ECHO
EUROPEAN COLLABORATION FOR HEALTHCARE OPTIMIZATION

Coronary revascularisation in Denmark

I. EXECUTIVE SUMARY

Mortality and morbidity from cardiovascular disease are considered a public health issue. In fact, coronary ischaemic disease is one of the leading causes of death in Europe.

The study of systematic variation on the management of the burden of ischemic heart disease and the implementation of alternative revascularization procedures offer a critical view on how healthcare organizations provide care to patients.

- This report analyses the magnitude and the variation of ischaemic coronary disease and its clinical management and treatment. To this end, the analysis is two-folded: it includes population exposure to burden of disease and to intensity of treatment, depending on their place of residence; but, it also examines quality of hospital care, by benchmarking providers' case fatality rates for patients with acute myocardial infarction (AMI) and for the procedures of election in those cases.

- Percutaneous Coronary Intervention (PCI, commonly known as coronary angioplasty) and Coronary Artery Bypass Graft (CABG) are effective and safe revascularization procedures that have improved survival and quality of life in the last decades. By and large, PCI has been proven to be a better option at reducing the risk of death; particularly, primary PCI supersedes any other alternative. Nevertheless, CABG is still considered more effective when dealing with multivessel disease (3 or more vessels implied).

- In the geographical approach, the mismatching between patterns of burden of coronary ischaemic disease (CID) and intensity of use of revascularization procedures shows that exposure to revascularisation interventions varies across kommuners regardless the burden of disease or the socioeconomic status of the area:

    - In 2009, 13,225 CID admissions occurred in Denmark, representing 1 admission per 336 Danish adult inhabitants (slightly below England). Almost 3-fold difference was found between *kommuners* with extreme high and low CID rates while systematic variation was moderate: 9% above that randomly expected. More than half of those admissions were labelled as AMI; the difference between *kommuners* with extreme rates of AMI admissions ($EQ_{5\text{-}95}$) was 2-folded.

    - The same year, 9,253 PCI interventions and 2,371 CABG surgeries were performed in Denmark, showing the highest CABG rate and the second highest PCI rate among ECHO countries (28% higher than England). That represented 3-fold difference compared to Spain, the country with the lowest CABG rate and almost twice the PCI rate in Portugal. The ratio across *kommuners* with extremes rates reached 2-fold and almost 3-fold difference in PCI and CABG respectively, and variation not deemed random was in both cases 3% above that expected. In PCI, region explains up to 35% of the observed variation, which may suggest certain relevant role of regions in modulating the provision of this intervention. This didn't occur in CABG, where region effect barely explained variation.

- There was little positive correlation between CID admissions (considering CID admission as a proxy of burden of coronary disease) and revascularisation procedures, implying that areas with higher CID admission rates didn't exhibit higher revascularisation rates. In fact, at regional level, intensity of CABG procedures and the risk of CID hospitalisation seem completely inversely related. Only, in *Hovedstaden*, there was some coincidence, as their residents had less risk than national average of suffering CID admissions together with the lowest regional PCI utilisation rate.

- In general, intensity in utilisation of PCI and CABG at *kommuner level* seem unrelated. In 2009, there is no general trend in the same direction for both procedures, but neither a clear substitution pattern; only a few *kommuners* in *Hovedstaden* show utilisation rates that could be interpreted as signalling such dynamics.

- From 2002 to 2009, CID admissions decreased by 34%, from 1 admission per 208 to 1 admission per 316 adult inhabitants. Of these hospitalisations, those corresponding to AMI decreased by 25%. Meanwhile, PCI utilisation rates increased by 48% and CABG rate decreased by 31%. These opposite behaviour in the evolution of revascularisation procedures, may point out a certain substitution of CABG procedures by PCI interventions along time. But it maybe also reflecting the positive effect of primary PCIs in preventing patients to progress to severe stages of the disease. Nevertheless, there was a homogeneous exposure across the territory for both interventions as pointed out by their low and stable systematic variation.

- Although CID admissions are quite homogeneous across wealth quintiles, PCI utilisation is higher for residents in most deprived *kommuners* – though not statistically significant as from 2007. It would be advisable to elucidate if these differences are due to access restrictions to PCI in wealthier *kommuners* or rather to patient's preferences choosing private providers. Only in the first case, we would be facing a real inequity situation.

- Regarding exposure to CABG, there are no significant differences related to the area level of wealth. However, while the utilisation rate in affluent areas is quite steady over time, deprived areas show a remarkable decrease, coinciding with a growing exposure to PCI, suggesting that CABG surgery might have been progressively substituted by PCI in most deprived *kommuners* and/or intense utilisation of PCI is leading to lower indications for CABG (multivessel disease).

- On the other hand, when performing the analysis on provider basis, different meso and micromanagement approaches towards cardiovascular ischaemic disease could explain an important part of the *unwarranted variation in outcomes*, that not expected by chance. Differences in the risk-adjusted case fatality rates (CFR) after both revascularisation procedures are still noticeable, with huge variation across hospitals; "volume" (amount of interventions carried out in a year) has been argued as a plausible factor of these differences:

    - Danish Risk-adjusted CFR for AMI, in 2009, was 133.45 per 1,000 patients aged 18 and older; the second highest rate, slightly above the ECHO average, only superseded by England. In terms of exposure, almost 25% of all Danish AMI patients were treated at poor performing hospitals, all of them low volume centres –the highest share of patients among ECHO countries. On the other hand, 63.78% of AMI patients were admitted to hospitals flagged as "good" or even "excellent" performers –also a much higher proportion than the ECHO average.

    - Regarding the revascularisation procedures, in-hospital mortality after PCI in Denmark, in 2009, was 22.78 per 1,000 patients aged 40 and older, the second highest among ECHO countries -15% above the ECHO benchmark-, only superseded by Spain. Besides, all Danish hospitals were labelled as high volume (above 250 procedures per year), but, contrary to expectation, those performing a larger number of interventions obtain worse risk-adjusted CFR than relatively lower volume hospitals; 67.5% of the patients undergoing a PCI were treated at "alarm" performer hospitals (50.21 percentage points above ECHO's average share), while 7.52% patients were intervened at hospitals pointed out as "good performers".

    - Though it involves the same group of hospitals, the scenario of risk-adjusted CFR after CABG (1 in 20 patients, aged 40 or older, undergoing the procedure) quite differs from that described for PCI. All but one of Danish hospitals have an average performance in the ECHO benchmarking. The exception (Gentofte Hospitalet) is flagged as *excellent performer,* both compared to ECHO or national standards. In 2009 this hospital carried out the highest number of CABG surgeries, 585, almost 25% of all performed in Denmark.

II. INTERNATIONAL COMPARISON

The cross-country comparison of the geographical distribution of population exposure to burden of disease and to intensity of use of procedures provides the basis for flagging situations of over and under-use of revascularisation.

The benchmarking of hospitals' case fatality rates adds a dimension of quality and safety of the care provided and its variation within each country.

Accounting for specific organisation features, the international comparison provides a wider perspective, boosting assessment beyond national inertias.

This chapter offers a view as to how Denmark behaves compared to the other ECHO countries when it comes to ischaemic coronary disease and its clinical management and treatment. To this end, the analysis is two-folded:

a. Geographic approach: it compares the population burden of disease and the exposure to intensity of treatment, depending on the place of residence (both the magnitude and the within-country variation);

b. Hospital approach: it examines the quality of hospital care in terms of their case fatality rates for patients with acute myocardial infarction (AMI) and for the procedures of election in those cases. These outcomes are used to benchmark all hospitals across ECHO, providing a view of where Danish hospitals' outcomes seat compared to those in the other ECHO countries

a. Geographic approach

This section offers a rough picture of the incidence of coronary ischaemic disease (CID) and AMI admissions taken as a proxy of burden of coronary disease; it also examines the intensity of use of the alternative revascularization procedures in Denmark compared to what happens in the other ECHO countries.

The geographic approach is focused on population exposure. The key question for analysis is how the risk of coronary disease and access to revascularisation procedures correlate, depending on the place where individuals live.

All through this section paired dot plots are used to show results. The chart on the right is always intended to give the reader a sense of the magnitude of burden of disease or utilisation of revascularisation procedures in each country; the image on the left provides an idea of the actual variation comparable across countries. Note that each dot represents the relevant health care geographic unit in each country

Coronary Ischaemic Disease (CID)

In 2009, Denmark has the third highest CID admission rate among ECHO countries– 1 admission per 326 adult inhabitants. That means a 1.7-fold difference in relation to Portugal, the country with the lowest rate and slightly below the English rate, the highest across ECHO (see table 1 in appendix 1.a).

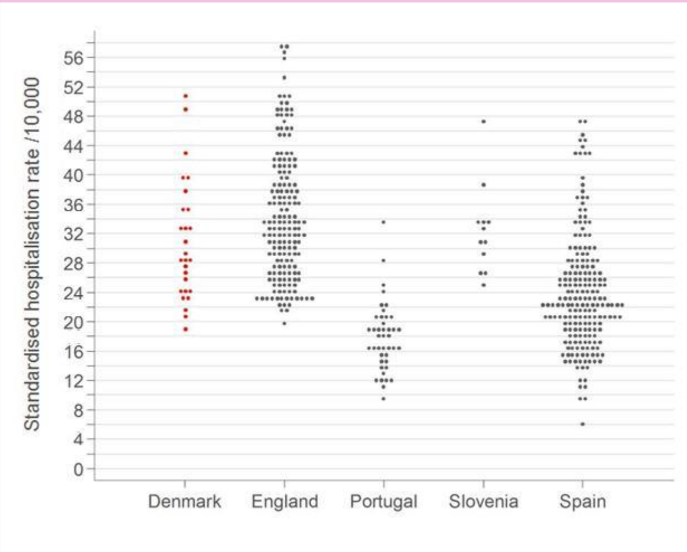

Figure 1.a. Age-sex standardised hospitalisation rates of CID per 10,000 inhabitants (natural scale to compare actual rates). Year 2009

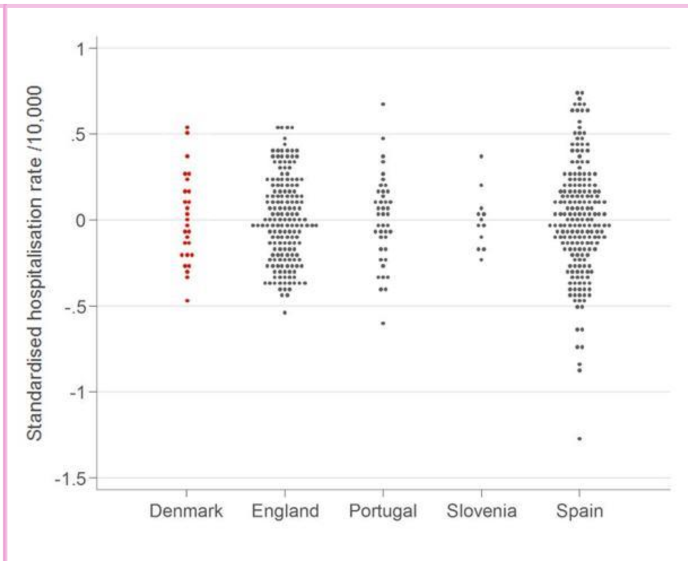

Figure 1.b. Age-sex standardised hospitalisation rates of CID per 10,000 inhabitants (normalised scale to compare degree of variation). Year 2009

** Each dot represents the relevant healthcare administrative area in each ECHO country (Kommuners in Denmark). The y-axis charts the administrative areas standardised rate per 10,000 inhabitants (+18 age). The figure is built over the total amount of CID hospitalisations in 2009 in ECHO countries. In Figure 1b admission rates have been normalised to ease comparison of the degree of variation across countries*

Similar ratios between areas with extreme rates are detected in Denmark Slovenia, England and Portugal: residents in areas with the highest rates have around twice the probability of CID admission to a hospital than those living in areas with the lowest. In Spain the ratio increases to more than 3 times. On the other hand, systematic variation not deemed random is moderate/low in all countries, ranging from 9% (Slovenia) to 24% (England) beyond that expected.

Acute Myocardial Infarction (AMI)

AMI admission rate in Denmark is similar to other ECHO countries, - 1 hospitalisation per 629 adults. Slovenia shows the highest rate -1 admission per 449 adult inhabitants- followed by England -1 in 597 adults. In all ECHO countries, differences between areas with extreme rates are around 2- fold.

The part of the variation observed not amenable to chance is low, except in Slovenia where it reaches 34% above that randomly expected. In Denmark only 5% of variation exceeds what could be randomly expected (see table 2 in appendix 1.a).

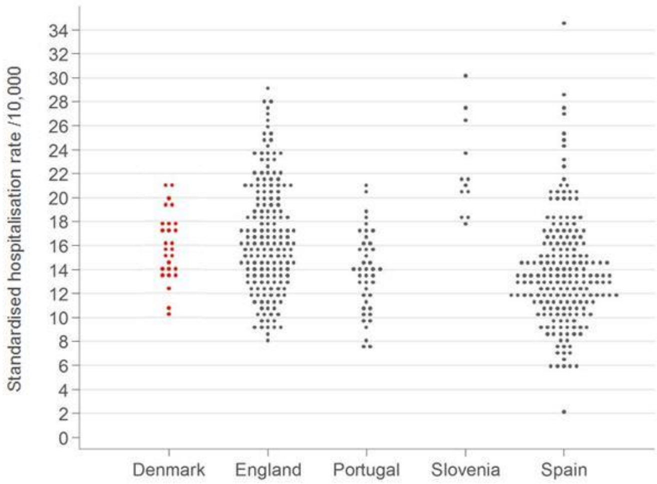

Figure 2.a. Age-sex standardised hospitalisation rates of AMI per 10,000 inhabitants (natural scale to compare actual rates). Year 2009

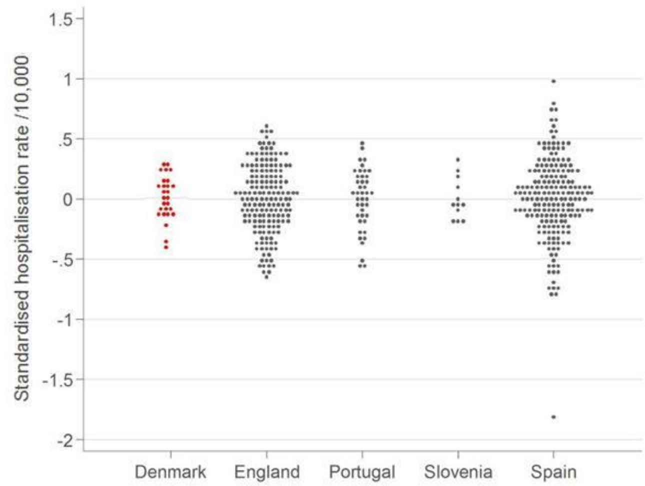

Figure 2.b. Age-sex standardised hospitalisation rates of AMI per 10,000 inhabitants (normalised scale to compare degree of variation). Year 2009

** Each dot represents the relevant healthcare administrative area in each ECHO country (Kommuners in Denmark). The y-axis charts the administrative area standardised rate per 10,000 inhabitants (+18 age). The figure is built over the total amount of AMI hospitalisations held in 2009 in the ECHO countries. In Figure 2b admission rates have been normalised to ease comparison of the degree of variation across countries*

Percutaneous Coronary Interventions (PCI)

Denmark shows the second highest PCI rate among ECHO countries, 1 admission per 267 inhabitant aged 40 or older. That represents, 28% higher than in England and almost twice the rate found in Portugal, the country with the lowest rate. Despite its high PCI rate, the ratio between the highest and lowest PCI rate found at local level is the lowest: almost 2-folded chance of undergoing a PCI intervention for residents in those kommuners with the highest rates. Slovenia, England and Portugal showed similar figures (ranging from 2.2 to 2.6). In Spain this ratio goes close to 5, pointing out acute differences in PCI utilisation across the Spanish territory.

Systematic variation ranges from just 8% above that expected by chance in England and Portugal to 1.8 times greater than expected in Slovenia (see table 3 in appendix 1.a).

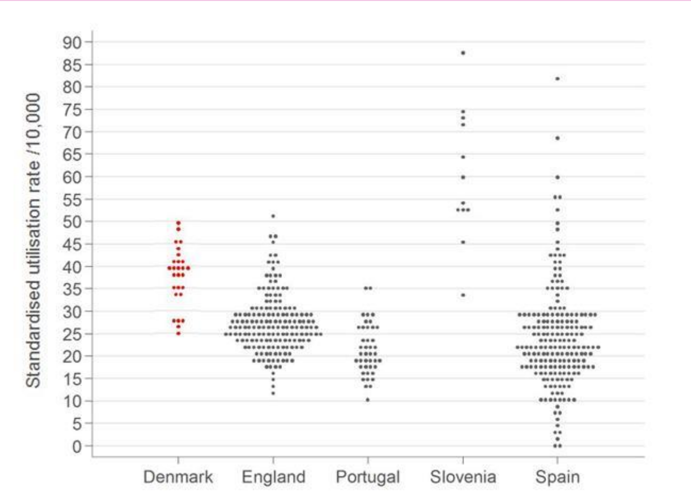

Figure 3.a. Age-sex standardised utilisation rates in PCI per 10,000 inhabitants (natural scale to compare actual rates). Year 2009

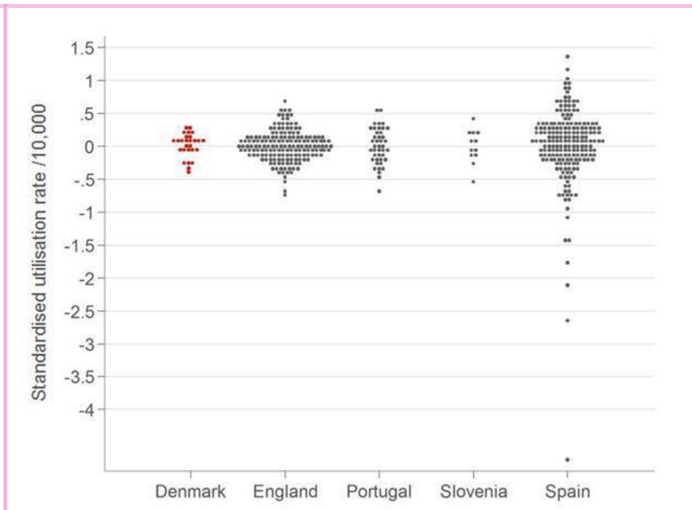

Figure 3.b. Age-sex standardised utilisation rates in PCI per 10,000 inhabitants (normalised scale to compare degree of variation). Year 2009

** Each dot represents the relevant healthcare administrative area in each ECHO country (Kommuners in Denmark). The y-axis charts the administrative areas' standardised rate per 10,000 inhabitants (+40 age). The figure is built over the total amount of PCI procedures held in 2009 in the ECHO countries. In Figure 3b intervention rates have been normalised to ease comparison of the degree of variation across countries*

Coronary Artery Bypass Grafting (CABG)

Denmark shows the highest CABG rate among ECHO countries – 1 admission per 1001 inhabitants aged 40 or older. Slightly above the English rate, it represents a 3-fold difference compared to Spain, the country with the lowest rate.

Conversely, the ratio between the highest and lowest CABG rate found at local level is the smallest: 1.7 folded chance of undergoing a CABG intervention for residents in those kommuners with the highest rates, close to the English ratio. In Spain depending on their area of residence, individuals can have almost 10 times more probability of getting a CABG procedure.

