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Survey of Pathogenic Bacteria in Neonatal Intensive Care Unit of Tripoli Medical Center, Libya.

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الملخص

عناية حديثي الولادة من اهم الاماكن التي يرتفع فيها معدل الالتهابات ويتم فيها انتقال البكتريا الممرضة بين المرضى الذين يتلقون العلاج فيها مما يؤدي الى انتشار المقاومة للمضادات الحيوية وزيادة حالات الوفيات بين الاطفال. لمعرفة اشهر البكتريا الممرضة و معدل انتشارها في عناية حديثي الولادة بمستشفى مركز طرابلس الطبي و اماكن تواجدها و مدى استجابتها للمضادات الحيوية و معدل المقاومة لهذه المضادات.

كانت هذه الدراسة وصفية مقطعية. اجريت لحديثي الولادة الذين تم دخولهم في ثلاثة اشهر مايو– يونيو –يوليو من عام 2013 حيث كان عددهم الاجمالي 479 منهم 244 كان دخولهم للعناية المركزة و 235 العناية الخاصة بأخذ العينات اللازمة لأجراء المسح الطبي لمعرفة سبب الالتهاب المصاحب لدخول الطفل للعناية كذلك المزرعة الميكروبية والمضاد الحيوي المناسب للعلاج واذا مصاحب لهذا العلاج أي نوع من المقاومة للعقار.

اظهرت النتائج ان اشهر بكتريا ممرضة في العناية هي اسينوباكتر بوماني و بمعدل (40%– 48%) يتبعها الكليبسيلا نمونيا بمعدل (31% – 33%) واشهر اماكن الاصابة هي الاذن والانف و الحلق بنسبة (53 % – (58% مقارنة بالدول الاخرى ان معدل انتشار العدوى متقارب مع دول العالم.

1. ABSTRACT:

Neonatal intensive care unit (NICU) is an ideal environment for transmission of many pathogens, which lead to high morbidity and mortality in neonates. Microbial pathogens which cause nosocomial infection are known of high resistance to many antibiotics which lead to economic burdens, in addition to social and psychological factors affecting the families due to long duration in hospitals. Prevention of infection requires identification of contaminated environment and equipment, effective infection control programs, and judicious of antimicrobial agents.

Methods: 244 neonates, who were admitted to NICU, and 235residing neonates at Special Care Baby Unit (SCBU) of Tripoli Medical Center (TMC) in the months of May to July 2013, and who were found positive for pathogenic infection were subjected to the study. Pathogenic organisms were isolated and identified according to Standard Microbiological Methods, and antibiogram was assessed against common antibiotics.

Results: Acinetobacter baumannii was the most frequently isolated bacterium from neonates at NICU and SCBU at a rate of 40% and 48%, followed by Klebsiella pneumoniae at a rate of (33% and 31%) respectively, while the less frequently isolated organisms were Staphylococcus haemolyticus (9% NICU and 5% SCBU), and S. hominis (7% NICU and 3% SCBU). Infection sites were 2 Ear, Nose, and Throat (53 % NICU and 58% SCBU), CSF (33% NICU and 3.85% SCBU), Urine, Eye swab (30% NICU and 47% SCBU), Vein Catheter 29 %) NICU), Skin swab catheter (30% NICU and 27% SCBU), blood (11% ICU and 12% SCBU), Umbilical Swab (7% NICU and 18% SCBU), Nasal swab (4% NICU and 12%S CBU), catheter (30.33NICU and 27%S CBU(.

Conclusion: data indicate significant infection problem in Tripoli Medical Center Hospital, and inefficient infection control programs. A. baumannii and Klebsiella pneumonia were the predominant cause of neonatal infection at TMC. Antimicrobial resistant pathogens isolated in Neonatal Intensive Care and Special Care Baby Units respectively were: K. pneumoniae (ESBL)(56.52% and 44.44%), Carbepenem-resistant K. pneumoniae 21.7%) and 11.11%), and E. coli (ESBL) (13.04% and 5.56%).

