domestically outsource their ICT needs. According to ICTC, in 2010 outsourcing (domestic, not offshore) represented approximately 9% of business spending on ICTs. IDC Canada anticipates that Canada's outsourcing market will grow by approximately 5% per year over the next four years.

Canadian studies of the domestic ICT labour market are at least a decade old (e.g., Haggerty and Shneberger, 2000). These studies were mostly concerned with whether the ICT labour market exhibited signs of worker shortages in the late 1990s: a topic acute at the time given rapidly growing demand for ICT. Haggerty and Shenberger (2000) concluded that there were some signs of ICT labour shortages given the dynamics of wages, hours, and employment rates. If during the period studied by Haggerty and Shenberger, labour mismatches were caused by the disproportionate growth in the demand for ICT labour, the current stock of ICT professionals in Canada is affected by the decreasing interest in mathematics and computer sciences among Canadian youths. Full-time undergraduate and college enrolments in mathematics and computer science peaked in the first half of the previous decade and declined thereafter, following the bursting of the dot-com bubble. The enrolment decline appears to have bottomed out in 2007-2008. Another factor contributing to the

supply of ICT professionals is a slow decrease in the number of computer and software engineers immigrating to Canada (roughly half of them have graduate degrees). As a result, as the ICTC labour outlook suggests, there has been a moderate deterioration in the supply of highly qualified ICT professionals, assuming that the number of graduate degrees awarded in computer and software engineering and the number of newly arrived immigrants in these fields are good proxy indicators of supply. The report concludes that the shortage of highly qualified will likely continue to be the main issue.

According to ICTC, the main reason for perceived skill shortages is not only the mismatch in terms of numbers but also a consistent mismatch between the capabilities that employers require and the skills and experience of job-seekers. Although technical skills of job seeker were found in general suitable, their soft skills (e.g., team working ability and communications skills) were lacking just like their relevant business experience. As more employers adopted broader capabilities profiles for ICT jobs, their difficulty in recruiting candidates who met these expanded requirements increased. At the same time, meeting the requirements of the broader capabilities profile also posed increasing problems for recent graduates, as well as for many laid-off ICT professionals seeking re-employment. By the end of the last decade it was apparent that there was a pervasive asymmetry in the ICT labour market between the capabilities profile sought by many employers and the skills and experience of many job-seekers, especially recent graduates and professionals educated abroad. For the latter, poor proficiency in English or French was an additional barrier to find jobs.

Markets for services and ICTs have substantially changed during the last decade or more for two main reasons: First, if previously services were thought immune to globalization due to their very nature, thanks to the development of ICT it has now become possible to deliver services more and more independently of location. Three technological developments facilitated this revolution in service delivery: undersea fibre optic cables that provide Internet bandwidth at almost zero marginal cost; the proliferation of personal computers; and the rise of software applications for global networking via personal computers and the Internet (Gomez and Gunderson, 2006). Second, ICT products and services were thought to be the monopoly of developed countries due to their reliance on high-skilled labour, which had been previously available primarily in developed countries. The 1990s were accompanied by almost doubling of the global labour market thanks to China, India, and the former Soviet Union. This sudden growth of available labour supply was not accompanied by a similar growth in terms of capital, and thus it changed the balance between production factors in the global economy. First, companies began offshoring tasks that required cheaper low-skilled labour available in those three countries. As the countries grew and got wealthier, the educational attainment of their citizens increased, except the former Soviet Union where educational attainment had already been high. India and China also benefited from returns of expatriates who contributed to the growth of ICT industries in these countries and the growth of foreign direct investments that brought in technologies and knowledge. This rise of innovative capacities in India and China facilitated offshoring of ICT and R&D in general to these countries affecting cross-border trades and

investments and implications for employment. Binder (2006) calls offshoring of services the third industrial revolution, and Friedman (2000) describes the phenomenon as the third era of globalization (Gomez and Gunderson, 2006).

Industry surveys cited in the ICT outlook by ICTC show that there has been an increase in the number of Canadian companies using offshore resources for so called “commodity” ICT work, which consists of mainly data processing, routine support for business applications, low-level programming, and “tier one” help desk work. However, the experience of using offshore resources for higher level programming and application support was much more mixed. This appears to have led to a reduction, or at least a deceleration, in the use of offshore resources for these types of ICT work and therefore a reduction in the intensity of ICT offshoring.