The systematic part of this variation is high in all countries, going up to 50% above that randomly expected in Denmark (see table 4 in appendix 1.a).

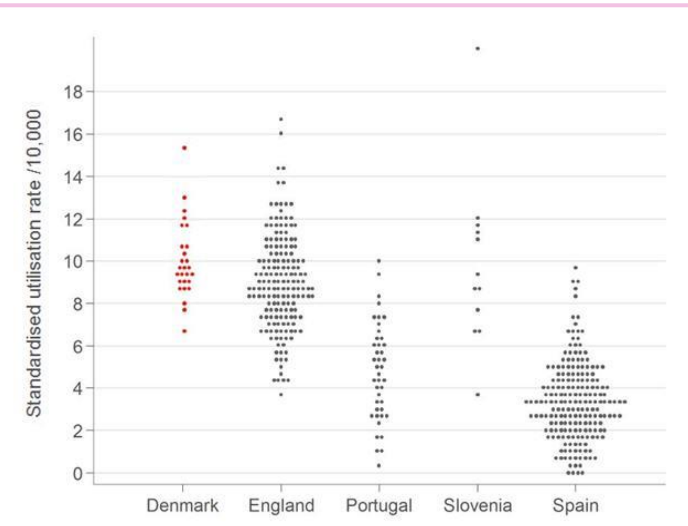

Figure 4.a. Age-sex standardised utilisation rates in CABG per 10,000 inhabitants (natural scale to compare actual rates). Year 2009

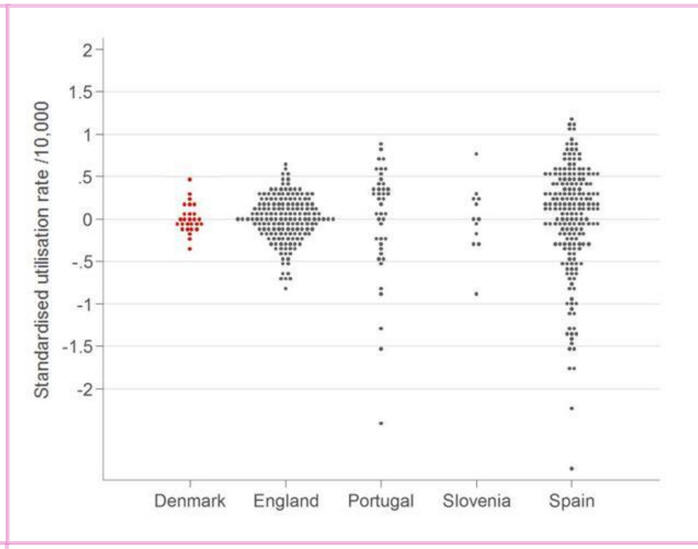

Figure 4.b. Age-sex standardised utilisation rates in CABG per 10,000 inhabitants (normalised scale to compare degree of variation). Year 2009

** Each dot represents the relevant healthcare administrative area in each ECHO country (Kommuners in Denmark). The y-axis charts the administrative area standardised rate per 10,000 inhabitants (+40 age). The figure is built over the total amount of CABG interventions held in 2009 in the ECHO countries. In Figure 4b intervention rates have been normalised to ease comparison of the degree of variation across countries.*

b. Hospital approach

Different healthcare systems across Europe, with different organizational arrangements, might obtain different outcomes in dealing with ischaemic coronary disease. Comparing the outcomes across individual hospitals in each country provides insights as to where intervention might be targeted to improve case fatality rate for patients with coronary conditions.

It also allows for a comparison of national patterns of hospital behaviour (minimum volume of cases, discharging policies …) drawing useful lessons

Through this section, analysis will focus on providers, benchmarking for 3 quality outcome indicators. Two insights to retain: the actual value of the hospital case-fatality rate (CFR), and the relative position compared to the ECHO benchmark and its confidence interval limits (95 and 99% levels) built into a funnel plot. This relative position allows for an assessment of the hospital performance as average, good, excellent, alarm and alert.

ECHO benchmark is built as the expected average behaviour, using data from all hospitals in the 5 countries analysed (multilevel regression modelling). All CFR are Risk-adjusted for sex, age, severity of the underlying condition and co-morbidity (Elixhauser index). This way, differences across providers should not be amenable to patient characteristics affecting their inherent probability of dying after admission or surgery (appendix 4 provides details as to the variables included in risk-adjustment)

Hospitals treating less than 30 patients or procedures/year have been excluded from the analysis in order to avoid noise when modelling (table 5, appendix 1.b, details the number of hospitals per indicator excluded under this criterion and the percentage of treated patients). In fact, the amount of interventions held at each hospital, or so called "volume", is one of the significant explanatory variables when analysing the risk-adjusted CFR; therefore, it has been argued as a plausible factor underpinning the observed differences in rates across hospitals. The threshold for high and low volume hospitals has been empirically set at 250 patients or procedures/year.

Funnel plots enable the assessment of individual hospital performance against the international benchmark. Each hospital (dot) is charted by its risk-adjusted case fatality rate and the volume of patients or procedures in a year. The benchmark is built on the ECHO hospitals average CFR (risk-adjusted) and its 95% and 99% CIs. The solid grey line represents the ECHO CFR, while red lines correspond to the 95% confidence interval control limits and the dashed blue lines to the 99% limits. Those thresholds represent the boundary between *expected* variation in outcomes (not significantly different from average) and *unwarranted variation*. Hospital outcomes laying beyond the upper thresholds flag hospitals as poor performers (in the alert or alarm position); outcomes below the bottom limits signal hospitals as good or excellent performers. Whichever the direction, outliers warrant further investigation and analysis to identify underlying factors and either tackle them or use as examples of good practice.

In-hospital mortality in Acute Myocardial Infarction (AMI).

In-hospital risk-adjusted CFR per 1,000 AMI patients (urgent admission in patients 18 and older) is a widely used indicator of quality and safety of the care provided in a hospital.

In 2009 at the ECHO countries, 146,859 hospital admissions in patients 18 and older were flagged as Acute Myocardial infarctions. From those, 12,582 passed away. After risk-adjusting modelling, these figures place the ECHO average CFR at 99.03 per 1,000 hospitalised patients, which means that 1 in each 10 AMI admissions died.

The total number of ECHO hospitals analysed is 435; of those, 55% were labelled as *high volume hospitals* (more than 250 AMI patients in a year*)*, and they took care of 82.5% of total AMI patients. *(See tables 5 and 6 in appendix 1b)*

Regarding Danish hospitals, 6 out of 30 centres were *high volume* hospitals in 2009, and took care of 70.3% of all AMI patients; actually, Denmark showed the second lowest proportion of AMI patients treated at high volume hospitals among ECHO countries. On the other hand, 13 out of those 30 centres were flagged as “alert” or “alarm” performers. In terms of exposure, almost 25% of all Danish AMI patients were treated at those “alert”/ “alarm” hospitals, yielding by far the highest percentage among all ECHO countries.

Nevertheless, it is also true that 63.78% of all AMI patients were admitted to hospitals placed as “good” or even “excellent” performers. Actually, in the ECHO framing, Denmark is the country treating a higher percentage of AMI patients at hospitals flagged as “excellent performance” (see table 6, appendix 1.b, for further details).

Overall, 1 in 7.5 AMI patients admitted to a Danish hospital died in 2009 (risk-adjusted CFR 133.45 per 1,000), slightly above the ECHO average.

Figure 5 shows the risk-adjusted CFR in each of the ECHO hospitals, drawing their relative position to the ECHO benchmark in a funnel plot.

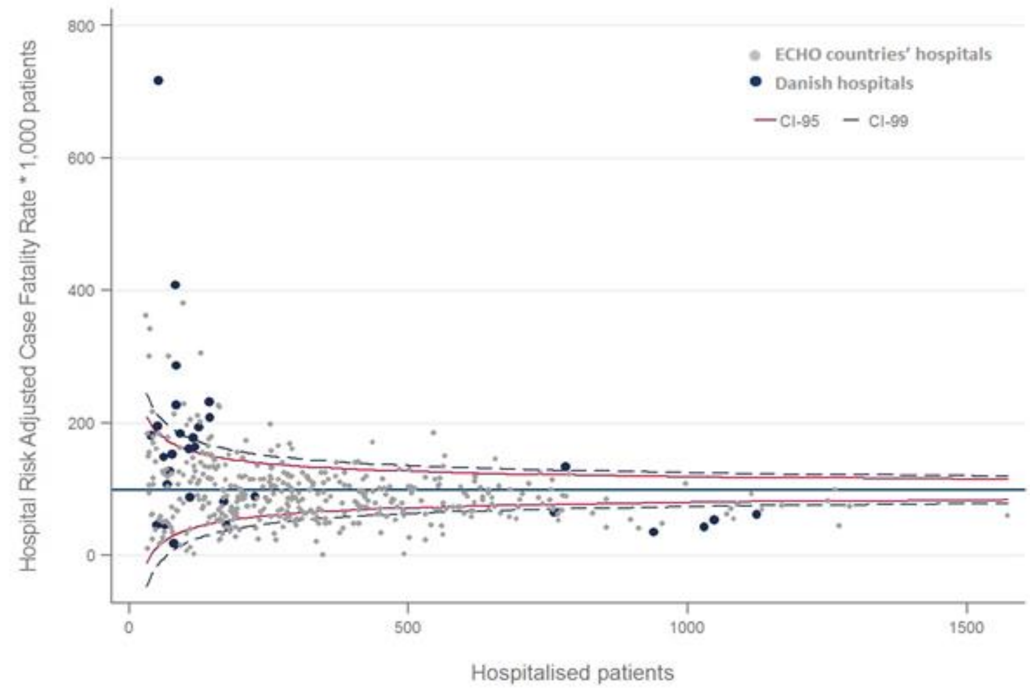

Figure 5. In-hospital case fatality rate for AMI admissions across hospitals in ECHO countries. Year 2009.

** Each dot represents one of the ECHO hospitals that treated more than 30 AMI cases in that year. The expected number of deceases per 1,000 hospitalised patients is built on the average across ECHO hospitals.*

An important issue to consider is the variation in outcomes among hospitals, depending on the volume of AMI patients treated. The bulk of hospitals flagged as alarm and alert in all ECHO countries are treating less than 250 AMI patients/year (the low-volume hospitals).

In-hospital mortality after Percutaneous Coronary Intervention (PCI)

In 2009, 132,737 patients aged 40 and older underwent PCI procedure at one of the hospitals in ECHO countries. 2,623 of them passed away, that is, 1 in 51 intervened patients. These figures set the ECHO risk-adjusted CFR at 19.86 per 1,000 patients (aged 40+) undergoing PCI procedure. Denmark had that year, behind Spain, the second highest risk-adjusted CFR, 15 % above ECHO benchmark. Within the ECHO framework, 79.9% of the hospitals performing PCI procedures were *high volume* and took care of 95.44% of patients undergoing that procedure in 2009. In Denmark that figure reaches 100%. *(See tables 5 and 6 in appendix 1b)*

Unlike what might be expected, Danish hospitals performing a larger number of angioplasties seem to get worse risk-adjusted case fatality rates than those performing fewer interventions; actually, the latter lay in the "*good performers*" area below CI-95% control limit. As a matter of fact, 5 out of the 7 incumbent hospitals carried out more than 1,000 PCIs in 2009 (figure 7); 4 of them fell in the "*alarm*" area. As a result, 67.5% of the patients undergoing a PCI procedure were treated at "alarm" performer hospitals (50.21 percentage points above ECHO's average share), while 7.52% patients were intervened at hospitals pointed out as "good performers" (12.79 percentage points below ECHO's average share). (See table 7, appendix 1.b, for further details).

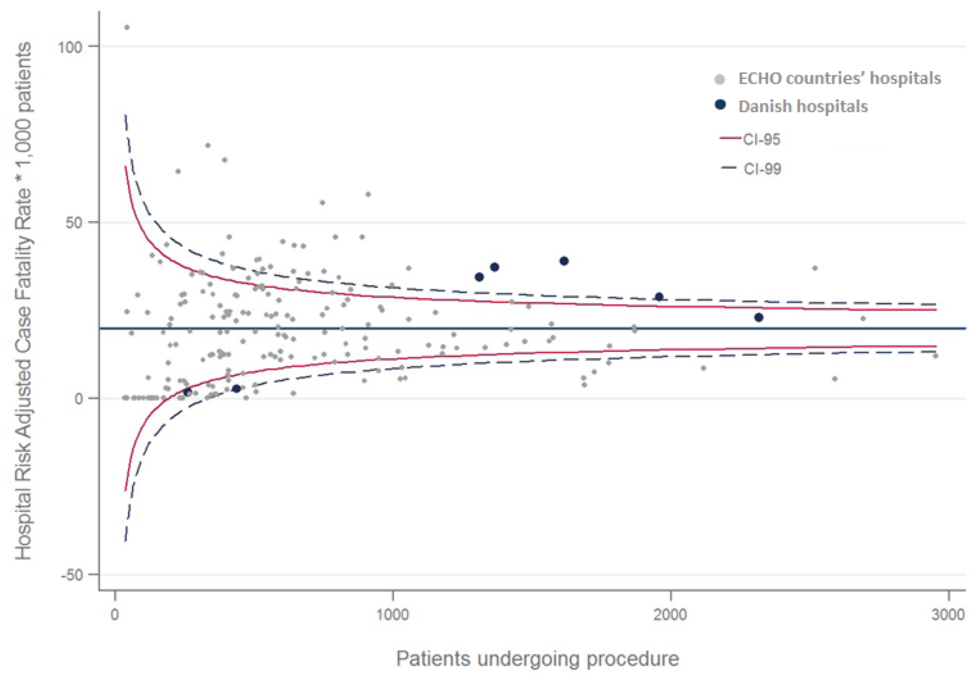

Figure 7. In-hospital case fatality rate after Percutaneous Coronary Intervention across hospitals in ECHO countries. Year 2009.

** Each dot represents one of the ECHO hospitals that performed more than 30 PCI in that year. The expected number of deceases per 1,000 hospitalised patients is built on the average across ECHO hospitals*

In-hospital mortality after Coronary Artery Bypass Graft (CABG)

In the 89 ECHO hospitals performing CABG surgery, 33,683 patients, aged 40 and older, were intervened in 2009 and almost 4% of them passed away. In terms of risk-adjusted CFR, this means 1 in 20 patients undergoing the procedure. More than half of those 89 centers was categorised as "high volume", and they took care of 82.16% of total CABG performed that year at ECHO countries.

It is also worth highlighting that 61.26% of all patients were intervened at hospitals placed in the "*alert/alarm*" zone, versus the 5.61% treated at hospitals flagged as "*good/excellence performance*".

In this context, Denmark shows quite a different picture. The percentage of Danish patients undergoing CABG surgery treated at higher volume hospitals rises to 93.43% and none of them is flagged as poor or less safe at performance.

The group of Danish hospitals performing CABG is the same as those involved in PCI analysed above. However, the scenario of risk-adjusted case fatality rate after CABG shown in figure 9 quite differs. Compared to the ECHO benchmark, all but one of Danish hospitals are placed within the funnel, that is, the average performers area (risk-adjusted CFR after CABG, not statistically different from the ECHO average). The exception is one of the best performers among ECHO hospitals.

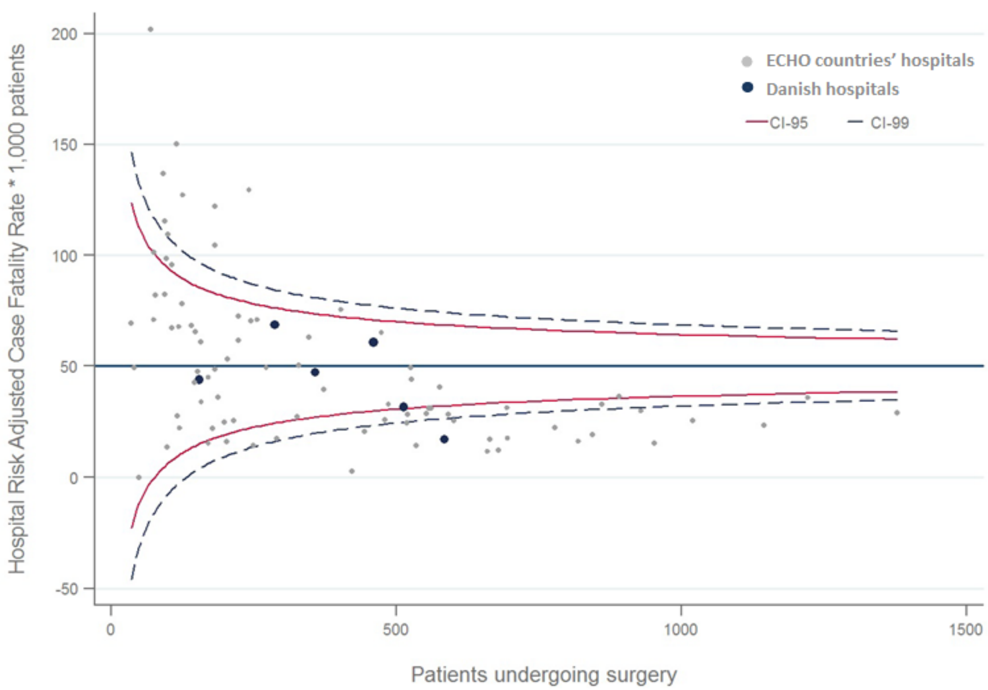

Figure 8. In-hospital case fatality rate after CABG across hospitals in ECHO countries. Year 2009

** Each dot represents one of the ECHO hospitals that performed more than 30 BYPAS surgeries in that year. The expected number of deceases per 1,000 hospitalised patients is built on the average across ECHO hospitals*

III. IN COUNTRY VARIATION

CID admissions are considered a proxy of the burden of cardiovascular disease at geographical level.

In the ECHO framework this indicator is used as “calibrator” and helps to interpret results about intensity of population exposure to revascularization options: coronary artery bypass graft and percutaneous coronary intervention.

At this section, the incidence of coronary ischaemic disease as well as the intensity of use of the alternative revascularization procedures performed in Denmark will be analysed from an internal perspective, comparing what happens at the different health care relevant administrative areas (geographic approach) or hospitals (providers approach) within the country.

Following the same structure as the previous chapter, the analysis is two-folded:

a. Geographic approach: it compares the population burden of disease and the exposure to intensity of treatment, depending on the place of residence (both the magnitude and within-country variation) across kommuners and regions;

b. Hospital approach: it examines the quality of hospital care in terms of their case fatality rates for patients with acute myocardial infarction (AMI) and for the procedures of election in those cases. These outcomes are used to benchmark individual Danish hospitals.

a. Geographic approach

The magnitude and the variation in coronary condition and/or revascularization procedures across the country will be mapped out following the two health relevant administrative tiers: 98 kommuners and 5 regions. While kommuners would represent local provision of care, regions are used as a surrogate for regional policies affecting all the kommuners within each one.

Coronary Ischaemic Disease admissions (CID)

In 2009, 13,225 CID admissions occurred in Denmark; that means 1 admission per 336 Danish adult inhabitants.

A close to 3-fold difference in chances to suffer a CID admission was found between kommuners with extreme high and low rates. Although systematic variation was just 9% above that randomly expected, it was highly explained by the region where the kommuner belongs, explaining up to 52% of it (see tables 9 and 10 at the appendix 2.a).