2. INTRODUCTION :

At any point of time, over 1.4 million people worldwide are suffering from infections acquired infection at hospitals. Between 5% and 10% of patients admitted to modern hospitals in the developed world acquire one or more infections. The risk in developing countries is 2 to 20 times higher (Pittet D .,and Donaldson 2006). In some developing countries, the proportion can exceed 25%)Mayon et al., 1988). Infections are an important cause of neonatal morbidity and mortality worldwide. Neonatal infections among low-birth weight infants are associated with significant risk of neurologic abnormalities, developmental and functional delays (Vohr et al., 2000(. Although most neonatal infections are of maternal or community origin, an increasing proportion of these infections is acquired in the nursery. (Zafar et al., 2001). Nosocomial bloodstream infections

(BSIs) are increasing in prevalence worldwide and result in significant morbidity, mortality (Rupp M.,2004). In recent years, the subject of the emergence and subsequent increase in the incidence of resistance to antimicrobial agents has become a serious threat)WHO, 1999.(Reports from all around the world suggest that antibiotics are rapidly losing their effectiveness, with some early reports going so far as to suggest that we are approaching a post-antibiotic era (Cohen M., 1992). Antimicrobial resistance is increasing for a variety of reasons, these includes un-optimal use of antimicrobials for prophylaxis and treatment of infection, prolonged hospitalization, increased number and duration of intensive-care-unit stays, multiple co-morbidities in hospitalized patients, increased use of invasive devices and catheters, (Osmon D., 2001).

3. OBJECTIVE :

This study intends to determine the following:

1. Rate of infection and the main source of these infection.
2. Identity of different pathogenic bacteria found in neonatal intensive care unit at Tripoli Medical Center, depicting isolate identity, infection rates, infection sites, anti-microbial susceptibility patterns of isolated bacterial agents.
3. Determine antimicrobial resistance of organisms isolated in the study.

4. LITERATURE REVIEW :

There was study carried out to survey both the epidemiology of nosocomial infection in NICU and the annual trends of pathogens in Korea, which occurred in NICU from January 1995 to December 1999. The data included clinical characteristics, site of infection, pathogens, and mortality. Nosocomial infection rate was 9.0 per 100 NICU admissions during the five-year period. Major sites of infection were bloodstream (32.3%), skin (18.4%), endotracheal tube (17.2%), and catheter (10.6%). The most common pathogen was S. aureus (29.9%). and the others were coagulase-negative staphylococci (CONS) (14.8%), Enterobacter (12.4%), and Candida (9.0%). During the five-year period, nosocomial infection rates increased from 9.5 to 11.6 per 100 admissions with the increase of CONS, Candida, Klebsiella, and Acinetobacter baumannii, while the infection rate of S. aureus decreased. (Kwon H, et al.2002).

There was a case records of all neonates admitted to the NICU of TMC, Libya for the period Sep.1996 through August 1997, inclusive, were reviewed. Blood and/or CSF cultures were used to establish the diagnosis of bacterial infection. The

admissions were categorized as sterile and unsterile. A total of 1123 newborns were admitted to NICU over the period of the study, 129 (11.5%) of them were proved to be bacterially infected, 10.6%and 24% of the sterile and unsterile admissions, respectively, had bacterial infection. Blood culture was positive in 115 (10.2%) of the admitted newborns, while CSF culture was positive in 24 (2.1%) of them. Gram-negative bacteria were the predominantly isolated bacteria. Serratia spp. was isolated from (38.3% and 50%) of blood and CSF cultures, respectively. K. pneumonia was isolated from about (25%) of both blood and CSF cultures. Coagulase negative staphylococcus (CONS) was isolated from (11.3%) of blood cultures. we can conclude from this study that neonatal infection is still a problem facing the country and there is a need for 6 study of bacterial colonization of anogenital tract of Libyan pregnant women and its relation to neonatal infections (Dekna, et al.2007(.

In a Brazilian neonatal intensive care unit (NICU), a study was a retrospective cohort from January to December, 2003. All neonates were admitted to the NICU. Study was conducted at a public, tertiary referral NICU of a teaching hospital in the Northeast of Brazil. A total of 948 medical records were reviewed. Overall NI incidence rate was 34%. (Ana Carolina, et al 2008. (

From February 2004 to January 2005, 579 consecutive episodes of blood stream infection were obtained at two neonatal intensive care units Al Nasser and Al Shifa hospitals in Gaza City. Forty (6.9%) isolates of A. baumannii were obtained from the neonates under 28 d. Most of the isolates (92%) were from hospitalized patients in the intensive care units. Community acquired infection was 8%. Sixty three percent of the patients were males. The isolates of A. baumannii were resistant to commonly used antibiotics while being sensitive to meropenem (92.5%(, imipenem (90%), chloramphenicol (80%), ciprofloxacin (75%), gentamicin (57.5%), ceftriaxone (50%), amikacin (37.5%), cefuroxime and cefotaxime (35%). Over all crude mortality rate was 20% with much higher crude mortality among patients with nosocomial infection. Based on logistic regression, the following factors were statistically significant :weight < 1500g, age < 7 d, mean of hospitalization equal 20 days, antibiotic use, and mechanical ventilation, when compared to the control group ($P<0.05$) (Aljarosha, et al, 2008(.