Gomez and Gunderson (2006) studied the implications of offshoring services for the Canadian labour market. First, the authors estimated the scope of the problem and predicted that 70% of all ICT jobs in Canada could be potentially moved offshore, and that while the general rate of outsourcing was about 10-15% a year, *offshore* outsourcing grew by 25% annually. The authors also estimated that 11% of the worldwide employment in services could potentially be outsourced offshore, although the current magnitude of business service offshoring at the time of their analysis was still estimated to be small (0.6% of employment in developed countries in 2003). Finally, they predicted that the global number of service jobs to be outsourced offshore by 2008 would be 1.2% of the total global demand for labour services from developed countries, a figure less than the average number of workers starting work for a new employer in a given month.

Second, Gomez and Gunderson compared the consequences of offshoring services to that of manufacturing jobs. They expected the trend in service offshoring to be gradual and have a lesser impact on employment than the loss of manufacturing jobs in the 1970s. The workers affected by service offshoring are expected to be highly educated recent graduates in jobs with higher than average wage growth. The authors expected that the main effects of offshoring in the short term would manifest themselves mostly through wage adjustments and minimal reductions in entry-level jobs in contrast to massive job losses observed in the manufacturing sector in 1970s. The authors explained this difference by the high degree of unionization in manufacturing jobs affected by offshoring and institutional arrangements preventing wage reductions. They also did not expect massive effects on careers of young ICT specialists due their high mobility and adaptability due to their lack of experience, and growing opportunities in other economic sectors due to the growth of the knowledge economy. Overall, the authors expected these adjustments to be less costly than massive plant closings experienced during low wage offshoring.

Morissette and Johnson (2009) also found that the current magnitude of offshoring from Canada is minimal enough not to be associated with any evidence on job losses; alternatively the effects of offshoring are offset by in-shoring. The authors reported that during the studied period (1996-2004)

Canadian exports of computer, information, and other business services to non-OECD countries exceeded Canadian imports of these services. They also found no evidence of slower employment growth in industries potentially affected by offshoring.

Helliwell (2006) suggests that offshoring is a substitute policy to immigration since both solve issues with inadequate supply of ICT labour. The author analyzed data on the scale and growth of immigration and offshoring at an aggregate level, assessed industries and skills likely to be important for either or both offshoring and immigration, and considered in theory how offshoring and immigration may be influenced by specific changes in policies or exogenous events. The author estimated that by 2003, about 90,000 jobs had been affected by IT outsourcing, with 18,000 per year more jobs affected by 2008, and 20,000 per year over the following 30 years. At the same time, the author reported that in 2003 there were around 25,000 immigrants with intended occupations of IT professionals and engineers, or roughly the same magnitude as the number of offshored IT jobs.

Studies on more recent developments in ICT are not yet available. However, data suggests that employment in ICT has been increasing since 2004, when it had reached its lowest value of roughly 528,000 employees. The most recent figure for 2010 is 563,269 employees, a 2.7% growth since 2009. However, this growth has been much slower compared to that of the overall employment (Industry Canada, 2011). Moreover, Gomez and Gunderson predicted that in the near future the role of Canada would change from a net provider to a net user of services, and the effects on employment would be more noticeable. ICTC estimates suggest that offshore ICT centres currently account for approximately 9.0-10.0% of the Canadian ICT outsourcing market, but around 15.0% of outsourced employment. The difference between the offshore suppliers' share of value and their share of employment arises from the trend to offshore a greater proportion of lower-value work. ICTC forecasts that the demand for lower value ICT work will continue to be met by offshore resources. Their outlook for mid-value ICT work is uncertain. Offshore suppliers may address the quality concerns and more of this work may move offshore. Alternatively, Canadian companies may continue to be highly cautious about offshoring mid-value ICT work.

Among the possible long-run effects of offshoring would be a decrease in perceived attractiveness of ICT jobs due to negative shocks to the profession: first by the dot-com bubble and now by increased offshoring. The reduction in current enrolment in mathematics and computer sciences reported by the UNESCO report could be the first sign that the effect of offshoring has already arrived.