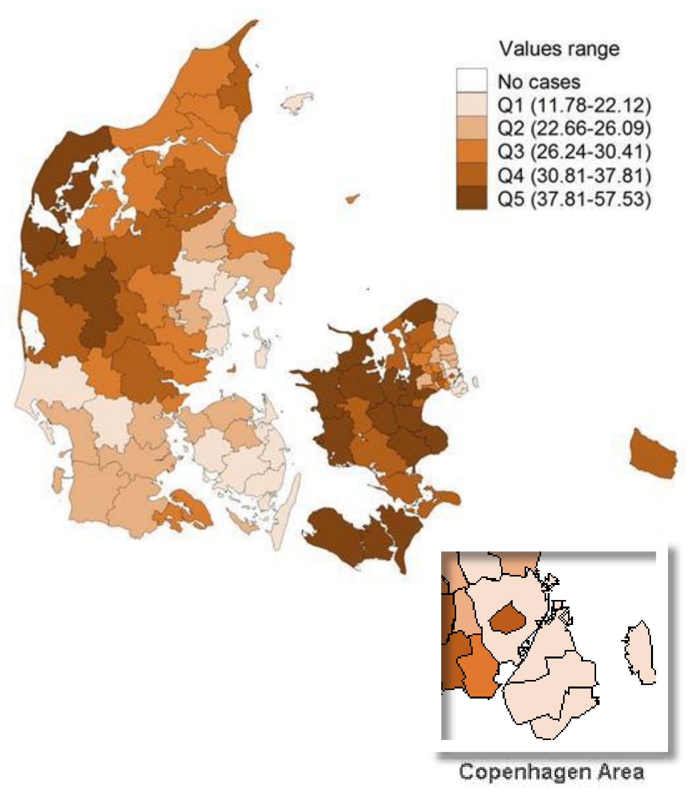

Figure 9. Age-sex standardised CID hospitalisation rate per 10,000 inhabitants by *kommuners*. Year 2009

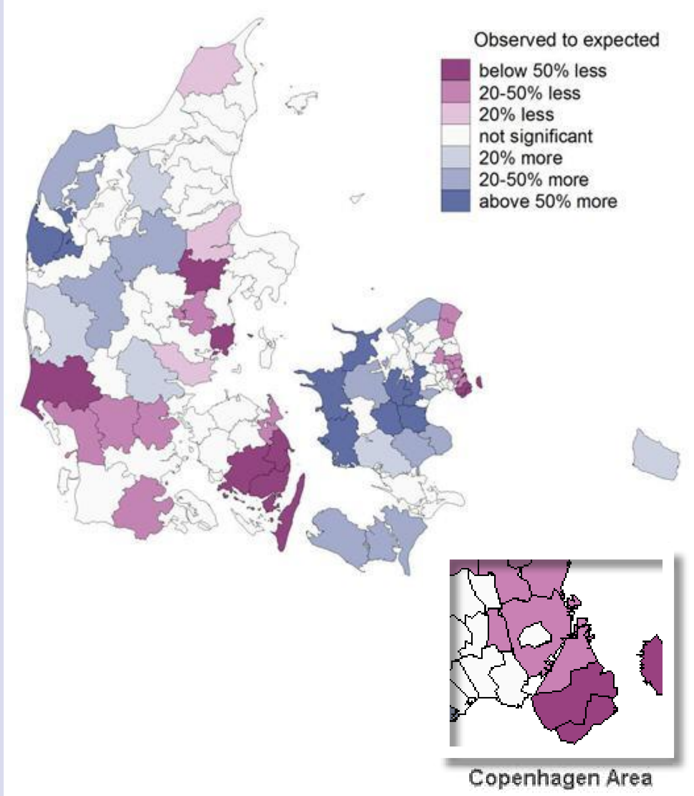

Figure 10. CID Admission Ratio *observed/expected* by *kommuners*. Year 2009

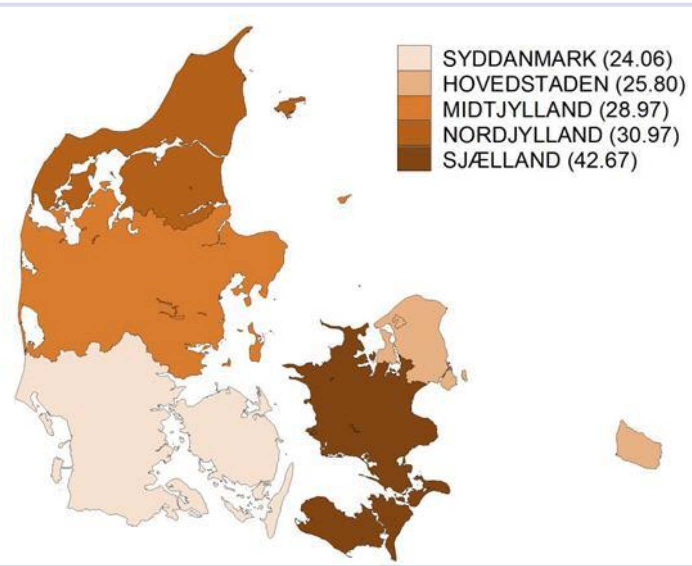

Figure 11. Age-sex standardised CID hospitalisation rate per 10,000 inhabitants by regions. Year 2009

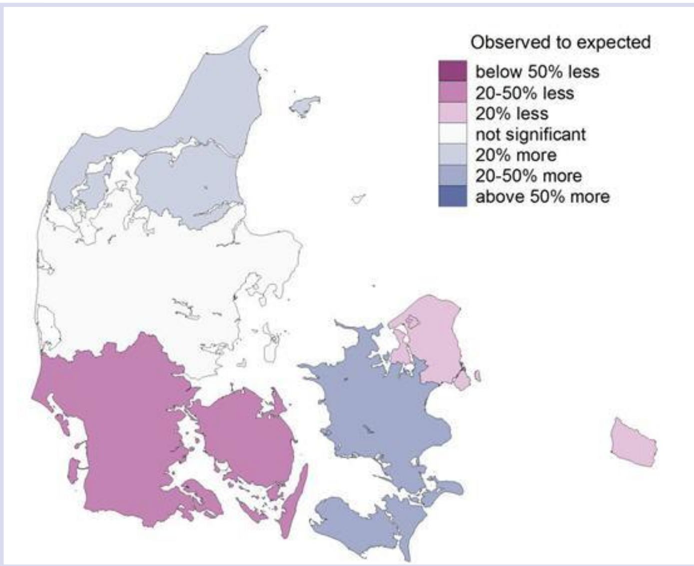

Figure 12. CID Admission Ratio *observed/expected* by regions. Year 2009

** Maps on the left (standardised rates) merely represent the amount of admissions flagged as CID admissions -the darker the colour, the higher the amount of admissions (always per 10,000 adult inhabitants). Areas are clustered into 5 quintiles according to their rate value (Q1 to Q5). –legend within the maps provides the range of standardised rates within each quintile. Maps on the right represent relative risk of hospitalization at each area using as a proxy the ratio observed to expected number of CID hospitalisations. Population living at areas with values above 1 (bluish) mean to be overexposed to risk of CID hospitalisation; population at areas with a ratio below 1 (pink) mean to be underexposed to risk of CID hospitalisation.*

Kommuners with high CID admission rates are found in central and southern *Sjæland* and northern half of *Jutland* (figure 9). Their residents bear at least 20% more risk of CID admission than national average (bluish areas in figure 10).

At regional level, residents in *Sjæland* and *Nordjylland* stand higher risk of undergoing CID hospitalisation than national average. In turn, population living in *Hovedstaden* and *Syddanmark* has at least 20% less risk than average.

Percutaneous Coronary Interventions (PCI) and its comparison with the burden of Coronary Ischaemic Disease (CID).

During 2009, 9,253 PCI interventions were performed In Denmark - 1 procedure per 313 inhabitants aged 40 or older.

A 2.13-fold difference in exposure to the procedure was found between kommuners with extreme rates. Systematic variation was low, just 3% above that randomly expected, but the region explains up to 35% of it, which may suggest certain relevant role of regions in modulating the provision of this intervention (see tables 9 and 10 in appendix 2.a).

One could expect some overlapping between PCI rates and relative risk of CID admission, considering CID admission as a proxy of burden of coronary disease. Interestingly, there is a strong pattern of high PCI rates in the central part of Jutland, but this pattern doesn't match with areas where residents have an increased relative risk of CID admission (figures 13 and 14). Similar behaviour occurs at regional level, *Mydtjylland* and *Nordjylland* show the highest PCI rates (figure 15), but their residents do not bear higher relative risk of CID admission (figure 16). In *Hovedstaden*, there is some congruence as it shows the lowest regional PCI rate and their residents have 20% less risk than national average of suffering hospitalisations from CID (figure 16)

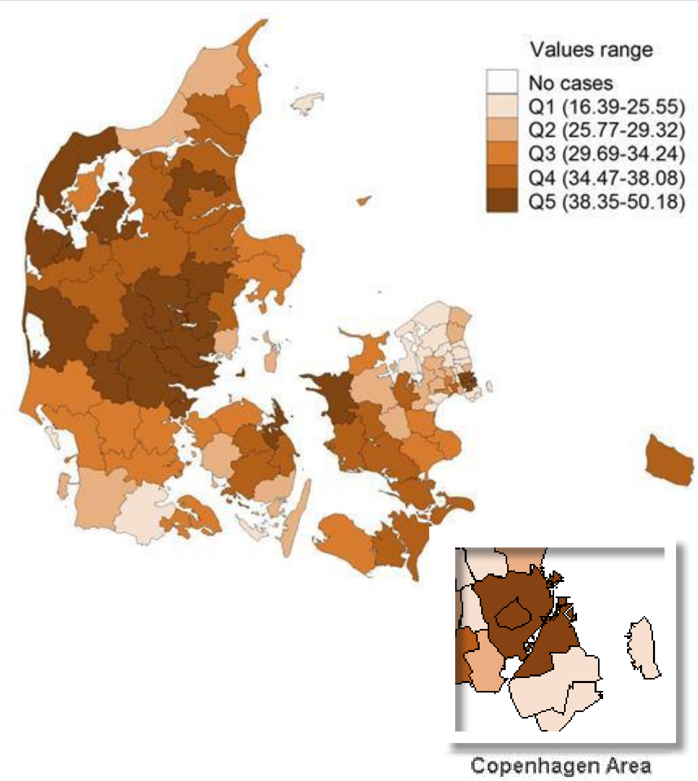

Figure 13. Age-sex standardised PCI utilisation rate per 10,000 inhabitants by kommuners. Year 2009

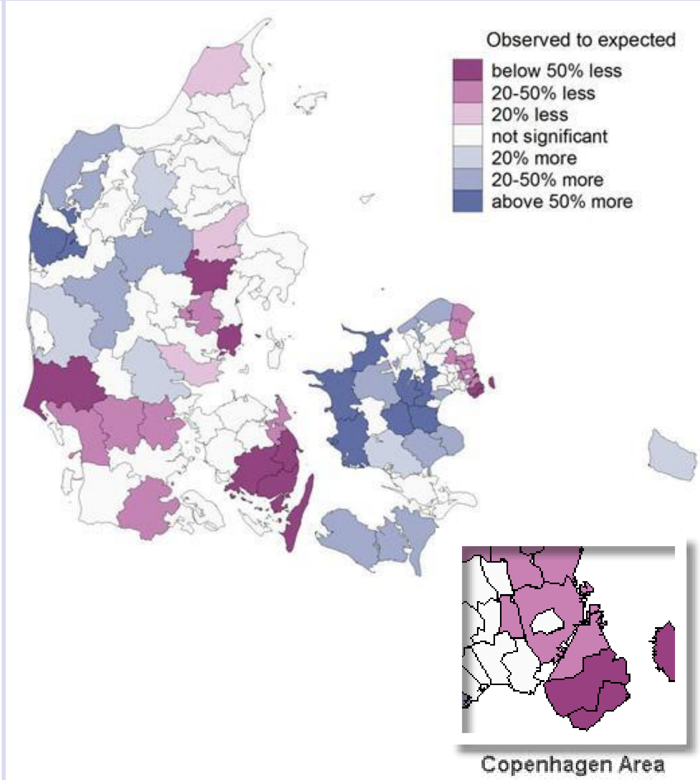

Figure 14. CID Admissions Ratio *observed/expected* by kommuners. Year 2009

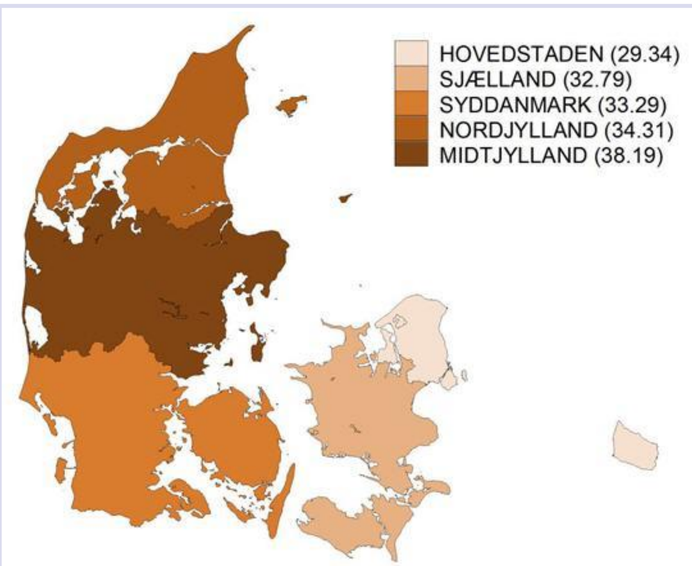

Figure 15. Age-sex standardised PCI utilisation rate per 10,000 inhabitants by regions. Year 2009

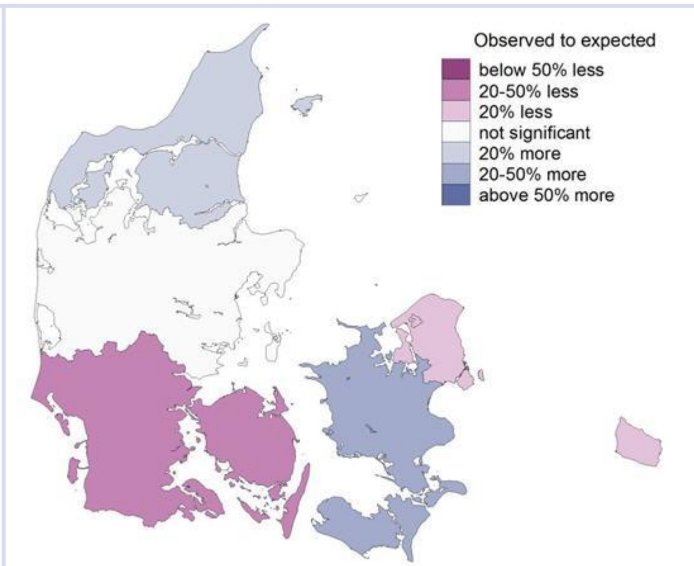

Figure 16. CID Admissions Ratio *observed/expected* by regions. Year 2009

** Maps on the left (standardised rates) merely represent the amount of procedures flagged as Percutaneous Coronary Intervention -the darker the colour, the higher the amount of procedures performed, per 10,000 inhabitants over 40 years old. Areas are clustered into 5 quintiles according to their rate value (Q1 to Q5). –legend within the maps provides the range of standardised rates within each quintile. Maps on the right represent relative risk of hospitalisation at each area using as a proxy the ratio observed to expected number of CID hospitalisations. Population living at areas with values above 1 (bluish) mean to be overexposed to risk of Cardiovascular hospitalisation; population at areas with a ratio below 1 (pink) mean to be underexposed to risk of Cardiovascular hospitalisation.*

Coronary Artery Bypass Graft (CABG) and its comparison with the burden of Coronary Ischaemic Disease (CID).

Along 2009, 2,371 CABG procedures were performed in Denmark, which represents 1 surgery per 1,129 inhabitants aged 40 or older.

The ratio across kommuners with extreme rates reached 2.8-fold difference, but only 3% of this variation cannot be deemed random. Conversely to PCI utilisation, variation in CABG surgery is very poorly explained by regions, just 7% of the observed variation could be related to the region where kommuner belongs (see tables 9 and 10 in appendix 2.a).

There is a certain pattern of kommuners with high rates in the western part of the country, and again, -even more markedly than for PCI- CABG utilisation does not correlate with the burden of disease in the same area -with a few exceptions (figure 17 and 18). However, taking the analysis to the regional level, CABG procedures and the risk of CID hospitalisation seem to be inversely related. As shown in figures 19 and 20, residents in *Hovedstaden* and *Syddanmark* stand the highest CABG rates, while having up to 50% less risk than expected of having a CID admission.