A noted study was carried out in September 2011. A three-month descriptive cross-sectional survey in two intensive care units in Gaza city (Al-Shifa and Al-Nasser hospitals). Results concluded that a total of 622 cases showed an incidence

rate of septicemia at 10.4%. The causative bacteria were: coagulase- negative Staphylococcus (39%), S. aureus (23%), Streptococcus spp. (12%), Pseudomonas spp. (8%), and E. coli and K. pneumoniae (5% each). Lack of institutional commitment and worker's interest in preventive measures, shortage of environment disinfection and unfacilitated hand washing are the main negative observations. The environment and healthcare workers were found loaded with potential bacterial pathogens. Ampicillin, Gentamicin and Cefotaxime (claforan) are extensively used in the units as a prophylactic medicine. K. pneumoniae has shown the highest rate of antibiotic resistance (53%)Eljadba, et al. 2009(.

A perspective study was conducted to describe the epidemiologic profile of nosocomial infection in the neonatal intensive care unit (NICU) in china. The newborn infants who were admitted in the NICU for more than 48 hrs. were enrolled from February 2006 to January 2007. The clinical data were collected. The rate of nosocomial infection was calculated according to the CDC (centers of disease control) surveillance system. The risk factors of nosocomial infection were investigated by multivariate regression analysis. A total of 1 159 neonates were recruited. A total of 169 nosocomial infections occurred, with a cumulative rate for nosocomial infection of (14.58%). The incidence of nosocomial infection was 19.52 per 1 000 patient-days. Ninety-two cases of pneumoniae, including 38 cases of ventilator-associated pneumonia (VAP(,were reported, with a nosocomial infection rate of 7.94%, which was the most common nosocomial infection in the NICU. Among these infants the rate of VAP was 48.8 per 1 000 ventilator days. The major microorganisms isolated from the infected patients were A. baumannii, K. pneumonia, and coagulase negative staphylococcus. Birth weight (OR 2.130, 95% CI 1.466-3.094), mechanical ventilation (OR 7.038, 95%CI 3.901-12.698), chest tube drainage (OR 7.004, 95% CI 1.841-26.653) and ibuprofen therapy (OR 2.907, 95% CI 1.303-6.487) (Cai XD, et al. 2010.(

A cohort study which measured the occurrence and risk factors of nosocomial infections in the neonatal intensive care unit was carried out in Abha General Hospital, Saudi Arabia. Of 401 neonates who stayed at least 48 hours in the unit, 77 developed bacterial infections. The most frequent infections were: pneumonia (50.0%), bacteremia (40.9%) and skin and soft tissues (6.5%). In logistic regression analysis, mechanical ventilation and parenteral nutrition were identified as significant risk factors. Neonates suffering from nosocomial infections had more than 3 times the risk of dying compared to neonates free of infection (Mahfouz, et al. 2010).

A prominent study in Egypt was published lately in 2013 with an objective to determine the incidence, anatomical sites and causative organisms of NI in an Egyptian NICU,. This was a descriptive hospital-based study carried out for 12 months in the NICU of the Mansoura University Children's Hospital. NI rates were calculated using different denominators (overall nosocomial infection rate, nosocomial infection incidence density, device-specific infection rates and device-days infection rates). Of the 238 neonates evaluated, 49 developed 51 nosocomial infective episodes, equating to an incidence rate of 21.4% or 13.8 infections per 1000 bed-days. Pneumonia was the most frequently occurring infection (11.3%) followed by bloodstream infection (8.8%). The most frequently isolated organisms were Klebsiella spp. (33.3%) followed by E. coli (21.6%). NIs were associated with prolonged hospital stay(Abdel-Wahab, et al. 2013).

When we compare our study with all previous study there is no significant different and mostly there is similar pattern and infectious agent with our hospitals.