R&D offshoring

Canada has been affected by the recent recession to a lesser extent than USA and Europe but nevertheless R&D programs often suffered severe cuts during this period: According to Statistics Canada, gross domestic expenditures on R&D went down by 4% between 2008 and 2010. The largest decrease in R&D expenditures was registered in the private sector (11%) which was partially offset by an increase in federal R&D expenditures by 6.3%. The share of Gross Expenditures on R&D

(GERD) in GDP started falling long before 2008: its highest rates were registered in 2001 (2.09%) and then again in 2004 (2.07%) and have been steadily falling ever since and reaching the lowest rate of the decade at 1.81% in 2010 (for comparison, this rate in 2009 was 1.92%). ICTC report explains this deceleration of R&D expenditures with the appreciation of the Canadian dollar and relocation of R&D activities to low cost countries like Eastern Europe and India.

Structural changes in the higher education sector

The higher education sector consists of universities and affiliated research hospitals. In 2009/2010, the sector spent about \$11 billion on R&D, most of which went to projects in natural sciences and engineering (\$8.8 billion). The sector employed 26% of all R&D personnel in the country (Statistics Canada, 2009). One interesting feature of this sector is that a substantial share of its researchers consists of doctoral students (73%). In addition to R&D, the sector of higher education provides training of future STEM professionals. Another interesting feature of the labour force in this sector is a growing reliance on contingent faculty (at least in the USA where these numbers are available). These non-traditional academics include part-time faculty, non-tenure-track faculty, and temporary researchers. According to the American Association of University Professors, in 1996 non-tenure track appointments accounted for 58% of all positions in American universities, and they make up an even larger part of all new university appointments. Through the 1990s, 75% of all faculty (including colleges) were appointed to non-tenure track positions. The number of full-time non-tenure-track appointments has been growing even faster than the number of part-time non-tenure-track appointments. By 1998, full-time non-tenure-track faculty comprised 28.1% of all full-time faculty and 16% of all faculty. Part-time non-tenure-track faculty comprised 95% of all part-time faculty, and 40% of all faculty. For comparison, full-time appointments off the tenure track amounted to only 3.3 % in the 1970s.

Because the phenomenon is relatively new, classification of these positions is difficult. Different universities often come up with their own titles and pay schemes (from per-course contracts to regular salaries) for these positions: Instructors, lecturers, adjunct faculty, affiliated researchers, and research professors are among titles referring to contingent appointments. But all these positions have one thing in common: very different rights, responsibilities, and remunerations than those of traditional full-time faculty. Postdoctoral fellows occupy a specific place in this new university hierarchy of positions, although postdocs are also employed in the private sector research and government laboratories. Institutions' increased reliance on postdoctoral fellows to handle their teaching and research needs delays the access of these individuals to security in the profession. It also creates yet another requirement for new PhDs seeking tenure-track appointments, thereby undermining reasonable expectations of long-term institutional commitments to new faculty. This in turn makes the profession less desirable for future generations of doctoral students and threatens the future supply of educators. Moreover, basic (or fundamental) research is still performed traditionally in the sector of higher education. Although not commercialized immediately, the stock of fundamental knowledge defines the innovations of the future. In the more immediate future,

emigration and career changes can be the results of this situation. In the late 1990s and early 2000s, many PhDs with degrees in natural sciences (physics and mathematics) increasingly sought jobs outside sciences in areas like finance. Both emigration and career changes are not optimal decisions from the social point of view since education in graduate schools is heavily financed by public funds.

This situation in the USA is the direct result of three parallel processes: tightening of university funding in the 1980s and 1990s, increases in enrolments in undergraduate programs (largely because of growth in the numbers of foreign students, women, and minorities), and an increased number of doctorates on the market. The latter is especially relevant to biomedical doctorates, whose numbers on the market increased soon after the National Institute of Health's funding nearly doubled in 1990s. One opinion is that the increasing number of postdoctoral appointments in some fields may be explained by increasingly insufficient training due to the growing complexity of equipment and research methodology. However, it could also be the result of a surplus of doctorates. Typical features of a market with a surplus of labour include an increasing unemployment rates and falling real wages. Although unemployment rates for PhDs are still much lower than for professionals in other fields, there has been some evidence that they are on the rise (Stephan (2007) in her presentation at the Sciences and Engineering Workforce Project at NBER). Low salaries of postdocs compared to those of regular faculty offer a direct evidence of falling wages. Finally, underemployment (employment in non-traditional appointments and out of field of study) is a special feature of a doctoral labour market that may also indicate labour surplus.

The phenomena described above are based on the American data and have not been studied in Canada. The only indirect evidence is a mentioning in Auriol (2007) that unemployment rates among PhDs were higher in Canada compared to the US, Germany, and Australia. It would be interesting to investigate this issue further.