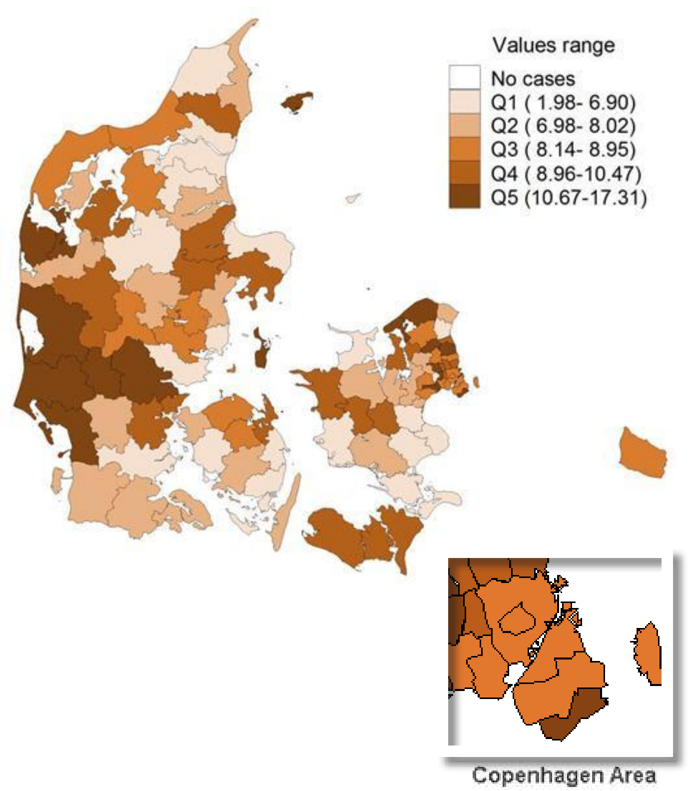

Figure 17. Age-sex standardised CABG utilisation rate per 10,000 inhabitants by *kommuners*. Year 2009

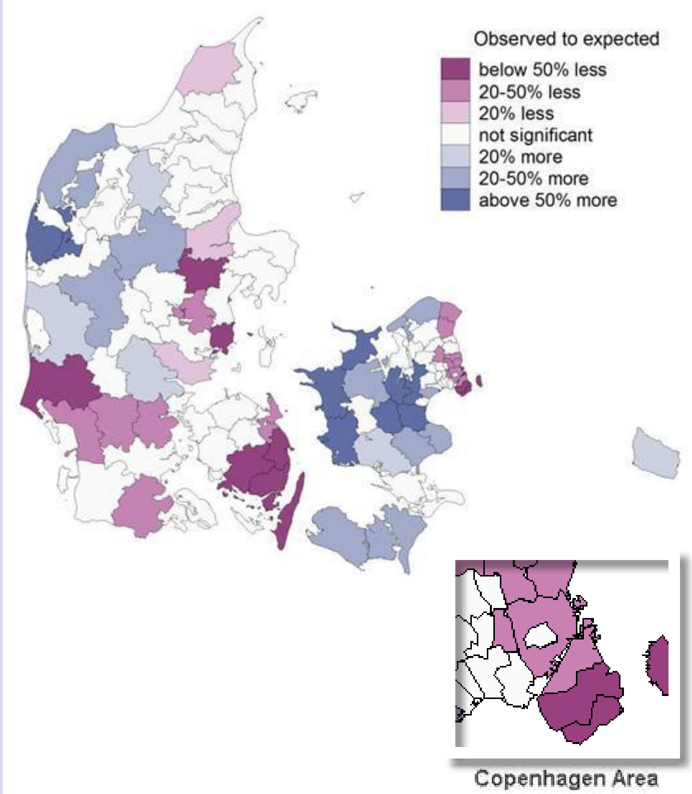

Figure 18. CID Admissions Ratio *observed/expected* by *kommuners*. Year 2009

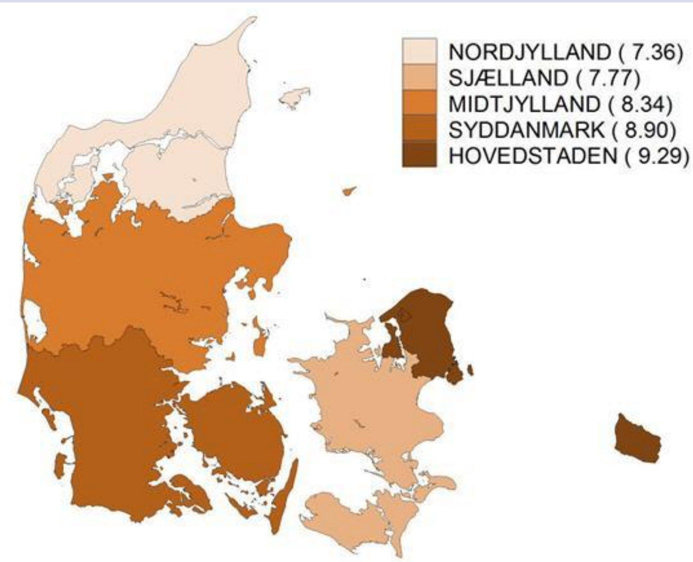

Figure 19. Age-sex standardised CABG utilisation rate per 10,000 inhabitants by regions. Year 2009

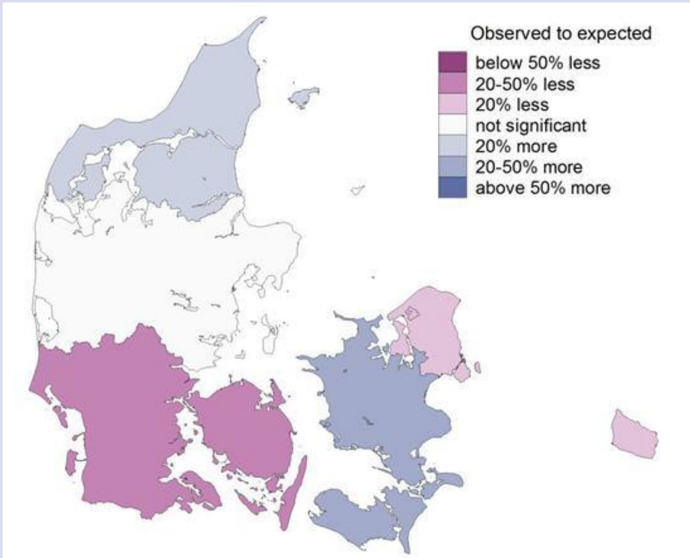

Figure 20. CID Admissions Ratio *observed/expected* by regions. Year 2009

** Maps on the left (standardised rates) merely represent the amount of procedures flagged as Coronary Artery Bypass Graft -the darker the colour, the higher the amount of surgeries performed, per 10,000 inhabitants over 40 years old. Areas are clustered into 5 quintiles according to their rate value (Q1 to Q5). –legend within the maps provides the range of standardised rates within each quintile. Maps on the right represent relative risk of hospitalisation at each area using as a proxy the ratio observed to expected number of CID hospitalisations. Population living at areas with values above 1 (bluish) mean to be overexposed to risk of Cardiovascular hospitalisation; population at areas with a ratio below 1 (pink) mean to be underexposed to risk of Cardiovascular hospitalisation).*

Percutaneous Coronary Interventions (PCI) vs. Coronary Artery Bypass Graft (CABG).

PCI and CABG are effective and safe revascularization procedures that have improved survival and quality of life in the last decades. PCI has been proven the best option at reducing the risk of death, mostly when the number of affected blood vessels is low (in fact, primary PCI has superseded any other alternative); however, CABG is still considered more effective when dealing with multivessel disease (3 or more vessels implied).

To a certain extent these procedures could be acting as two interventions with different clinical indications, or, alternatively, as “substitute” approaches to the same clinical condition. Therefore, considering together their patterns of utilisation may shed some light as to how populations are being served. Trends in the same direction for both procedures may discard the “substitution” hypothesis; opposed patterns, on the other hand, may suggest a certain degree of compensation across procedures.

Another hypothesis that may contribute to explain how utilisation of each procedure relates to the other, lays on the fact that greater exposure to PCI may lead to lower need for CABG by effectively diminishing the population probability of disease progressing to the multivessel stage –which is the primary indication for CABG. Under this hypothesis, sustained high levels of PCI intensity would lead to a decrease in CABG utilisation, and may be also lowering the CID/AMI admission rate.

Comparing the relative risk of exposure to both interventions, *kommuners* where exposure to PCI is above that expected, do not show concomitant higher risk for CABG; likewise, exposure below expectation for PCI does not coexists with under-exposure to CABG. On the contrary, a certain inverse relation or substitution between these two procedures can be observed in a few *kommuners*. This results in *Hovedstaden* residents having risk below average of undergoing PCI, but increased relative risk of undergoing CABG. Thus, in this region CABG may be the preferred revascularisation alternative (figure 21-24). It is also possible that relative under-exposure to PCI could be increasing the proportion of severe cases and, thus, the need for CABG.

Nevertheless, it seems that, in general, PCI and CABG rates in each *kommuner* are not related, neither directly, nor inversely.

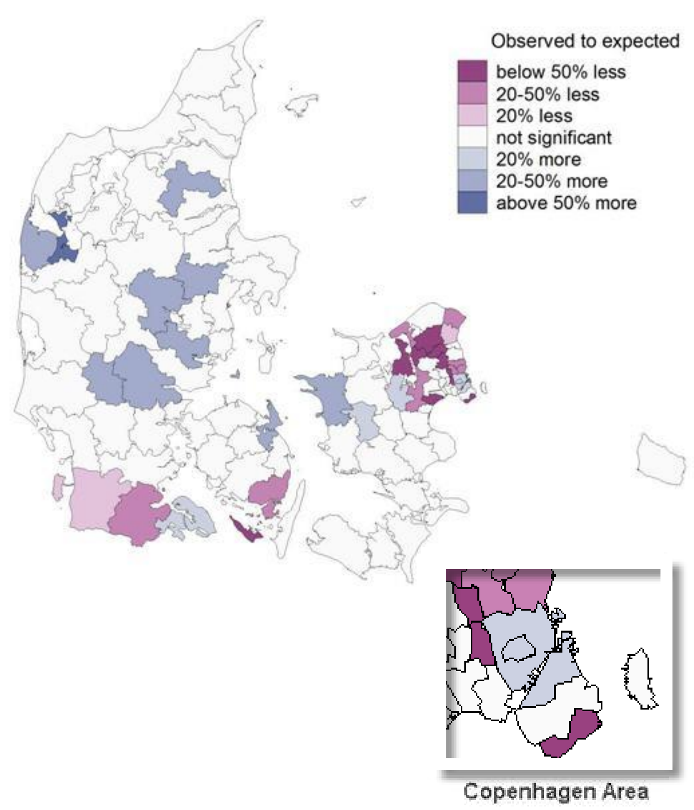

Figure 21. PCI utilisation ratio *observed/expected* by *kommuners*. Year 2009

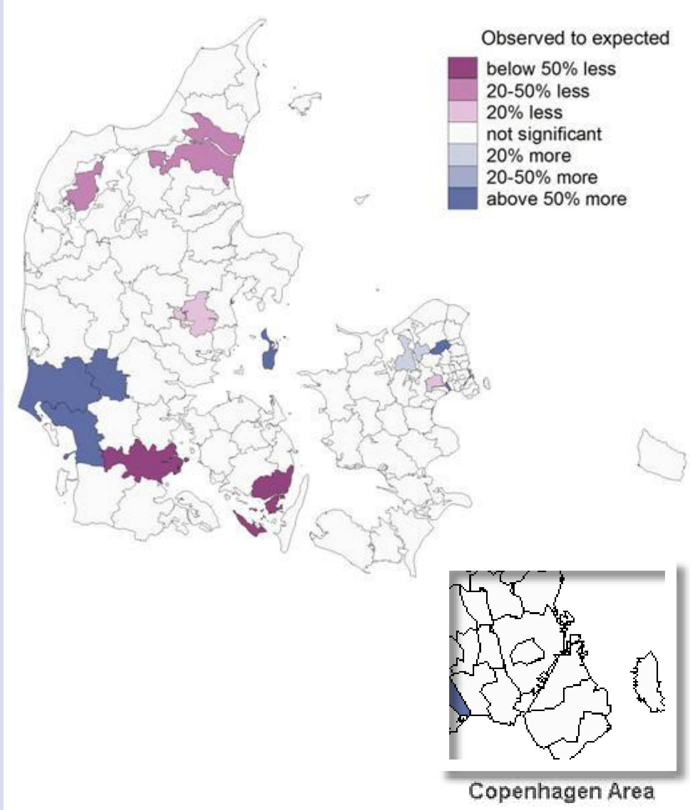

Figure 22. CABG utilisation ratio *observed/expected* by *kommuners*. Year 2009

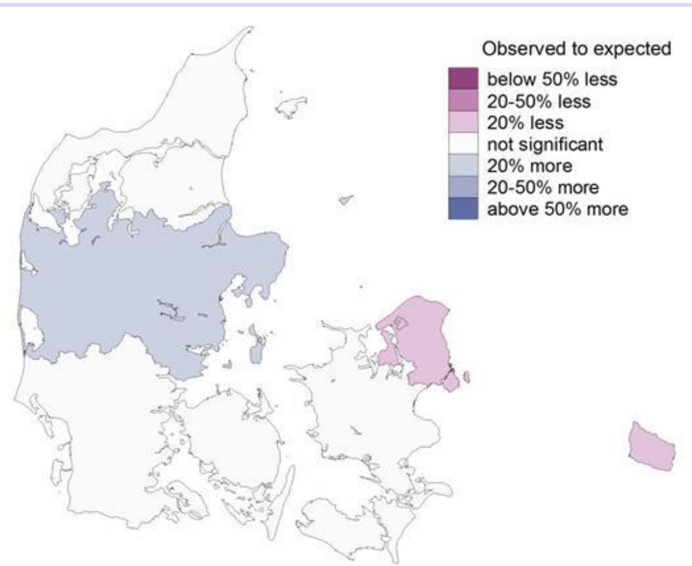

Figure 23. PCI utilisation ratio *observed/expected* by regions. Year 2009

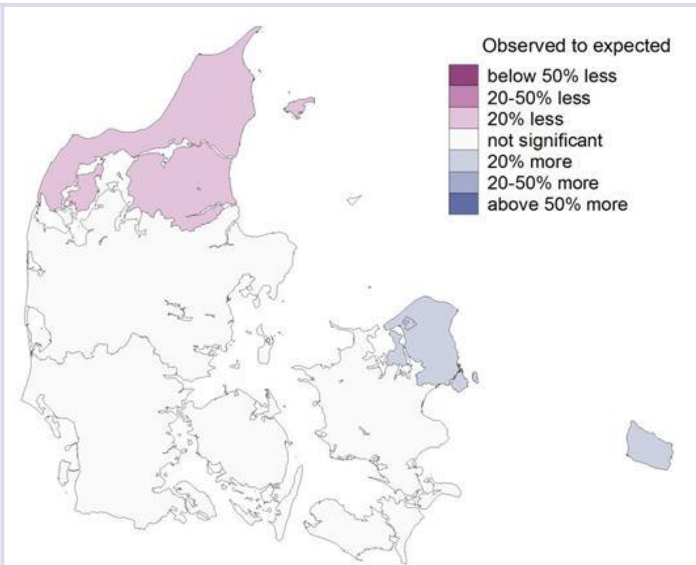

Figure 24. CABG utilisation ratio *observed/expected* by regions. Year 2009

** These maps represent the level of performance at each area, using the ratio "observed to the expected" number of revascularisation procedures as a proxy of the risk of cardiovascular intervention. Population living at areas with values above 1 (bluish) mean to be overexposed to the risk of certain cardiovascular interventions; population at areas with a ratio below 1 (pink) mean to be underexposed to the risk of those cardiovascular interventions.*

b. Hospital approach

Higher hospital risk-adjusted case fatality rates might signal lower quality and safety of care for coronary ischemic conditions.

The following sections will deal with in-hospital case fatality rates (CFR) after admission from Acute Myocardial Infarction and after one of the revascularization procedures, percutaneous coronary intervention (PCI) or coronary bypass surgery (CABG), across Danish hospitals.

When analysing data on a provider basis, different meso and micromanagement arrangements towards coronary ischaemic disease could explain an important part of the observed variation in outcomes.

Funnel plots are used along this section to represent at a glance Danish hospitals performance against their national standard or benchmark. When the number of relevant hospitals was too small to reliably establishing a national benchmark, we have also kept the ECHO standard as term of reference.

Each hospital (dot and numerical code) is charted by its risk-adjusted case fatality rate and the volume of patients or procedures in a year. The benchmark is built on the Danish hospitals average CFR (risk-adjusted) and its 95% and 99% CIs. The solid grey line represents the Danish CFR, while red lines correspond to the 95% confidence interval control limits and the dashed blue lines to the 99% limits. Those thresholds represent the boundary between *expected* variation in outcomes (not significantly different from average) and *unwarranted variation*. Hospital outcomes laying beyond the upper thresholds flag hospitals as poorer performers (in the alert or alarm position); outcomes below the bottom limits signal hospitals as good or excellent performers. Whichever the direction, outliers warrant further investigation and analysis to identify underlying factors and either tackle them or use as examples of good practice.

For methodological reasons, those hospitals treating less than 30 episodes or procedures per year have been excluded from the analysis.

In-hospital case fatality rate for Acute Myocardial Infarction patients.

In 2009, 8,085 admissions across 30 Danish hospitals were flagged as Acute Myocardial Infarction, from which 67 patients died –around 1 in 12 patients. The overall risk-adjusted CFR adds up to 1 death per 7 AMI admissions, setting the Danish average at 133.45 per 1,000 patients (+18), 35% above the ECHO benchmark.

Individual hospitals' risk-adjusted CFR ranged from 35.4 (percentile 5) to 329.4 (percentile 95) per 1,000 AMI patients; thus, depending on the centre where they were treated, AMI patients could bear up to a 9-fold higher probability of dying. (See table 12 at the appendix 2.b for further details).

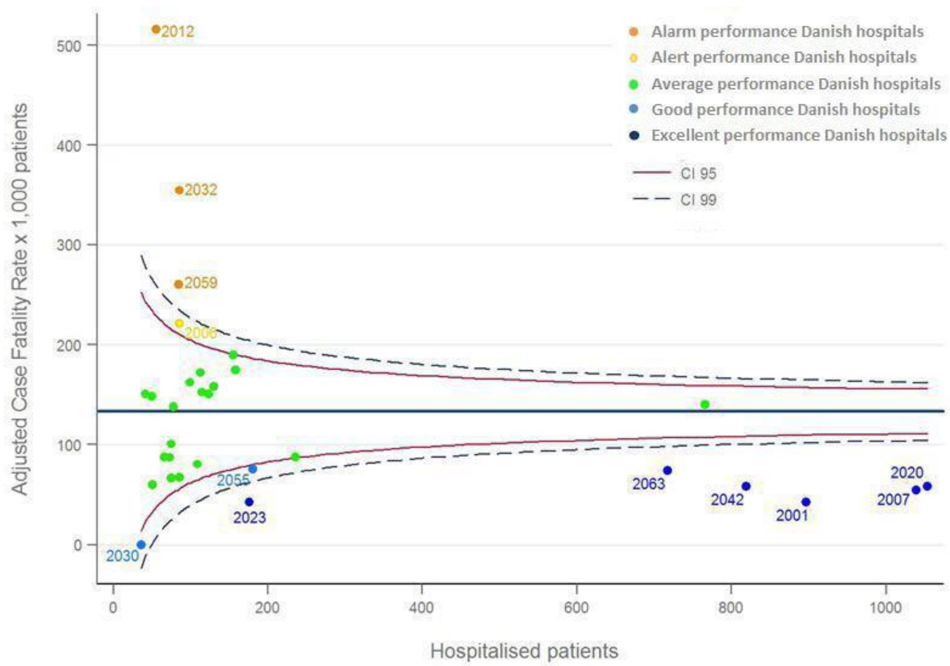

Figure 25. In-hospital mortality after AMI admission at Danish hospitals. Year 2009.

**Each dot represents one of the hospitals in the country that treated more than 30 AMI cases. The expected number of deceases per 1,000 hospitalised patients is built on the average across Danish hospitals.*

Examining the funnel in figure 25, most Danish hospitals show an annual volume of AMI patients below 250 (80% of the hospitals),which in ECHO terms was set as the threshold for low volume activity; a certain trend to better performance can be observed as the number of patients treated increases. Actually all poor performers (showing risk-adjusted CFR up to 4 times larger than the national average) are below the low volume threshold (none reaches even beyond 100 AMI patients). Good and excellent performers, on the other hand, tend to concentrate in the area beyond 700 patients per year, more than halving the national average risk-adjusted CFR. Three exceptions to this general pattern outstand, obtaining good or excellent outcomes with an annual volume of AMI patients below 200. (table 12 at the Appendix 2.b provides detailed information on each hospital)

In-hospital case fatality rate for Percutaneous Coronary Interventions.

In 2009, 9,266 PCI procedures were performed across 7 Danish hospitals, yielding a risk-adjusted CFR of 1 death per each 44 interventions in patients aged 40 or older.

PCI CFRs varied widely across hospitals in a range from 1 to 38 deaths in 1,000 patients, i.e. depending on the hospital where the procedure was performed, patients faced almost 38-times higher probability of dying.

Given the fact that only a few Danish hospitals perform PCI procedures and the uneven distribution of the volume of procedures across them, we have chosen to keep the ECHO reference for the performance benchmarking exercise (figure 26). Nevertheless, national benchmark was also calculated and the resulting relative position of hospitals shown in Appendix 2.b, table 13. Only two hospitals changed their position according to the reference used: one shifting from average performer in the national context to an alarm flag when judged by ECHO standards; the other was considered excellent by national standards but only good performer in the international comparison (table 13 at the Appendix 2.b provides detailed information on each hospital).