5. SUBJECTS AND METHODS:

Tripoli Medical Center is tertiary care center. The NICU (neonatal intensive care unit) consists of five rooms with capacity of 40 neonates from inside the hospital. SCBU (special care baby unit) with capacity of 30 neonate servers for babies referred from outside the hospital and outside Tripoli. Three months descriptive Cross- sectional study done where the data were collected from newly admitted neonates for more than 24 hour .

during a period of three months (May, June, and July 2013). 479 neonates were examined at the time of admission the following information were recorded, gestational age, birth weight, mode of delivery, exposure vascular catheter, endotracheal tube, mechanical ventilation.

Full septic screen was performed, bacterial isolates were run through Gram stain, and biochemical identification using different culture media were used for different samples, Table1, (Murray, et al 2007), and culture identification tests based on biochemical features according to Standard Microbiological Methods (Winn, et al. 2005).

6. Protocol for specimens processing :

Blood samples were obtained from infant, most samples were collected prior to antimicrobial therapy. Superficial swab (rectal, nose, ear, umbilical, skin, eye) for

every admitted neonate, UVC TIP, endotracheal tube, umbilical vein catheter, urine catheter cerebrospinal were all processed for culturing on appropriate media shown in Table 1. Instrument tip (ENT, Catheter tip, CSF for Gram stain and culture if indicated. Sputum or throat swab, joint fluid aspiration and culture if indicated.Venous blood was obtained from admitted newborns by nursing staff by means of a septic technique: briefly 0.5ml of blood was drawn in to aerobic bottle (broth media) incubated at 37C aerobically and checked daily for turbidity for six days. Turbid bottles were cultured on Blood agar, MacConkey agar, Chocolate agar, and incubated aerobically at cytoperm incubator with 10% Co 2 for 24h at 37C, followed by bacterial isolation and identification.Swabs were used for umbilical, eye, ear, skin and cultured on Blood Agar , MacConkey agar, Chocolate agar, and Thioglycolate broth.CSF samples were cultured on Blood Agar, Chocolate Agar, Brain Heart Infusion Broth (BHI), while Catheter tips were cultured on Blood Agar, MacConkey and BHI. Nasal swabs were cultured in Blood Agar and MacConkey agar. After 24 hr bacterial isolates for were picked for identification and antibiogram testing. Plates or broths with no growth were further incubated for 72 hs. and colonies were processed as indicated. Identification, and antimicrobial resistance for isolated pathogen were determined according to National Committee of Clinical Laboratory Standards , break point value was done with VITEK Susceptible System.

Disc Diffusion Method:

Antibiotic susceptibility testing for isolated bacterial pathogens was done according to Bauer and Kirby (1966) using Disc diffusion method using Mueller-Hinton agar with commercial antibiotic disc discs: amoxicillin, cefotaxime, cefixime, ciprofloxacin, ampicillin, nitrofurantoin, norfloxacin, ofloxacin, amikacin, nalidxic acid, ceftazidime, ceftriaxone and gentamycin. Plates were incubated at 37C for 24h.

7. RESULTS:

NICU and SCBU at Tripoli Medical Center suffer from potential contamination and hazardous infection. Infection rate as related to body weight of les than 2.5 kg was 49% (n119) and 19% (n44) at NICU and SCBU respectively.

- A. baumannii was the most frequently isolated bacterium from neonates at NICU and SCBU at a rate of 40% and 48%, followed by K.pneumoniae at a rate of (33% and 31%) respectively, while the less frequently isolated

organisms were S. haemolyticus (9% NICU and 5% SCBU), and S. hominis (7% NICU and 3% SCBU .(

- Isolated pathogens in NICU and SCBU respectively were:
  - o A. baumannii (40% and 48%.(
  - o K. pneumoniae (33% and 31%).
  - o S. haemolyticus (9% and 5%(.
  - o S. Hominis (7% and 3%).
  - o Entercoccus spp (7% and 5%.(
  - o E. coli (5% and 9%).

Main sources of infection in Neonatal Intensive Care and Special:

Care Baby Units were:

- Endotracheal tubes: 37 samples total, 20 positive (54%).
- Eye swab (C/S): 35 samples total, 13 positive (37%(.
- Umbilical vein catheter: 35 samples total, 10 positive (29%(.
- Urine Catheter: 25 samples total, 7 positive (28%).
- CSF: 41 samples total, 6 positive (15%).
- Umbilical swab: 206 samples total, 25 positive (12%).
- Blood Culture Sensitivity (C/S) 292 samples total, 32 positive (11%.(
- Rectal swab: 210 samples total, 21 positive (10%(.
- Nasal swab: 270 samples total, 18 positive (7%).
- Skin swab: samples total, 10 positive (7%).