3.2. International demand

International demand for Canadian STEM labour may be direct in a form of job offers from growing ICT and R&D industries abroad or indirect through offshoring world ICT and R&D to Canada. UNESCO reports a 45% increase in the world GERD between 2002 and 2007. Although the share of GERD in the global GDP has remained stable, there has been a shift in the global landscape of innovation. The share of Asia in the world's R&D grew from 27% to 33% led primarily by China, India, and the Republic of Korea. This growth happened at the expense of the USA whose share fell from 35% to 32.6% and the European Union (from 26% to 23%).

International demand for Canadian ICT and services

Canada participates in the world market for ICT products and services not only as a sender but also as a receiver (a process sometimes called "in-shoring"). Gomez and Gunderson (2006) estimated that in 2004 Canada exported \$3.8 billion worth of services, ranking 3rd next to India at \$12.2 billion and

Ireland at \$8.6 billion, and slightly above Israel at \$3.6 billion and China at \$3.4 billion. Current data demonstrates that in 2010 the Canadian ICT sector was mostly export-oriented, with growing exports of ICT services (up by 23% since 2002) and falling exports of ICT goods (down by 18.7% since 2002, primarily to the USA - 64% of all exports). Overall, Canada is a net importer of ICT goods, with its trade deficit falling by about one third since 2000, and a net exporter of ICT services, with 84% of the trade surplus coming from software and computer services.

The attractiveness of offshore outsourcing in addition to its lower costs may include tapping into a wider pool of talent unavailable at home, providing services 24/7 due to working in different time zones, fulfilling labour needs in times of skill shortages (due to demographic imbalances or poor skill matching to tasks), and accommodating positive and negative demand shocks given costly personnel adjustments (i.e., high firing and hiring costs). According to the annual Global Service Location Index, Canada ranked 9th in 2003 in terms of attractiveness for offshore outsourcing mainly due to its high skilled labour and favourable business environment. In terms of costs, Canada ranked 33rd, but the appreciation of the Canadian dollar since 2003 may have been worsening the country's position even further, and cost considerations would eventually outweigh the country's other advantages.

A study by PriceWaterhouseCoopers (2004) cited in Feinberg and Keane (2006) warned about a potential loss of 75,000 Canadian IT jobs to the USA due to the higher value of the Canadian dollar, higher taxes, and the erosion of technologies. Feinberg and Keane (2006) already found evidence that Canada has been losing its appeal as an offshoring location. The authors studied data from 1,300 US multinational corporations (MNC) operating in Canada and found that the fastest growing sectors of US MNCs in Canada were those with low median wages. They also reported that the importance of Canadian operations to American MNCs has been steadily declining in the past two decades: relative to employment in other foreign countries, Canadian employment of US MNCs dropped from 27.6% of total foreign employment in mid-1980s to 21.6% in the early 2000s. The authors attributed these changes to MNCs' growth in countries other than Canada rather than job cuts. Among the favoured destinations are the so-called Asian "tigers" (the "old" newly industrialized countries in Asia) and, secondly, Brazil, discussed more in the section below.

Rapid Expansion of China and India: Economic and Innovative

China and India have been the fastest-growing economies since the early 1990s. To a large extent, their economic growth is attributed to an increase in productivity. The reasons for this fast productivity growth were identified as: a) high adoption rate of new and existing technologies, b) the pace of domestic scientific innovations, and c) changes in production organization. Mani (2010) finds that not only there has been an increase in the GDPs of these two countries, but also an increase in the knowledge-intensity of their manufacture and service exports. Both countries have achieved international competitiveness in high technology areas such as astronautic technology, telecommunications equipment, information technology, and pharmaceuticals. The author also

reports that in terms of R&D intensity, both countries have been advancing very fast. In 2006, government expenditures in R&D (GERD) were USD37 billion (1.42% of GDP) in China and USD6.35 billion (0.88% in India). Since 1995, these numbers grew almost nine-fold in China and three-fold in India. Even though India's R&D intensity grew only slightly between 2003 and 2007 (from 0.80% to 0.88% of GDP), the share of the business enterprise sector in GERD grew from 18% to 28%.