Contrary to the direction of the “volume effect” observed for AMI admission outcomes, Figure 26 shows how the larger the number of PCIs per year in a hospital the more likely is poor performance; with only one exception, which, with the highest number of procedures in the country, remains within the ECHO average performance region.

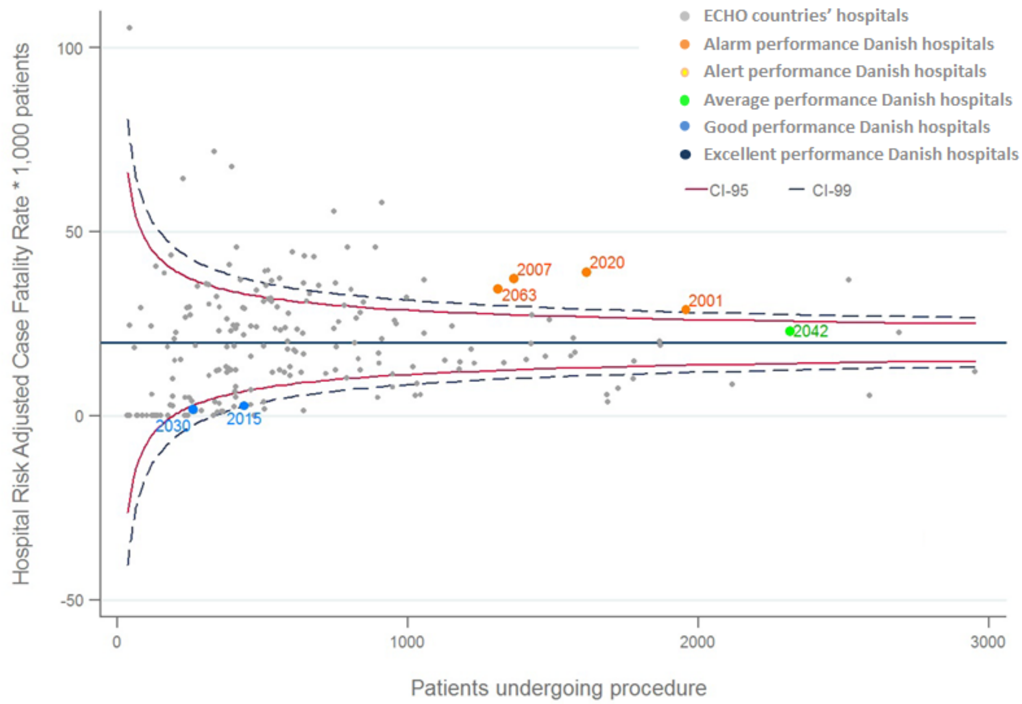

Figure 26. In-hospital mortality after going through PCI procedure at Danish hospitals. Year 2009.

** Each dot represents one of the hospitals in the country performing more than 30 interventions during the period of analysis. Given the limited number of centres the risk-adjusted case fatality rates per 1,000 patients undergoing CAGB surgery is depicted in respect of the ECHO's average.*

In-Hospital case fatality rate for Coronary Artery Bypass Graft procedure.

In 2009, 2,360 CABG surgeries were performed at 6 Danish hospitals, of which 4% resulted in death. As for risk-adjusted hospital CFR, this means 1 death per each 23 interventions in patients aged 40 or older.

In terms of individual hospitals, CABG CFR took values from 16 to 66 deaths per 1,000 interventions, so patients undergoing CABG surgery could be bearing more than 4 times higher probability of death, depending on the hospital (See tables 14 at the appendix 2.b for further details).

Though the distribution of cases across hospitals was more even than for PCI (see section above) the number of centres was still low. Therefore we have chosen to keep the ECHO reference for the performance benchmarking exercise (figure 27). Nevertheless, national benchmark was also calculated and the resulting relative position of hospitals shown in Appendix 2.b, table 14. No hospital changed its position in changing the reference used.

There are no poor performers among Danish hospitals with all of them keeping their risk-adjusted CFR for CABG within the expectation, given the patients treated. There was only one forerunner, flagged excellent by both national and international standards, showing a 99% significantly lower risk-adjusted CFR than expected (actually 3 times smaller than the benchmark) 1 in 59 interventions resulted in death before leaving the hospital. This hospital (Gentofte Hospitalet) is also the Danish center performing the higher amount of this type of revascularisation procedure (585 cases); actually, 24% of all Danish patients undergoing CABG procedure in 2009 were treated there (table 8, appendix 1.b).

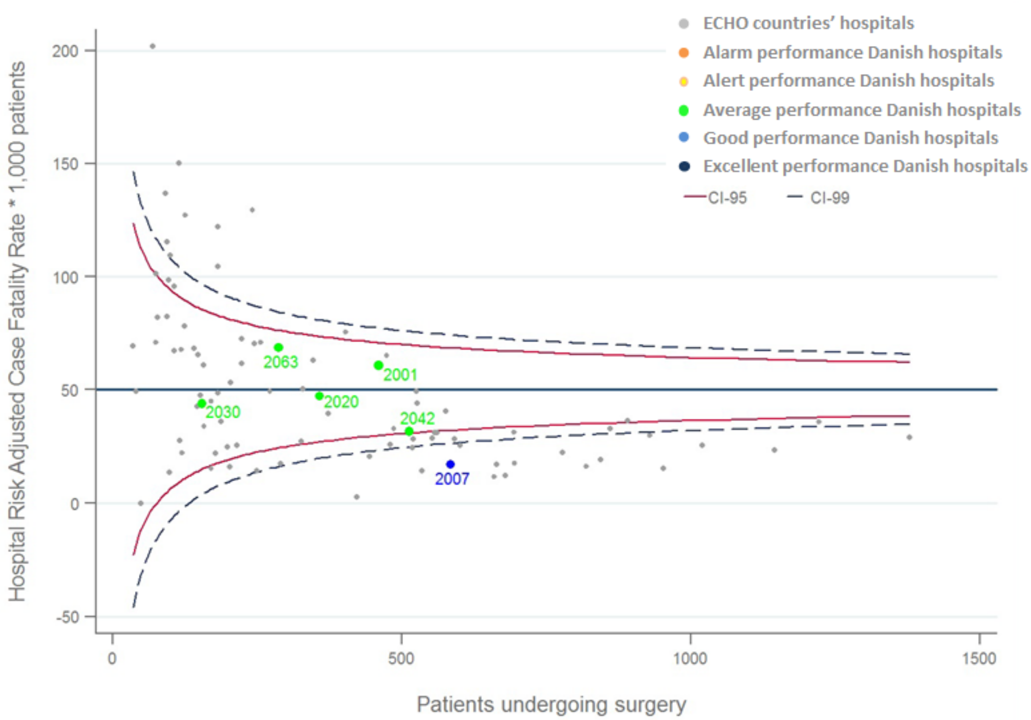

Figure 27. In-hospital mortality after going through CABG surgery at Danish hospitals. Year 2009.

** Each dot represents one of the hospitals in the country performing more than 30 interventions during the period of analysis. Given the limited number of centres the risk-adjusted case fatality rates per 1,000 patients undergoing CAGB surgery is depicted in respect of the ECHO's average.*

IV. EVOLUTION OVER TIME

Along the period 2002-2009, hospitalisations from coronary ischaemic disease have decreased while revascularisation utilisation has increased.

a. Geographic approach

From 2002 to 2009, coronary ischaemic disease admissions decreased by 34%, from 1 admission per 208 to 1 admission per 316 adult inhabitants. Its systematic variation increased over the period, but values remained moderate/low- between 0.05 and 0.1 (see table 15 in appendix 3.a).

Analysing AMI admissions, we found that rates have decreased by 25%- from 1 admission per 469 to 1 admission per 629 adult inhabitants. Variation not deemed random remained low and stable along the period (see table 16 in appendix 3.a)

In the same period, PCI utilisation rates increased by 48%, from 24 to 35 admissions per 10,000 inhabitants aged 40 or older – that is, from 1 admission per 420 to 1 admission per 283 inhabitants. However, systematic variation remained stable and low over this period (see table 17 in appendix 3.a), pointing out the homogeneous exposure across the territory, despite having almost doubled the overall rate

Establishing the trend (upwards, downwards or steady) in revascularisation surgery over time is helpful in understanding the overall dynamic of adoption/ established use/withdrawing of the medical procedure. Both smaller and larger than expected utilisation rates should be looked into; the first may suggest inequalities in population access to care; the second could be also pointing out over-use and, thus, increased probability of inappropriate care for the residents.

The degree of systematic variation denotes how homogeneous population's exposure to the procedure has been at each point in time; the higher the SCV, the more the unwarranted variation in exposure to the procedure across residents in different *kommuners*.

Conversely CABG rate decreased by 31% over the same period, – from 1 admission per 699 to 1 admission per 1018 inhabitants aged 40 or older. Systematic variation in CABG utilisation also remained stable and very low along the period.

These opposed behaviour in the evolution of revascularisation procedures, may point out a certain substitution of CABG procedures by PCI interventions along time.

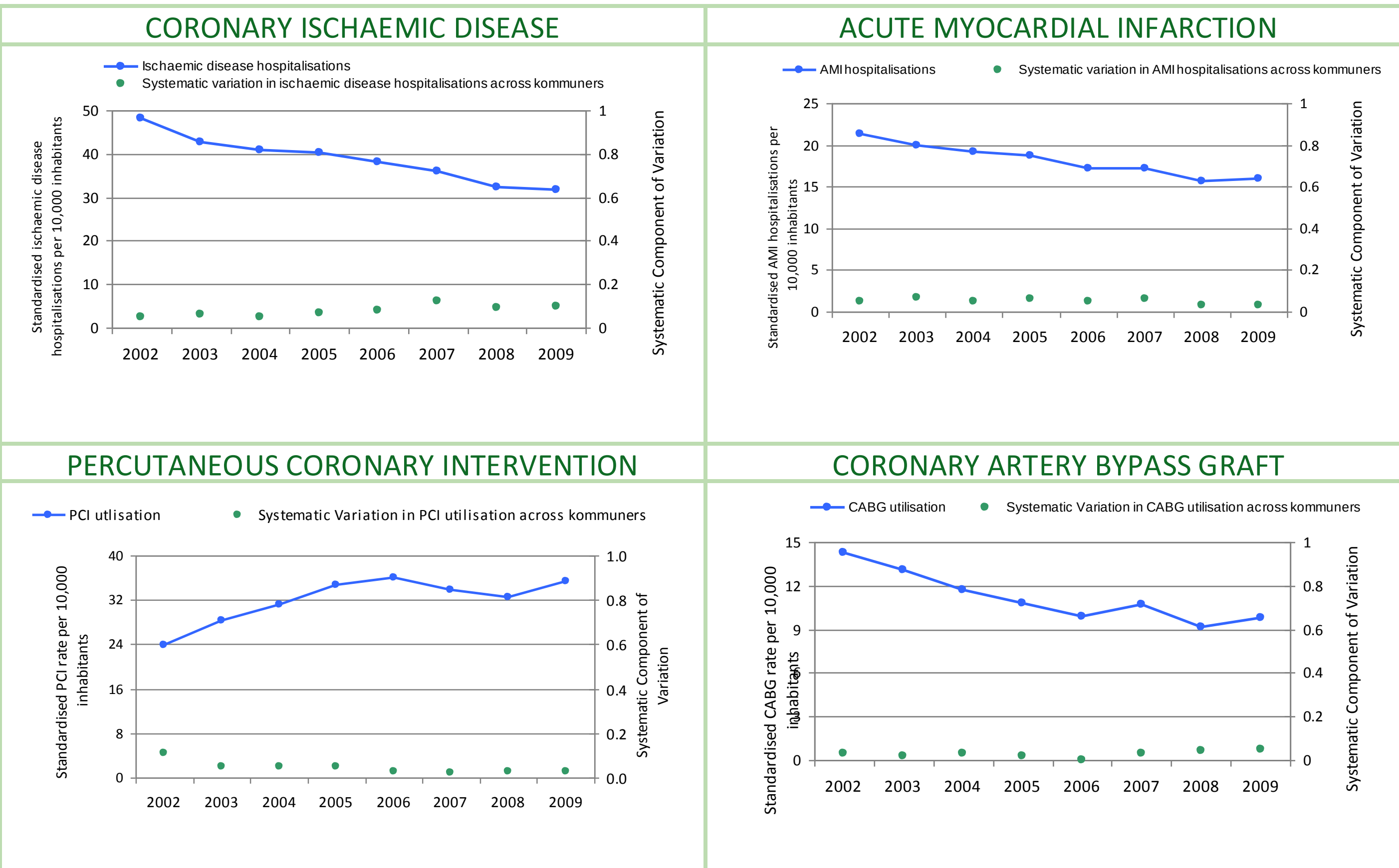

Figure 28. Temporal evolution of cardiovascular indicators from a geographical approach

** At these graphs the evolution over time of two different types of outcomes about the same indicator are jointly depicted: Blue lines inform about the standardised rates (either hospitalisation or utilisation rates) and green dots inform about the systematic variation across healthcare administrative areas (Kommuners).*

Trends at those healthcare administrative areas within the lowest and highest quintiles – utilisation rates of PCI and CABG.

This section offers only a few selected examples, but Individual *kommuners*' evolution over time can be tracked in their original dynamic charts at

http://echo-health.eu/handbook/quintiles_cv_dnk.html

Besides the specific examples of change in revascularisation utilisation, it is also relevant to consider the spread of bubbles on 2009; since they all started at the same utilisation quintile in 2002, the variety of colours they have taken up by the final year (one for each quintile of utilisation intensity), provides a flavour of how established might be the medical practice underpinning such utilisation and how homogeneous or diversely shaped over time and across kommuners.

As mentioned above, Danish PCI rate has sharply increased over the period 2002-2009. Analysing evolution of *kommuners* whose PCI rates were among the lowest at the beginning of the period (Q1), we see that all rates have gone upwards; however, most *kommuners* with relative low intensity of use have remained there and most at the other end have decreased to intermediate intensity of use (figure 29). For example, in ***Bornholm*** rates have increased over time until it reached the fourth quintile in 2009. Instead, ***Rudersdal*** remained among the lowest rates for the whole period. Figure 30 portraits the same phenomenon, but for *kommuners* starting in the opposite side, at the top of the utilisation range (Q5). The resulting array of bubbles in 2009 shows some kommuners, as ***Horsens***, which already starting in the upper utilisation level have remained at the same intensity. While, others, as ***Jammerbugt***, have had their rates decreased until the forth quintile of PCI utilisation.

Similar patterns of kommuners spreading across all utilisation quintiles over time, can be observed in CABG surgery. Taking as an example ***Lingby-Taarbæk*** and ***Syddjurs***, both areas showed low rates in 2002 but their evolution was extremely uneven. While ***Lingby-Taarbæk*** remained among the lowest quintiles, ***Syddjurs*** after a bumpy evolution, reached the highest utilisation levels by the end of the period (figure 31).

Moreover, it can be observed that areas with highest CABG utilisation in 2002 (Q5 in orange) also experienced uneven evolution over the period. Thus, while ***Billund*** remained in the same quintile in almost all years, the CABG rate in ***Odsherred*** decreased steadily over time until the lowest quintile of exposure (figure 32).

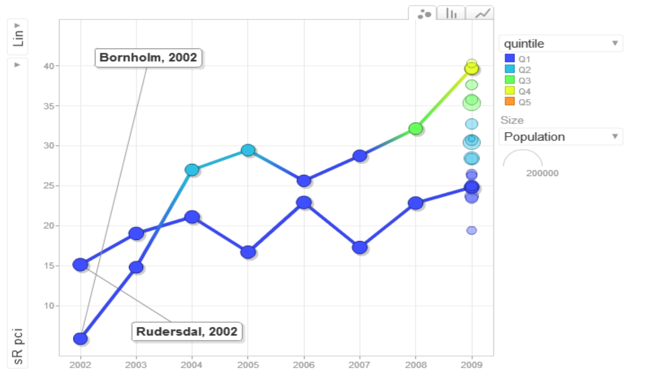

Figure 29. Trends in utilisation rates of PCI across *Kommuners* showing the lowest rates at the beginning of the period.

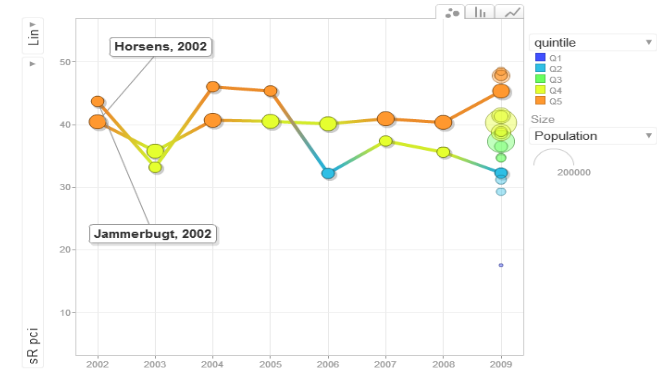

Figure 30. Trends in utilisation rates of PCI across *Kommuners* showing the highest rates at the beginning of the period.

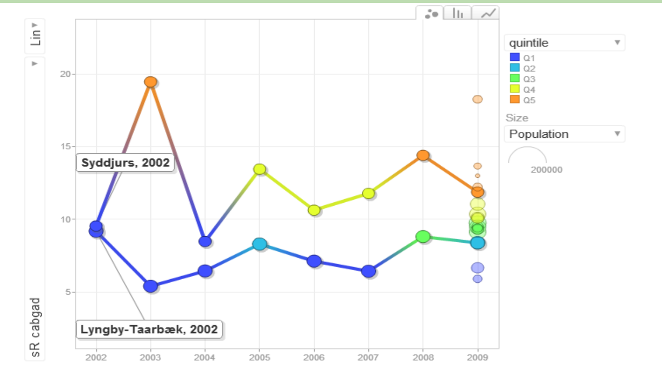

Figure 31. Trends in utilisation rates of CABG across *Kommuners,* showing the lowest rates at the beginning of the period.

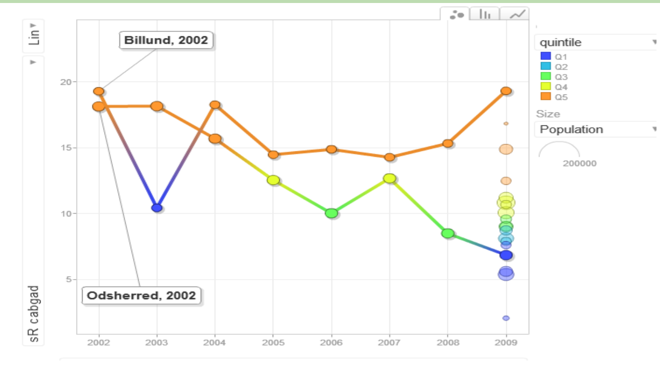

Figure 32. Trends in utilisation rates of CABG across *Kommuners*, showing the highest rates at the beginning of the period.

b. Hospital approach

In order to study how the in-hospital mortality behaved along the period of analysis, some examples are offered showing the evolution of hospitals with the lowest or the highest rates at the beginning of the period.