Antimicrobial resistant pathogens isolated in Neonatal Intensive Care and Special Care Baby Units respectively were:

- K. pneumoniae (ESBL) (56.52% and 44.44%).
- Carbepenem-resistant K. pneumoniae (21.7% and 11.11%) E. coli (ESBL), (13.04% and 5.56%).
- E. coli (ESBL), (13.04% and 5.56%).

The following Tables show more detailed numbers and percentages of all tested pathogens, antibiotics, and body sites.

Table 1. Isolated pathogens in NICU and SCBU .

Type of organism	NICU		SCBU		X^2
	NO	%	NO	%	
Klebsiella pneumoniae	33	32.67	20	3076	
Acinetobacter baumannii	40	39.60	31	47.69	
Staph. haemolyticus	9	8.91	3	4.62	4.18 NS
Staph. hominis	7	6.93	2	3.07	
E. Coli	5	4.95	6	9.23	
Entercoccus spp	7	6.93	3	4.62	
Total	101		65		
Total infection(%)	(101/244) X 100 = 41.39		(65/235) X 100=27.66		

Table 2. Pathogens isolated from blood samples.

Blood Culture Sensitivity (C/S) Type of organism	NICU Total sample(190) Positive sample (20)		SCBU Total sample(102) Positive sample (12)	
	NO	%	NO	%
Klebsiella pneumoniae	5	2.63	5	4.90
Acinetobacter baumannii	6	3.16	5	4.90
Staph. haemolyticus	3	1.58	2	1.96
Staph. hominis	4	2.11	2	1.96
Enterococcus spp	3	1.58	---	---
Strep. a galactiae	1	0.53	---	---
Non hemolytic streptococcus	1	0.53	---	---
Total infection(%)	(20/190) X 100 = 10.53		(12/102) X 100=11.76	

Table 3. Pathogens isolated from endotracheal samples.

Endo Tracheas tube Type of organism	NICU Total sample(25) Positive sample (13)		SCBU Total sample(12) Positive sample (7)	
	NO	%	NO	%
Acinetobacter baumannii	10	40	6	50.00
Klebseilla pneumoniae	5	20	3	25.00
Staph. haemolyticus	1	4	1	8.33
Pseudomonos aeruginosa	3	12	---	---
Entercoccus coleacea 1	1	4	---	---
Entercoccus faecalis 1	1	4	---	---
Total infection	(13/25) X 100 = 52.00		(7/12) X 100=58.33	

Table –4– Biogram of organisms isolated in NICU and SCBU.

Type of organism and drugs resistance	NICU		SCBU	
	NO	%	NO	%
MRSA	2	8.70	7	38.89
Klebsiella pneumoniae (ESBL)	13	56.52	8	44.44
E. Coli (ESBL)	3	13.04	1	5.56
KP Carbapenem. resistance	5	21.74	2	11.11

8. DISCUSSION:

Babies are born without an endogenous microbial flora and rapidly become colonized with microbes encountered in the maternal genital tract and their immediate postnatal environment. Since their immature immune system is unable to provide a robust defense against virulent pathogens, neonates are at high risk of developing invasive infections if exposed to pathogenic microorganisms. Premature neonates are at especially high risk of infection because of their lack of protective maternal antibodies, underdeveloped innate immunity and their fragile, easily damaged skin.

Our study showed a relatively high infection rate in TMC (NICU and SCBU) but comparing it with other hospitals in other countries we realize that our local situation is not an extreme. Rates of infection were 41 and 28 % in Tripoli NICU and SCBU, respectively should not be regarded as average by all means. Such high numbers call for prudent and immediate attention for maximum infection control measures, especially that we now know the aetiological agents behind this dilemma. Significant pathogens isolated from NICU and SCBU respectively were A. baumannii (39.60% and 47.69%), and K. pneumonia 32.67%) and 30.76%). These pathogens commonly cause similar problems in other countries as well (Eljadba et al, 2010), basically denoting gross negligence and lack of hygiene and infections control programs.

9. RECOMMENDATIONS:

Simply, improving hand hygiene. Soap and sinks should be accessible. Alcohol- based rubs should be available at the entrance to the infant's room. Written procedures that encourage routine hand washing should exist. The use of antibiotics in the NICU should be carefully monitored. broad-spectrum antibiotics should be used until culture and sensitivity results are available.. An isolation room should be available for NICU patients. Furthermore, adequate staffing is more critical in special care units, where virulent pathogens and immunocompromised patients are more common the women bearing, Initiation of interal feeding as early as possible and promotion of the use the human milk.