The main performers of R&D in both countries differ: while 68% of all R&D in India is performed by the government sector, businesses account for 72% of R&D in China. There are historic reasons for this development. For example, India formed its R&D sector after the model of the Soviet Union which resulted in the dominance of large research institutes and government laboratories. Only recently, India has gained access to new technologies in the private sector through mergers and acquisitions of large companies in developed countries, many of which were high-profile technology-based acquisitions. The country's foreign direct investments (FDI) grew from USD2 million in 1993 to almost USD19 billion in 2009. Improvements in the ICT sector (including ICT education) were originated by Indian expatriates returning from the USA after the burst of the dot-com bubble.

In China the current state of the R&D sector is due to the country's development policy. In its transition to a market economy, national government agencies of China encouraged returnees from the West to set up high technology enterprises and research laboratories, which were successfully established and provided a base for growing domestic STEM labour and providing them with employment. Another reason is the contribution of MNCs to the country's industrial development and innovation. The Chinese government has been recently increasing and restructuring its R&D expenditures focusing on basic research, public goods research, and frontier technology research. The country has emerged more or less unscathed from the global economic recession triggered by the subprime crisis in the USA in 2008. After an initial slump in employment caused by falling demand for exports to Europe and the USA, China's economy bounced back in 2009, growing by 8.7% (UNESCO, 2010).

Firms from emerging economies are now also buying up large firms in developed countries and thereby acquiring the firms' knowledge capital (UNESCO, 2009). As a result, the global distribution of R&D effort between North and South is shifting rapidly. In 1990, more than 95% of R&D was being carried out in the developed world and just seven OECD economies accounted for more than 92% of world R&D. By 2002, developed countries accounted for less than 83% of the total and by 2007 for 76%. India in particular has been increasing diversifying into exports of services rather than manufacturing (40% vs. 60%), the majority of services (80%) coming from exports of IT and R&D services, engineering and technical services, and communications services. This share grew from 55% to 80% just in the past 10 years (Mani, 2010). There has been a tremendous increase in the number of foreign R&D centres, which have grown from fewer than 100 in 2003 to about 750 by the

end of 2009. Most of these R&D centres relate to ICTs and the automotive and pharmaceutical industries.

Neither country intends to rest on its current achievements. For example, China has a clear innovation policy to raise the share of its GERD to 2.5% of GDP by 2020 to become an innovation-driven country. The country also plans to launch 16 megaprojects in areas such as electronics, genetically-modified organisms, pollution control, infectious disease control, and others. India has established a 5-year science and technology policy for 2012-2017, which pays special attention to the quantity and quality of S&E personnel. Currently, there are plans to double the number of Indian Institutes of Technology to 16 and establishing 10 new National Institutes of Technology, three Indian Institutes of Science Education and Research, and 20 Indian Institutes of Information Technology to improve engineering education. These ambitious plans of both countries will require a significant STEM workforce and very soon. India is reported to have a very modest density of scientists and engineers (138 per 1,000,000 people). The country's rapid industrial expansion created a tremendous demand for specialists and educators, with the shortage of personnel currently estimated to be at 25%. The situation of shortages is worsened by long-term emigration trends from India to the West, and the growth of FDI in the country. In addition to improving the educational system (which also requires human resources to create future labour force), India is planning to improve its efforts in attracting its expatriates. The country's return policies previously aimed only at maintaining good relationships with migrant networks abroad, but currently efforts are being made to follow the experience of China and establish temporary and permanent return programs to meet the needs of domestic demand for labour. The effects of these plans on the Canadian STEM labour market are yet to be seen.

Section 4. Conclusion

This report identified and reviewed literature aimed at understanding the current state of the STEM labour market in Canada and the main trends in Canada and abroad that help shape the market presently and in the future.

The main conclusion was that STEM products and services have become increasingly mobile and so have the individuals who produce them. Therefore, the Canadian labour market for STEM professionals was analyzed from a global perspective. Moreover, the position of developed countries on the global market for knowledge and its workers has been changing. The previously unchallenged monopoly of developed countries on technologies and high skilled labour has been gradually eroded by the emerging countries. The literature suggests that although the effects of this transition have been small and not registered in some areas, there will be bigger changes in the future. Not all tendencies present market failures and therefore there may not always be a need for public policies. However, understanding of the underlying processes and their effects on the changing global knowledge landscape is required.

Existing studies mainly cover the USA which has traditionally provided rich data promoting research. Many issues outlined in these studies could be potentially relevant to Canada but in many cases Canadian studies are not yet available due to lags in data availability and the publication lag. For some topics, Canadian data has not been collected or is not available to a wide circle of researchers. Literature gaps were also identified and directions for further work proposed.

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