For further details, please have a look at the dynamic graphics where you can track individual hospitals' behaviour from 2002 to 2009:

http://echo-health.eu/handbook/hospital_cv_dnk.html

Bubble dynamic graphs show the sequence of results from funnel plots assessing outcomes annually along the period of analysis. The size of the bubble is proportional to the amount of patients or interventions. Hospitals flagged as good or even excellent performers (blue coloured bubbles) in 2002 are expected to remain blue all along the period. However, those hospitals identified as poorer performers in alert/alarm position at the beginning of the period (orange coloured bubbles) should had improved their results along time (turning into green –average- or ideally bluish).

Departures from this pattern of change can be considered undesirable trends, warranting further investigation.

In-hospital case fatality rate trends for Acute Myocardial Infarction patients, period 2006-2009.

Regarding the behaviour of hospital risk-adjusted CFR for AMI patients, none of the hospitals seems to improve or worsen radically along the analysed period. As shown in the example in figure 33, good performing hospitals tend to remain as such or even improve to "*excellent performance*". Hospitals starting in an "*alarm position*", on the other hand, could fluctuate through the area of average but, then again tend to return to a "*less safe*" performance position. Further details of the evolution of Danish hospitals' relative performance for AMI admissions along this period in table19, appendix 3.b.

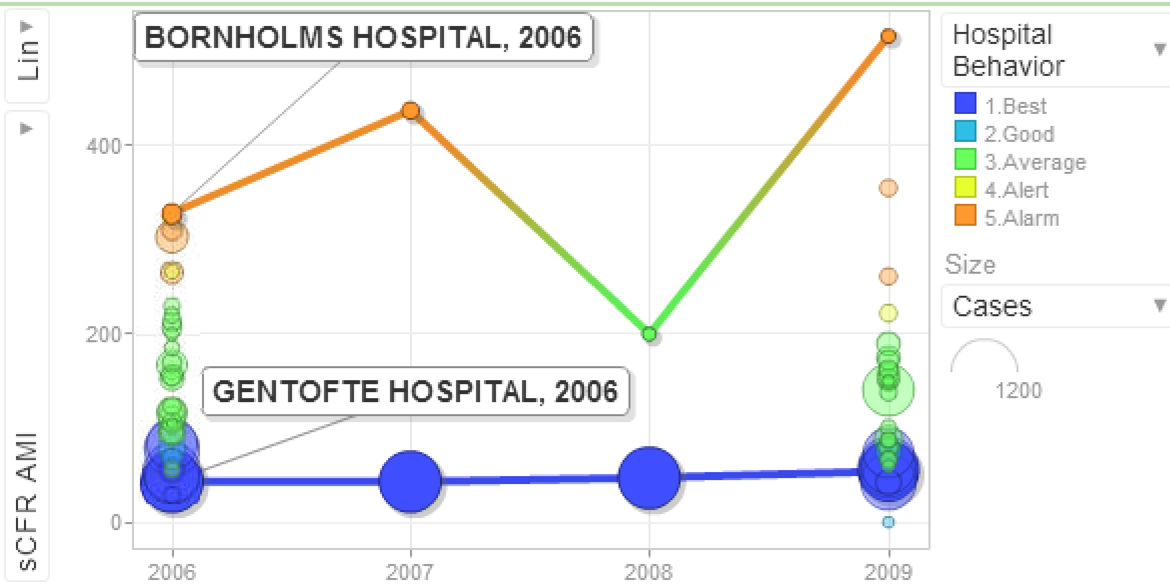

Figure 33. In-Hospital mortality trends of AMI, 2006-2009, showing some of the highest and lowest rates and their evolution.

** Bubbles represent hospitals. The broader the bubble, the larger the amount of AMI hospitalised patients at that hospital. Dark-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-99% control limit, so then pointed as an "excellent performance". Light-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-95% control limits, so then pointed as a "good performance". Yellow bubbles represent hospitals with risk-adjusted case fatality rates above the CI-95% control limits, so then pointed as "alert positioned". Orange bubbles represent hospitals with risk-adjusted case fatality rates above the CI-99% control limits, so the pointed as "alarm positioned".*

In-hospital case fatality rate for Percutaneous Coronary Intervention, period 2002-2009.

Again, none of the hospitals performing PCI during the period has shown an extreme evolution from better to less safe performance or vice versa (Figure 34). We find hospitals starting and ending at an “alert/alarm position” (*Gentofte Hospitalet*), hospitals fluctuating between the areas of non-significant differences and "alarm position" (*Rigshospitalet*) but also hospitals improving, from average outcomes to be positioned as an “*good/excellent performance*” (*Hjertecenter Varde*). Further details of the evolution of Danish hospitals' relative performance for PCI along this period in table 20, appendix 3.b.

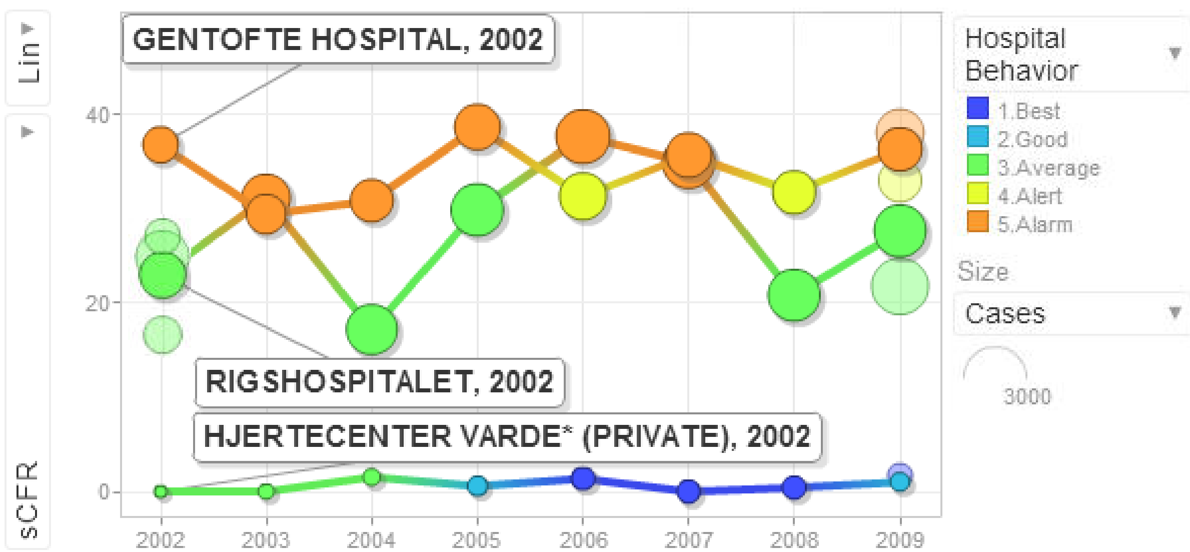

Figure 34. In-Hospital mortality trends of PCI -2002-2009, showing some of the highest and lowest rates and their evolution

** Bubbles represent hospitals. The broader the bubble, the larger the amount of patients undergoing PCI procedure at that hospital. Dark-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-99% control limit, so then pointed as an “excellent performance”. Light-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-95% control limits, so then pointed as a “good performance”. Yellow bubbles represent hospitals with risk-adjusted case fatality rates above the CI-95% control limits, so then pointed as “alert positioned”. Orange bubbles represent hospitals with risk-adjusted case fatality rates above the CI-99% control limits, so the pointed as “alarm positioned”.*

In-hospital case fatality rate trends for Coronary Artery Bypass Graft surgery, period 2002-2009.

Concerning the coronary artery bypass procedure, there are non-extreme changes during the period. Figure 38 shows as an example two hospitals, the first one (*Rigshospitalet*) fluctuates around the areas of average performance and "*alert/alarm*" while increasing its risk-adjusted case fatality rate, so it is difficult to conclude if it improves or worsen its performance (it does worsen in absolute, but not in relative terms). *Gentofte Hospitalet* instead, seems to improve going from average to the excellent performance area while reducing its risk-adjusted CABG fatality rate. Further details of the evolution of Danish hospitals' relative performance for CABG along this period in table 21, appendix 3.b.

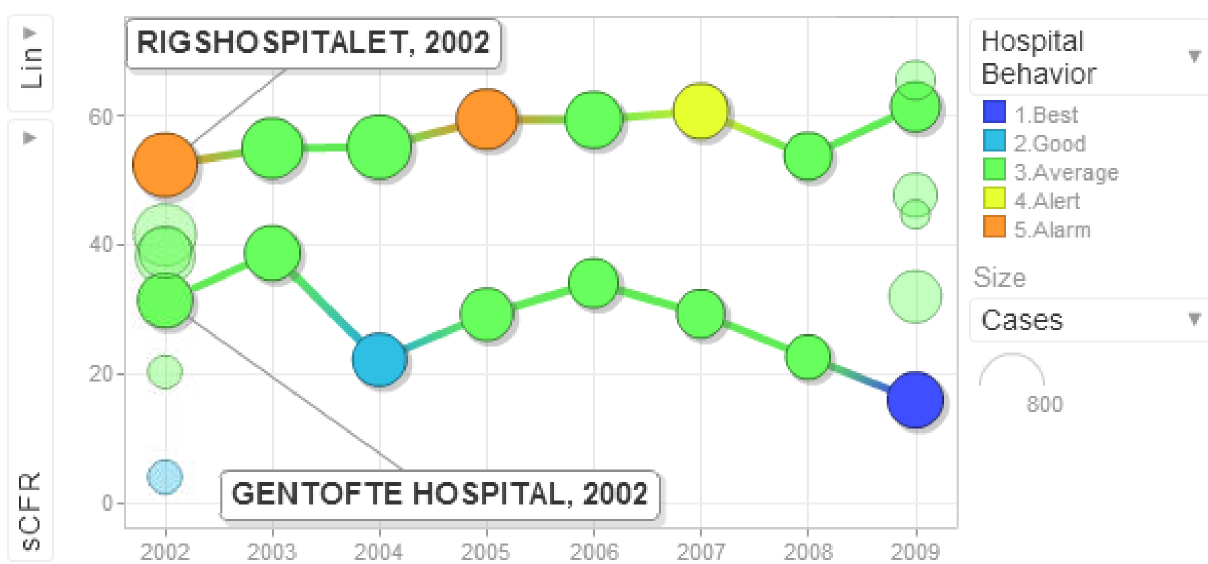

Figure 35. In-Hospital mortality trends of CABG -2002-2009, showing some of the highest and lowest rates and their evolution

** Bubbles represent hospitals. The broader the bubble, the larger the amount of patients undergoing CABG surgery at that hospital. Dark-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-99% control limit, so then pointed as an "excellent performance". Light-blue bubbles represent hospitals with risk-adjusted case fatality rates below the CI-95% control limits, so then pointed as a "good performance". Yellow bubbles represent hospitals with risk-adjusted case fatality rates above the CI-95% control limits, so then pointed as "alert positioned". Orange bubbles represent hospitals with risk-adjusted case fatality rates above the CI-99% control limits, so the pointed as "alarm positioned".*

V. SOCIAL GRADIENT

Although CID admissions are quite homogeneous across wealth quintiles, PCI exposure is higher for the population living in most deprived kommuners. Regarding exposure to CABG, there are no significant differences related to the area level of wealth. However, while the utilisation rate in affluent areas is quite steady over time, deprived areas show a remarkable decrease as from 2005, coinciding with their peak of exposure to PCI.

The distribution of CID admissions and, specifically, AMI hospitalisations, seems to be quite homogeneous across different quintiles of *kommuner* wealth. Thus, the variation across kommuners described in previous sections seems not amenable to area income level.

When analysing PCI utilisation, most deprived areas showed higher rates than those more affluent. The gap between extreme quintiles became narrower over time; however, from 2007 on differences across levels of wealth are no longer statistically significant.

On the other hand, CABG surgery showed an interesting behaviour. Utilisation rates in more affluent areas (Q5) remained quite stable over time, but in more deprived kommuners (Q1), CABG rates decreased by 41%. This decrease is coincident with the increase in PCI rates occurred in these kommuners during the same period. Such trend suggests that CABG surgery might have been progressively substituted by PCI in most deprived kommuners. That led to wealth quintiles' switching of relative positions over time: in 2002 deprived areas had higher CABG rates than wealthier ones, whilst in 2009 significant higher rates are detected in more affluent areas.

Graphs in this section aim at providing some sense of the behaviour of CID admissions and revascularization procedures depending on the average level of affluence in the *kommuner*. At a glance it will show whether there are differences between the better-off and the worse-off areas, and if these differences vary over time.

The wider the gap between most and least affluent quintile lines, the more inequitably distributed the exposure to revascularisation surgery will be. It is also relevant to keep track of the 95% confident interval (whiskers) drawn around the annual rates estimated for quintiles 1 and 5. Only those not overlapping signal a statistically significant difference between wealthier and deprived areas.

The desirable pattern will show no statistically significant differences across kommuners amenable to their wealth. As a second best, any eventual existing gap should disappear over time.

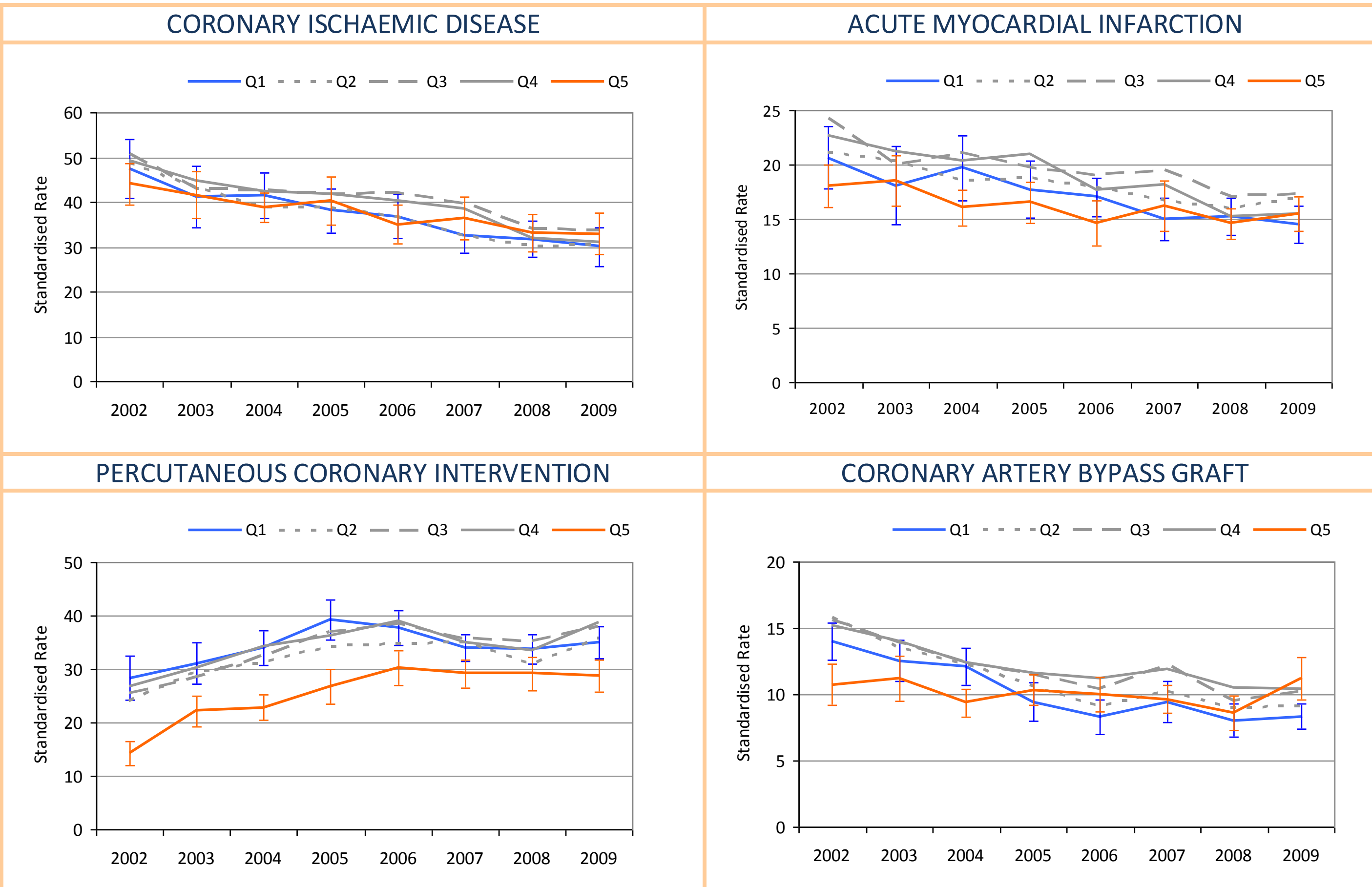

Figure 36. Trends in standardised rate by income quintile

VI. POLICY IMPLICATIONS

Coronary ischaemic disease is one of the leading causes of death, disability and decreased quality of life in Europe; particularly one of three main causes of death in Denmark in 2009. It is also a leading cause of premature death in men generating important social costs associated to potential years of life lost. Hence, mortality and morbidity from cardiovascular disease has become a relevant issue for all health systems in Europe, as well as an important driver of health expenditure.

Several studies in the last decade showed that the incidence of coronary heart disease in the northern half of Europe, particularly Scandinavian countries, is higher than in the south. Even though hospitalizations for ischemic heart disease shows a decreasing trend, rates showed higher figures in England and Denmark (in this order) than in Spain and Portugal. This is a factor that should be taken into account in assessing hospitalisation fluxes and the intensity of consequent interventions; this section will highlight elements in the healthcare system and/or the organisational processes that may underpin the observed results and thus, might be worth a closer examination.

The mapping out of burden of disease and PCI intensity of use produces contradicting patterns: *kommuners* counting among the highest PCI utilisation rates could show either lower relative risk of CID hospitalisation or come along with the highest risks of hospitalisation. Given the potential benefit of primary PCI, two hypotheses are at play (perhaps concomitant, rather than alternative): a higher amount of early interventions might be preventing hospitalisation at further stages of the disease, and thus, reducing the corresponding admission rate. But, at the same time, the local risk of suffering a hospitalisation from CID should be also leading the need for PCI procedures and, thus, the local intensity of use; if that were not the case, such high intensity of PCI revascularisation unrelated to need might be pointing out over-utilisation of the procedure, that is, populations being over-exposed and thus, subject to inadequate provision of care.

The geographical analysis also revealed a relevant role for the regional tier in explaining variation in CID admissions (burden of disease) and exposure to PCI revascularisation across kommuners–up to the 52% of the variation in CID and 35% in PCI could be amenable to some sort of contextual phenomenon that differs between regions. This may be due to the application of different regional health plans or differing implementation of a national strategy at local level. The suggested role of regions in modulating the provision of PCI contrasts sharply with the irrelevant part this tier seems to play when it comes to explaining variation in CABG utilisation.

At kommuner level, CABG utilisation does not correlate with the burden of disease either. The joint analysis of utilisation patterns for both revascularisation procedures (PCI and CABG) does not provide grounds to induce any substitution or complementary utilisation. Actually, their utilisation rates seem to be unrelated. The conclusion that can be drawn is that factors other than need or technological change might be at play in explaining Danish revascularisation rates. Since utilisation is higher than in other ECHO countries with similar burden of disease, the hypothesis of over-utilisation gains likelihood.

Looking now at the case fatality rates for these patients and those procedures at hospital level, even though it had gone downwards over time, Danish risk-adjusted in-hospital mortality rate for AMI patients was still the second highest among ECHO countries in 2009. Detailed analysis reveals two extreme patterns of care provision: on the one hand 43% of hospitals -treating almost 25% of all Danish AMI patients- obtained in-hospital mortality results significantly higher than expected, and were consequently flagged as alert/alarm (they were all low volume). Meanwhile, another 23% of them -treating 63.8% of total AMI patients (mostly high volume)- were flagged as good or excellent in performance with CFR significantly lower than expected. There was a 9–fold difference in the risk of dying depending on where the AMI patient was hospitalised, but multilevel analysis showed that the hospitals (cluster effect) explained moderately this variation in outcomes, just a 6%. Volume has been argued as one of the plausible factors underpinning these differences; low volume seems to increase the probability of worse outcomes.

One of the recent reforms implemented in Denmark from 2007 pursues this idea, encouraging centralisation of specialised interventions into fewer centres, so the minimum amount of procedures per centre is guaranteed to maintain high level of expertise and consequent quality. The analysis of more recent years may unveil some changes fostered by this reform that might have not been so patent in 2009 (last year in ECHO analysis). Nevertheless, studying case fatality rates for CABG in 2009, high volume hospitals already treated almost 94% of patients undergoing this surgery in Denmark; risk-adjusted CABG CFRs for Danish hospitals ranked at average or excellent level of performance by ECHO countries' standards.

However, this phenomenon is not present when analysing PCI outcomes. Along the assessed period, Denmark shows consistently high risk-adjusted PCI CFR (the second highest among ECHO countries in 2009, just behind Spain) and also the largest share of these patients intervened in “alarm” hospitals, those with risk-adjusted CFR significantly above the maximum threshold. This poor outcome, together with the suspicion of over-use of this procedure, stemming from the geographical analysis, could suggest that the appropriateness and quality of PCI indications might be an issue to investigate.

The literature recommends assessing a number of factors critical to explain differences in hospital outcomes (both at local and global levels); these include pre-hospital diagnosis and planning of urgent transportation to the appropriate medical centre. In this respect, assessing the relationship to the eventual hospital of reference could provide relevant insights as to whether there is a well-defined, stable and fluid bypass circuit for severe patients or special techniques and if transfer to reference centres takes place immediately or within 24 hours, depending on the severity of the situation. Such are key elements of care in successful treatment and, thus, their further understanding could be very helpful in improving patient outcomes as well as overall costs for the health system.

The analysis conducted, suggests that there is room for enhancing outcomes in the Danish system. Burden of disease and revascularisation rates are generally larger as compared with other ECHO countries; however, they do not seem to relate to each other, suggesting that factors other than need or technological change might be driving the revascularisation intensity.

The comparatively poorer results of Danish hospitals when it comes to PCI and AMI patients warrant some closer look. The fact that almost half of the patients undergoing PCI procedure were treated in "alert/alarm" hospitals, well above the high volume of activity, deserves further consideration.

APPENDIX 1.a:

International Comparison across ECHO countries

GEOGRAPHICAL APPROACH

Year 2009

Table 1. General descriptive statistics for burden of disease: CID admissions

	CORONARY ISCHAEMIC DISEASE				
	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Cases	13225	141167	14526	4288	78585
Stand. Rate	30.68	34.32	17.86	32.40	23.79
EQ5-95	2.32	2.16	2.12	1.89	3.04
SCV	0.14	0.24	0.15	0.09	0.10

** sR: Age-sex Standardised Rate (Reference population: ECHO countries 2009); EQ: Extremal Quotient; SCV: Systematic Component of Variation;*

Table 2. General descriptive statistics for burden of disease: AMI admissions

	ACUTE MYOCARDIAL INFARCTION				
	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Cases	6711	69713	11365	2911	46206
Stand. Rate	15.90	16.76	13.80	22.29	13.78
EQ5-95	1.91	2.63	2.37	1.67	2.98
SCV	0.05	0.15	0.05	0.34	0.11

** sR: Age-sex Standardised Rate (Reference population: ECHO countries 2009); EQ: Extremal Quotient; SCV: Systematic Component of Variation;*

Table 3. General descriptive statistics for utilisation of PCI procedure

	PERCUTANEOUS CORONARY INTERVENTION				
	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Cases	9253	63220	10587	5025	48368
Stand. Rate	37.50	27.18	21.37	60.16	23.89
EQ5-95	1.86	2.20	2.24	2.61	4.71
SCV	0.33	0.08	0.08	1.97	0.22

** sR: Age-sex Standardised Rate (Reference population: ECHO countries 2009); EQ: Extremal Quotient; SCV: Systematic Component of Variation;*

Table 4. General descriptive statistics for utilisation of CABG surgery

	CORONARY ARTERY BYPASS GRAFT				
	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Cases	2371	20434	2446	774	7068
Stand. Rate	9.99	9.00	4.77	9.77	3.38
EQ5-95	1.71	2.33	7.42	5.32	9.83
SCV	0.50	0.41	0.19	0.74	0.27

** sR: Age-sex Standardised Rate (Reference population: ECHO countries 2009); EQ: Extremal Quotient; SCV: Systematic Component of Variation;*

APPENDIX 1.b:

International Comparison across ECHO countries

HOSPITAL APPROACH

Year 2009

Table 5. Data description of hospitals and patients included* in the analysis.

	ECHO	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
	ACUTE MYOCARDIAL INFARCTION					
Total discharges	147670	8124	71001	12391	3471	52683
Total nº hospitals	522	35	154	46	16	271
hospitals excluded	87	5	5	6	2	69
(% patients excluded)	0.55%	0.48%	0.01%	0.28%	0.06%	1.38%
Discharges analysed	146859	8085	70994	12356	3469	51955
Nº Hospitals analysed	435	30	149	40	14	202
	PERCUTANEOUS CORONARY INTERVENTION					
Total discharges	133161	9306	64253	10760	4817	44025
Total nº hospitals	283	25	97	39	9	113
hospitals excluded	84	18	24	9	1	32
% patients excluded	0.32%	0.43%	0.18%	0.92%	0.29%	0.36%
Discharges analysed	132737	9266	64139	10661	4803	43868
Nº Hospitals analysed	199	7	73	30	8	81
	CORONARY ARTERY BYPASS GRAFT					
Total discharges	33765	2390	21036	2496	678	7165
Total nº hospitals	145	17	53	10	2	63
hospitals excluded	56	11	24	4	---	17
% patients excluded	0.24%	1.26%	0.14%	0.16%	---	0.25%
Discharges analysed	33683	2360	21006	2492	678	7147
Nº Hospitals analysed	89	6	29	6	2	46

**Hospitals treating less than 30 patients or procedures/year have been excluded from the analysis in order to avoid noise when estimating risk-adjustment within logistic multivariate modelling.*

Table 6: ECHO hospitals' description and relative performance per country for AMI hospitalised patients. (ECHO benchmark estimation)

	ACUTE MYOCARDIAL INFARCTION					
	ECHO	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Discharges	146859	8085	70994	12356	3469	51955
Deceased	12582	674	6281	1183	240	4204
Nº Hospitals	435	30	149	40	14	202
Hospitals > 250 (% patients treated)	239 (82.47%)	6 (70.3%)	125 (93.9%)	23 (79%)	3 (66.59%)	82 (70.59%)
Average expected Risk-adjusted CFR	99.03	133.45	94.41	109.57	101.58	93.75
hosp. Alarm position (% patients treated)	40 (5.83%)	10 (21.13%)	9 (4.30%)	10 (20.31%)	3 (7.81%)	6 (1.09%)
hosp. Alert position (% patients treated)	18 (3.19%)	3 (3.45%)	6 (3.54%)	1 (1.45%)	1 (1.59%)	9 (4.09%)
hosp. Good performers (% patients treated)	42 (11.42%)	2 (3.15%)	14 (10.65%)	3 (9.43%)	2 (5.85%)	20 (13.97%)
hosp. Excellent performers (% patients treated)	67 (26.7%)	5 (60.63%)	22 (23.6%)	5 (19.06%)	3 (51.14%)	32 (25.85%)

** Hospitals>250: Hospitals above the activity threshold of 250 AMI hospitalisations/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of AMI patients in the country hospitalised at those hospitals.*

APPENDIX 1.b:

International Comparison across ECHO countries

HOSPITAL APPROACH

Year 2009

Table 7: ECHO hospitals' description and relative performance per country for patients undergoing PCI. (ECHO benchmark estimation)

	PERCUTANEOUS CORONARY INTERVENTION					
	ECHO	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Discharges	132737	9266	64139	10661	4803	43868
Deceased	2623	255	924	188	143	1113
Nº Hospitals	199	7	73	30	8	81
Hospitals > 250 (% patients treated)	159 (95.44%)	7 (100%)	64 (97.17%)	15 (84.05%)	5 (97.04%)	68 (94.53%)
Average expected Risk-adjusted CFR	19.86	22.78	13.70	20.77	15.61	25.59
hosp. Alarm position (% patients treated)	28 (17.26%)	4 (67.47%)	1 (1.55%)	3 (9.69%)	2 (74.47%)	18 (25.19%)
hosp. Alert position (% patients treated)	10 (3.9%)	--- ---	2 (1.80%)	1 (1.76%)	--- ---	7 (8.74%)
hosp. Good performers (% patients treated)	17 (4.8%)	2 (7.52%)	13 (7.80%)	--- ---	1 (5.58%)	1 (0.92%)
hosp. Excellent performers (% patients treated)	15 (15.51%)	--- ---	12 (28.27%)	1 (9.80%)	--- ---	2 (3.20%)

** Hospitals>250: Hospitals above the activity threshold of 250 PCI performed/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of patients in the country undergoing PCI procedure at those hospitals.*

Table 8: ECHO hospitals' description and relative performance per country for patients undergoing CABG. (ECHO benchmark estimation)

	CORONARY ARTERY BYPASS GRAFT					
	ECHO	DENMARK	ENGLAND	PORTUGAL	SLOVENIA	SPAIN
Discharges	33683	2360	21006	2492	678	7147
Deceased	1212	96	571	87	37	421
Nº Hospitals	89	6	29	6	2	46
Hospitals > 250 (% patients treated)	46 (82.16%)	5 (93.43%)	29 (100%)	6 (100%)	1 (70.06%)	5 (20.93%)
Average expected Risk-adjusted CFR	50.33	44.54	27.81	33.55	44.97	66
hosp. Alarm position (% patients treated)	9 (3.58%)	--- ---	--- ---	--- ---	--- ---	9 (16.87%)
hosp. Alert position (% patients treated)	4 (2.03%)	--- ---	--- ---	1 (16.21%)	--- ---	3 (3.92%)
hosp. Good performers (% patients treated)	13 (20.65%)	--- ---	8 (26.09%)	2 (32.58%)	1 (29.94%)	2 (6.46%)
hosp. Excellent performers (% patients treated)	18 (40.61%)	1 (24.79%)	16 (60.32%)	1 (16.97%)	--- ---	--- ---

** Hospitals>250: Hospitals above the activity threshold of 250 CABG performed/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of patients in the country undergoing CABG surgery at those hospitals.*

APPENDIX 2.a:

Tables Denmark

WITHIN-Country analysis

GEOGRAPHICAL APPROACH

Year 2009

Table 9: Descriptive Statistics of burden of coronary disease and use of revascularisation procedures across *kommuners*.

	CID	AMI	PCI	CABG
Cases	13225	6711	9253	2371
Population	4,503,365	4,503,365	2,781,314	2,781,314
Crude Rate	31.83	15.97	32.37	9.05
Stand. Rate	29.74	14.93	31.95	8.86
sR Min.	11.78	2.11	16.39	1.98
sR Max.	57.53	24.22	50.18	17.31
sR. P5	16.32	9.87	20.47	5.09
sR. P25	23.23	12.69	26.1	7.23
sR. P50	27.9	15.07	33.11	8.43
sR. P75	34.74	17.09	37	10.05
sR. P95	47.6	19.92	43.71	14.06
EQ5-95	2.92	2.02	2.13	2.77
EQ25-75	1.5	1.35	1.42	1.39
ICC	0.52	0.1	0.35	0.07

** sR: Age-sex Standardised Rate (Reference population: national 2009); sR Px: percentile x of sR distribution; EQ: Extreme Quotient; ICC: Intra class Correlation Coefficient*

Table 10: Relative risk of exposure to coronary disease and revascularisation procedures across Kommuners.

	CID	AMI	PCI	CABG
SUR Mín.	0.48	0.19	0.49	0.22
SUR Máx.	1.97	1.64	1.51	2.16
SUR P5	0.56	0.67	0.61	0.6
SUR P25	0.79	0.87	0.79	0.85
SUR P50	0.95	1.01	0.99	0.99
SUR P75	1.18	1.15	1.11	1.19
SUR P95	1.64	1.34	1.31	1.7
SCV	0.09	0.03	0.03	0.03

** SUR: Standardised admission/Utilization Ratio (observed/expected); SUR Px: percentile x of the SUR distribution; SCV: Systematic Component of Variation;*

APPENDIX 2b:

Tables Denmark

WITHIN-Country analysis

HOSPITAL APPROACH

Year 2009

Table 11: Descriptive statistics of hospital activity and outcomes.

	AMI in-hospital mortality	PCI in-hospital mortality	CABG in-hospital mortality
Deceased	674	255	96
N. hospitals	30	7	6
Crude CFR	125.60	22.88	43.57
Risk-adjusted CFR	133.45	22.78	44.54
R-adj CFR MIN	35.38	1.05	15.92
R-adj CFR MAX	329.42	38.04	65.52
Rho Statistic	0.057	0.043	0.155

**CFR: Case Fatality Rate per 1,000 hospitalised patients or patients undergoing procedure; R-adj CFRx: risk-adjusted rate of the percentile x of the CRF distribution; Rho Statistic: cluster effect.*

Table 12: Hospital outcomes for Acute Myocardial Infarction patients*

Hospital					Expected Rate		Relative Position		Expected Rate		Relative Position	
Code	Name	AMI cases (i)	Hospital CFR	Hospital sCFR	UCI 95%	LCI 95%	Above IC95	Below IC95	UCI 99%	LCI 99%	Above IC99	Below IC99
2012	BORNHOLMS HOSPITAL	53	377.36	512.06	231.79	35.10	*		262.69	4.20	*	
2032	60FK / FREDERICIA OG KOLDING SYGEHUSE	83	277.11	329.42	212.03	54.86	*		236.73	30.16	*	
2059	SYGEHUS THY - MORS / NYKXBING - THISTED	85	211.76	241.27	211.10	55.79	*		235.51	31.38	*	
2010	HERLEV HOSPITAL	143	188.81	204.00	193.32	73.57	*		212.13	54.76		
2006	HVIDOVRE HOSPITAL	85	176.47	192.73	211.10	55.79			235.51	31.38		
2051	REGIONSHOSPITALET VIBORG, SKIVE OG KJELLERUP	145	165.52	177.96	192.90	73.99			211.59	55.30		
2004	FREDERIKSBERG HOSPITAL	52	153.85	167.83	232.73	34.16			263.93	2.96		
2029	55ES / SYDVESTJYSK SYGEHUS / ESBJERG	125	152.00	166.82	197.48	69.41			217.61	49.28		
2024	SYGEHUS SXNDERJYLLAND, SXNDERBORG	92	152.17	166.25	208.09	58.80			231.55	35.34		
2061	HOBRO-TERNDRUP SYGEHUS / SYGEHUS HIMMERLAN	40	150.00	157.92	246.65	20.24			282.22	-15.33		
2048	REGIONSHOSPITALET RANDERS	115	147.83	156.85	200.21	66.68			221.19	45.70		
2066	SYGEHUS VENDSYSSEL	119	142.86	147.89	199.08	67.81			219.70	47.19		
2022	SYGEHUS FYN / OUH SVENDBORG SYGEHUS	108	138.89	142.78	202.34	64.55			223.99	42.90		
2043	ERHUS AMTSSYGEHUS	78	141.03	141.17	214.51	52.38			239.99	26.90		
2015	REGION SJFLLANDS SYGEHUSVFSEN	782	127.88	129.44	159.05	107.84			167.09	99.80		
2009	GLOSTRUP HOSPITAL	62	112.90	121.05	224.37	42.52			252.95	13.94		
2053	REGIONSHOSPITALET HOLSTEBRO	73	109.59	105.24	217.24	49.65			243.58	23.31		
2050	REGIONSHOSPITALET SILKEBORG	68	102.94	98.36	220.27	46.62			247.55	19.34		
2011	HOSPITALERNE I NORDSJFLLAND	226	88.50	83.54	181.07	85.82		*	196.04	70.85		
2038	BRFDSTRUP SYGEHUS	110	90.91	82.87	201.71	65.18			223.16	43.73		
2055	REGIONSHOSPITALET HERNING	170	82.35	75.37	188.36	78.53		*	205.61	61.28		
2063	AALBORG SYGEHUS, ERHUS UNIVERSITETSHOSPITAL	762	62.99	61.91	159.38	107.51		*	167.53	99.36		*
2020	ODENSE UNIVERSITETSHOSPITAL	1124	61.39	60.42	154.80	112.09		*	161.51	105.38		*
2007	GENTOFTE HOSPITAL	1047	53.49	51.95	155.57	111.32		*	162.53	104.36		*
2023	SYGEHUS SXNDERJYLLAND, HADERSLEV	175	57.14	45.07	187.57	79.32		*	204.57	62.32		*
2002	BISPEBJERG HOSPITAL	65	61.54	44.98	222.25	44.64			250.16	16.73		
2003	AMAGER HOSPITAL	49	61.22	42.79	235.73	31.16			267.87	-0.98		
2042	ERHUS UNIVERSITETSHOSPITAL, SKEJBY	1030	43.69	41.51	155.75	111.14		*	162.76	104.13		*
2001	RIGSHOSPITALET	939	38.34	35.38	156.81	110.08		*	164.15	102.74		*
2033	VEJLE SYGEHUS	80	37.50	18.53	213.49	53.40		*	238.65	28.24		*

(i) Total amount of AMI admissions per hospital accumulated during the period of analysis.
** Hospitals with less than 30 AMI admissions per year are dropped from the analysis.*
CFR: Crude case fatality rate per 1,000 AMI hospitalised patients; sCFR: Risk-adjusted Case Fatality Rate per 1,000 AMI hospitalised patients. Hospitals above the CI-99 control limit are considered in "Alarm position"; hospitals above the CI-95 control limit are considered in an "Alert position"; hospitals below the CI-95 control limit are considered "Good performers" and hospitals below the CI-99 control limit are considered "Excellent performers".

APPENDIX 2b:

Tables Denmark

IN-Country analysis

HOSPITAL APPROACH

Year 2009

Table 13: Hospital outcomes for Percutaneous Coronary Interventions,.

National benchmark estimation*

Hospital					Expected Rate		Relative Position		Expected Rate		Relative Position	
Code	Name	PCI cases (i)	Hospital CFR	Hospital sCFR	UCI 95%	LCI 95%	Above IC95	Below IC95	UCI 99%	LCI 99%	Above IC99	Below IC99
2020	ODENSE UNIVERSITETSHOSPITAL	1616	36.51	38.04	30.14	15.42	*		32.45	13.11	*	
2007	GENTOFTE HOSPITAL	1367	34.38	36.28	30.78	14.78	*		33.29	12.26	*	
2063	AALBORG SYGEHUS, ERHUS UNIVERSITETSHOSPITAL	1310	31.30	32.95	30.95	14.61	*		33.52	12.04		
2001	RIGSHOSPITALET	1959	27.57	27.64	29.46	16.09			31.56	13.99		
2042	ERHUS UNIVERSITETSHOSPITAL, SKEJBY	2317	22.01	21.75	28.92	16.63			30.85	14.70		
2015	REGION SJFLLANDS SYGEHUSVFSEN	437	4.58	1.73	36.93	8.63		*	41.37	4.18		*
2030	HJERTECENTER VARDE* (PRIVATE)	260	3.85	1.05	41.12	4.43		*	46.89	-1.33		

ECHO benchmark estimation*

Hospital					Expected Rate		Relative Position		Expected Rate		Relative Position	
Code	Name	PCI cases (i)	Hospital CFR	Hospital sCFR	UCI 95%	LCI 95%	Above IC95	Below IC95	UCI 99%	LCI 99%	Above IC99	Below IC99
2020	ODENSE UNIVERSITETSHOSPITAL	1616	36.51	38.96	26.74	12.99	*		28.89	10.83	*	
2007	GENTOFTE HOSPITAL	1367	34.38	37.16	27.33	12.39	*		29.68	10.04	*	
2063	AALBORG SYGEHUS, ERHUS UNIVERSITETSHOSPITAL	1310	31.30	34.29	27.50	12.23	*		29.89	9.83	*	
2001	RIGSHOSPITALET	1959	27.57	28.61	26.10	13.62	*		28.07	11.66	*	
2042	ERHUS UNIVERSITETSHOSPITAL, SKEJBY	2317	22.01	22.77	25.60	14.12			27.41	12.32		
2015	REGION SJFLLANDS SYGEHUSVFSEN	437	4.58	2.70	33.08	6.65		*	37.23	2.50		
2030	HJERTECENTER VARDE* (PRIVATE)	260	3.85	1.73	36.99	2.73		*	42.38	-2.65		

(i) Total amount of interventions per hospital accumulated during the period of analysis.

** The national benchmarking is based on the average outcomes obtained using just the 7 Danish hospitals while the ECHO benchmarking uses the average across all hospitals in ECHO performing this type of intervention*

Hospitals performing less than 30 interventions per year are dropped from the analysis

CFR: Crude case fatality rate per 1,000 patients undergoing PCI procedure; sCFR: Risk-adjusted Case Fatality Rate per 1,000 patients undergoing PCI procedure. Hospitals above the CI-99 control limit are considered in "Alarm position"; hospitals above the CI-95 control limit are considered in an "Alert position"; hospitals below the CI-95 control limit are considered "Good performers" and hospitals below the CI-99 control limit are considered "Excellent performers".

APPENDIX 2b:

Tables Denmark

WITHIN-Country analysis

HOSPITAL APPROACH

Year 2009

Table 14: Hospital outcomes for Coronary Artery Bypass Graft, 2009.

National benchmark estimation*

Hospital					Expected Rate		Relative Position		Expected Rate		Relative Position	
Code	Name	CABG cases (i)	Hospital CFR	Hospital sCFR	UCI 95%	LCI 95%	Above IC95	Below IC95	UCI 99%	LCI 99%	Above IC99	Below IC99
2063	AALBORG SYGEHUS, ERHUS UNIVERSITETSHOSPITAL	288	69.44	65.52	68.91	20.16			76.57	12.51		
2001	RIGSHOSPITALET	461	58.57	61.41	63.80	25.27			69.86	19.22		
2020	ODENSE UNIVERSITETSHOSPITAL	358	44.69	47.71	66.40	22.68			73.27	15.81		
2030	HJERTECENTER VARDE* (PRIVATE)	155	38.71	44.70	77.76	11.31			88.20	0.87		
2042	ERHUS UNIVERSITETSHOSPITAL, SKEJBY	513	31.19	31.96	62.80	26.28			68.54	20.54		
2007	GENTOFTE HOSPITAL	585	18.80	15.92	61.64	27.44		*	67.01	22.06		*

ECHO benchmark estimation*

Hospital					Expected Rate		Relative Position		Expected Rate		Relative Position	
Code	Name	CABG cases (i)	Hospital CFR	Hospital sCFR	UCI 95%	LCI 95%	Above IC95	Below IC95	UCI 99%	LCI 99%	Above IC99	Below IC99
2063	AALBORG SYGEHUS, ERHUS UNIVERSITETSHOSPITAL	288	69.44	68.56	76.24	24.42			84.38	16.28		
2001	RIGSHOSPITALET	461	58.57	60.63	70.81	29.85			77.25	23.42		
2020	ODENSE UNIVERSITETSHOSPITAL	358	44.69	47.40	73.57	27.09			80.87	19.79		
2030	HJERTECENTER VARDE* (PRIVATE)	155	38.71	43.80	85.65	15.01			96.75	3.92		
2042	ERHUS UNIVERSITETSHOSPITAL, SKEJBY	513	31.19	31.72	69.75	30.92			75.85	24.82		
2007	GENTOFTE HOSPITAL	585	18.80	17.07	68.51	32.15		*	74.22	26.44		*

(i) Total amount of interventions per hospital accumulated during the period of analysis.

** The national benchmarking is based on the average outcomes obtained using just the 6 Danish hospitals while the ECHO benchmarking uses the average across all hospitals in ECHO performing this type of intervention. Hospitals performing less than 30 interventions per year are dropped from the analysis.*

CFR: Crude case fatality rate per 1,000 patients undergoing CABG surgery; sCFR: Risk-adjusted Case Fatality Rate per 1,000 patients undergoing CABG surgery. Hospitals above the CI-99 control limit are considered in "Alarm position"; hospitals above the CI-95 control limit are considered in an "Alert position"; hospitals below the CI-95 control limit are considered "Good performers" and hospitals below the CI-99 control limit are considered "Excellent performers".

APPENDIX 3.a:

Tables Denmark

Evolution over time

GEOGRAPHICAL APPROACH

Period of analysis: 2002-2009

Table 15. Denmark descriptive statistics over time for burden of disease: CID

	CORONARY ISCHAEMIC DISEASE							
	2002	2003	2004	2005	2006	2007	2008	2009
Cases	20924	18645	17674	16874	15806	14827	13341	13225
Stand. Rate	48.08	42.8	40.8	40.18	38.17	35.87	32.19	31.61
sR Q1.	47.44	41.32	41.51	38.08	36.82	32.56	31.72	30.03
sR Q5.	44.06	41.63	38.82	40.30	35.04	36.45	33.07	32.91
SCV	0.05	0.06	0.05	0.07	0.08	0.12	0.09	0.1

**sR: Age-sex Standardised Rate (Reference population: national 2002); sR Qx: quintile x of sR distribution; SCV: Systematic Component of Variation;*

Table 16. Denmark descriptive statistics over time for burden of disease: AMI

	ACUTE MYOCARDIAL INFARCTION							
	2002	2003	2004	2005	2006	2007	2008	2009
Cases	9285	8523	8281	7785	7190	7227	6568	6711
Stand. Rate	21.33	19.88	19.17	18.76	17.24	17.12	15.61	15.97
sR Q1.	20.66	18.10	19.73	17.70	17.02	14.97	15.19	14.55
sR Q5.	18.04	18.57	16.04	16.53	14.62	16.24	14.58	15.50
SCV	0.05	0.07	0.05	0.06	0.05	0.06	0.03	0.03

** sR: Age-sex Standardised Rate (Reference population: national 2002); sR Qx: quintile x of sR distribution; SCV: Systematic Component of Variation;*

Table 17. Denmark descriptive statistics over time for procedure utilisation: PCI

	PERCUTANEOUS CORONARY INTERVENTION							
	2002	2003	2004	2005	2006	2007	2008	2009
Cases	6503	7803	8350	9073	9464	8833	8536	9253
Stand. Rate	23.82	28.39	31.09	34.74	36.08	33.78	32.57	35.29
sR Q1.	28.30	31.11	34.06	39.20	37.72	34.04	33.83	34.93
sR Q5.	14.31	22.21	22.86	26.68	30.27	29.22	29.18	28.73
SCV	0.11	0.05	0.05	0.05	0.03	0.02	0.03	0.03

** sR: Age-sex Standardised Rate (Reference population: national 2002); sR Qx: quintile x of sR distribution; SCV: Systematic Component of Variation;*

APPENDIX 3.a:

Tables Denmark

Evolution over time

GEOGRAPHICAL APPROACH

Period of analysis: 2002-2009

Table 18. Denmark descriptive statistics over time for procedure utilisation: CABG

	CORONARY ARTERY BYPASS GRAFT							
	2002	2003	2004	2005	2006	2007	2008	2009
Cases	3657	3336	3004	2750	2544	2635	2308	2371
Stand. Rate	14.3	13.05	11.72	10.79	9.89	10.67	9.13	9.82
sR Q1.	14.02	12.53	12.08	9.45	8.32	9.45	8.04	8.32
sR Q5.	10.74	11.23	9.36	10.33	10.01	9.64	8.62	11.19
SCV	0.03	0.02	0.03	0.02	0	0.03	0.04	0.05

** sR: Age-sex Standardised Rate (Reference population: national 2002); sR Qx: quintile x of sR distribution; SCV: Systematic Component of Variation;*

APPENDIX 3.b:

Tables Denmark

Evolution over time

HOSPITAL APPROACH

Period of analysis: 2002-2009

Table 19. Evolution of Danish hospitals' relative performance for AMI admissions – Period 2006-2009. (In-country benchmark estimation)

	ACUTE MYOCARDIAL INFARCTION			
	2006	2007	2008	2009
Discharges	8437	8563	7836	8085
Deceased	888	851	663	674
Nº Hospitals	34	34	35	30
Hospitals > 250	8	8	5	6
(% patients treated)	(64.54%)	(64.01%)	(58.49%)	(70.3%)
Average expected risk-adjusted CFR	148.61	144.77	132.33	133.45
hosp. Alarm position	4	5	5	3
(% patients treated)	(7.81%)	(7.42%)	(6.14%)	(2.73%)
hosp. Alert position	1	---	3	1
(% patients treated)	(0.72%)	---	(4.03%)	(1.77%)
hosp. Good performers	2	3	4	2
(% patients treated)	(3.83%)	(4.95%)	(5.63%)	(4.9%)
hosp. Excellent performers	7	7	7	7
(% patients treated)	(57.58%)	(57%)	(62.65%)	(63.78%)

**Hospitals>250: Hospitals above the activity threshold of 250 AMI hospitalisations/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of AMI patients in the country hospitalised at those hospitals*

Table 20. Evolution of Danish hospitals' relative performance for patients undergoing PCI procedure. (In-country benchmark estimation)

	PERCUTANEOUS CORONARY INTERVENTION							
	2002	2003	2004	2005	2006	2007	2008	2009
Discharges	6451	7800	8324	9071	9458	8826	8569	9266
Deceased	155	213	183	274	261	242	203	255
Nº Hospitals	6	9	7	7	7	7	8	7
Hospitals > 250	5	5	5	6	6	6	6	7
(% patients treated)	(98.29%)	(94.19%)	(96.97%)	(99.56%)	(99.31%)	(99.3%)	(98.39%)	(100%)
Average expected Risk-adjusted CFR	21.38	16.05	16.61	23.47	22.64	22.68	23.28	22.78
hosp. Alarm position	1	4	3	2	2	3	1	2
(% patients treated)	(14.4%)	(80.32)	(59.66%)	(32.63%)	(39.05%)	(57.82%)	(12.85%)	(32.19%)
hosp. Alert position	---	---	---	---	1	---	1	1
(% patients treated)	---	---	---	---	(16.9%)	---	(15.6%)	(14.14%)
hosp. Good performers	---	---	1	1	---	---	---	1
(% patients treated)	---	---	(15.15%)	(3.16%)	---	---	---	(2.81%)
hosp. Excellent performers	---	---	---	---	1	1	1	1
(% patients treated)	---	---	---	---	(3.96%)	(4.32%)	(4.46%)	(4.72%)

** Hospitals>250: Hospitals above the activity threshold of 250 PCI performed/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of patients in the country undergoing PCI procedure at those hospitals*

APPENDIX 3.b:

Tables Denmark

Evolution over time

HOSPITAL APPROACH

Period of analysis: 2002-2009

Table 21. Evolution of Danish hospitals' relative performance for patients undergoing CABG surgery. (In-country benchmark estimation)

	CORONARY ARTERY BYPASS GRAFT							
	2002	2003	2004	2005	2006	2007	2008	2009
Discharges	3618	3289	2971	2720	2509	2623	2294	2360
Deceased	132	156	125	115	119	111	83	96
Nº Hospitals	7	7	6	6	6	6	6	6
Hospitals > 250	5	5	5	5	5	6	6	5
(% patients treated)	(88.2%)	(90.03%)	(93.77%)	(92.57%)	(93.9%)	(100%)	(100%)	(93.43%)
Average expected Risk-adjusted CFR	32.37	42.74	41.48	39.05	47.38	40.63	36.66	44.54
hosp. Alarm position	1	1	---	1	---	1	---	---
(% patients treated)	(21.2%)	(14.32%)	---	(24.96%)	---	(22%)	---	---
hosp. Alert position	---	1	---	---	---	---	---	---
(% patients treated)	---	(19.91%)	---	---	---	---	---	---
hosp. Good performers	1	1	1	---	---	---	1	1
(% patients treated)	(5.97%)	(4.26%)	(18.01%)	---	---	---	(13.38%)	(24.79%)
hosp. Excellent performers	---	---	---	---	---	---	---	---
(% patients treated)	---	---	---	---	---	---	---	---

** Hospitals>250: Hospitals above the activity threshold of 250 CABG performed/year; Alarm position: hospitals above the CI-99 control limit; Alert position: hospitals above the CI-95 control limit; Good performers: hospitals below the CI-95 control limit; Excellent performers: hospitals below the CI-99 control limit. In brackets the percentage of patients in the country undergoing CABG surgery at those hospitals*

APPENDIX 4:

Technical note

Cardiovascular Ischaemic Disease and AMI, as well as the revascularisation procedures, PCI and CABG, are conceived as geographical and hospital-specific indicators, within the ECHO performance model.

First of all, from a geographical basis, this approach entails some implications, both for methodology and in interpreting results. The report is based on ecologic analyses –data aggregated at a certain geographical level which becomes the unit of analysis; thus, the correct interpretation of the findings highlights the risk of being exposed to hospitalisations due to cardiovascular conditions or revascularisation procedures for the population living in a certain area (as opposed to the risk for an individual patient). Afterwards, from a provider perspective, individual data is analysed and risk-adjusted within multivariate logistic 2-level hierarchical modelling, so then clustered into hospitals, where the interpretation would be the risk of dying after being hospitalised and/or intervened in a specific hospital compared to the national average o the ECHO benchmark.

Main endpoints:

This report maps out standardised utilisation rates per geographical area as well as the risk-adjusted case fatality rates per each provider, analysing events amenable to healthcare quality. As a summary measure of variation, the report includes the classical statistics Ratio of Variation between extremes, Component of Systematic Variation and Rho Statistic or cluster effect.

Instruments:

In the geographical approach, being an ecologic study, each admission was allocated to the place of residence of the patient, which in turn was referred to a policy relevant geographic unit – the 98 *kommuners* and the 5 Regions building up the Danish National Health System.

For the risk-adjustment of the hospital approach within the multivariate logistic 2-level hierarchical modelling, the following variables have been included:

- Age and sex
- Having the patient a primary diagnosis of AMI:

  Whether he or she was classified as transmural (with ST segment elevation, STEMI), non-STEMI or unclassified.

Whether the patient underwent heart valve replacement and/or implantation of a cardiac or circulatory assistance device.

Whether the intervention was a major structural surgery (including repair or revision of atrial and ventricular septa, cardiotomy, pericardiotomy, pericardiectomy and excision of a heart lesion).

– Another specific measures of the severity of the underlying condition (42 co-morbidities variables included in the Elixhauser index), such as:

Cardiac arrhythmias	Hypothyroidism
Valvular disease	Liver disease
Congestive heart failure	Obesity
Chronic lung disease	Alcohol abuse
Hypertension, uncomplicated	Drugs abuse
Hypertension, complicated	Lymphoma
Hypertension with congestive Heart failure	Solid tumor without metastasis
Hypertension without congestive Heart failure	Metastatic cancer
Hypertensive heart and renal disease with heart failure	Weight loss
Hypertensive heart and renal disease without heart failure	Psychoses
Hypertensive heart and renal disease with heart and renal failure	Depression
Hypertensive heart and renal disease without heart and renal failure	AIDS/HIV
Hypertensive renal disease with renal failure	Fluid and electrolyte disorders
Hypertensive renal disease without renal failure	Peptic ulcer disease excluding bleeding
Total hypertension disease	Deficiency anemia
Pulmonary circulation disorders	Blood loss anemia
Renal failure	Coagulopathy
Pre-existing hypertension complicating pregnancy	Rheumatoid arthritis/collagen vascular diseases
Other hypertension in pregnancy	Peripheral vascular disorders
Diabetes, without chronic complications	Paralysis
Diabetes, with chronic complications	Other neurological disorders

For both approaches, the operational definitions for each indicator are detailed in the coding table in appendix 5. Indicators are based on those in use in the international arena as proposed by AHRQ and OECD. For its use in the analysis of variations across countries they were subject to a construct validity process developed by the Atlas VPM project in Spain and cross-walking across different diseases and procedures classifications underwent a face-validation carried out as a task within the ECHO project.

This report is based on the hospital admissions registered in the National Discharges Dataset (*Ministeriet Sunhed Forebyggelse*). Cross- and in-country sections were built upon 2009 discharges, whereas time-trends and social gradient analyses used 2002 to 2009 data.

Social gradient data were obtained from the National Statistics office (*Danmarks Statistik Statistikbanken*) data for *kommuners* on average family annual income (both based in transfers and available) was obtained from the *Statistikbanken*. For regions, transfer and available income were calculated as the weighted average of the individual kommuners/municipalities values.

APPENDIX 5:

Definitions of indicators

	Diagnosis codes ICD10 and Procedures codes Nomesco					
	Primary diagnosis		Secondary diagnosis2-30		Procedures	
	Inclusions	Exclusions	Inclusions	Exclusions	Inclusions	Exclusions
Ischaemic Disease +18 Age Type of admission unplanned	I21 I22 I20.0 I24.0 I24.8 I20.8 I20.1 I20.9 I25.10 (IF DX2-30= I20.0)					
Acute Myocardial Infarction (AMI) +18 Age Type of admission unplanned	I21* I22*					
Percutaneus Coronary Interventions (PCI) +40 Age					FNG05 FNG02 FNG22 FNG96 FNW98	
Coronary Artery Bypass Grafting (CABG) +40 Age					FNA* FNB* FNC* FND* FNE*	

APPENDIX 5:

Definitions of indicators

	Diagnosis codes ICD10 and Procedures codes Nomesco					
	Primary diagnosis		Secondary diagnosis2-30		Procedures	
	Inclusions	Exclusions	Inclusions	Exclusions	Inclusions	Exclusions
Acute Myocardial Infarction in Hospital Mortality +18 Age	I21* I22*	O00*-O99*		O00*-O99*		
Percutaneus Coronary Interventions in Hospital Mortality +40 Age		O00*-O99*		O00*-O99*	FNG05 FNG02 FNG22 FNG96 FNW98	
Coronary Artery Bypass Grafting in Hospital Mortality +40 Age		O00*-O99*		O00*-O99*	FNA* FNB* FNC* FND* FNE*	