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Co- integration and Causality Relationship Between Capital Goods Imports and Economic Growth of Libya During (1970 -2018)

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المستخلص:

تناقش هذه الورقة العلاقة بين واردات السلع الرأسمالية والنمو الاقتصادي في ليبيا، وقد استخدمت بيانات سلاسل زمنية سنوية خلال الفترة 1970–2018. وتم استخدام تقنية التكامل المشترك لتحديد علاقة التوازن طويلة المدى ، بين مغيرات الدراسة . وفقا لاختبارGrange ونموذج VECM، تؤكد نتائج التكامل المشترك وجود علاقة واحدة طويلة الامد بين هذه المتغيرات، وقد تم تقدير نموذج متجه تصحيح الخطأ وتحديده في جزأين، الجزء الاول هو دراسة تأثير النمو الاقتصادي على واردات السلع الرأسمالية على المدى الطويل والقصير، والجزء الثاني هو دراسة تأثير واردات السلع الرأسمالية على النمو الاقتصادي على المدى الطويل والقصير، حيث تشير النتائج الي وجود علاقة سببية كبيرة على المدى الطويل تمتد من النمو الاقتصادي إلي واردات السلع الرأسمالية وليس العكس، اما بالنسبة للعلاقة قصيرة المدى، تشير النتائج إلى وجود علاقة سببية باتجاه واحد من واردات السلع الرأسمالية الى النمو الاقتصادي ولا توجد سببية تنائية الاتجاه بين النمو الاقتصادي وواردات السلع الرأسمالية.

الكلمات المفتاحية : النمو الاقتصادي، واردات السلع الرأسمالية، التكامل المشترك، سببية قرانجر، نموذج متجه تصحيح الخطأ .

Abstract:

This paper discusses the relationship between capital goods imports and economic growth in Libya, and annual time series data was used during the period 1970-2018. And the technique of joint integration was used to determine the long-term balance relationship between the study variables. According to the Grange test and the VECM model, the results of joint integration confirm that there is one long-term relationship between these variables, and the error correction vector model has been estimated and defined in two parts, the first part is the study of the impact of economic growth on the imports of capital goods in the short and long term, and the second part is the study of the impact Capital goods imports on

economic growth in the short and long term, where the results indicate a significant causal relationship in the long run that extends running from economic growth to imports of capital goods and not the other way around. As for the short-term relationship, the results indicate a unidirectional causality relationship running from imports of goods Capitalism to Economic Growth There is no bidirectional causality relationship between economic growth and imports of capital goods.

Keywords: Economic Growth, capital goods Imports, Granger Causality, Cointegration , VECM.

1- **Introduction**

Import plays an important role in overcoming the gap between resource supply and it's demand in the economic sphere, especially in developing countries no country can produce all goods to meet production needs and thus import goods and goods from other countries . Developing countries often import capital and heavy machinery from developed countries. to create a productive growth sector that can- contribute to developing countries economic growth most developing

countries rely heavily on imports of goods and services that can be added and cannot be produced locally or at a cheaper price. Libya is also a developing countries import country of heavy machinery from developed countries, where empirical studies show that import, such as export, is an important determinant of productivity. In addition, the positive effects of imports are not only due to the competitive pressure resulting from the importation of consumer goods, but also to the technological transfer of capital goods imported from developed countries that can stimulate economic growth (directly or indirectly).

The analysis of the relationship between economic growth and imports of capital goods in the Libyan economy helps to better understand the potential contribution such as the contribution of exports to economic growth , causal relationship between total imports and economic growth was limited and mixed . while no study had yet examined the causal relationship between capital goods imports and economic growth of Libya's economic , Therefore, this study will fill this literature gap and reconsider the causal relationship between capital goods imports and economic growth in Libya , and Detecting various causal effects that can have an effect Between capital goods imports and economic growth In this study.

1.1 Statement Problem

Previous empirical studies on the relationship between trade and economic growth in the economies of developing and developed countries have always identified trade as exports. Similarly, these studies focus only on the relationship between exports and economic growth and ignore the role of imports in economic growth. However, the almost complete disregard for imports remains astonishing, as intuition and economic theory show that imports can be an important channel for technology transfer, productivity growth, and economic growth. Such neglect is also unfortunate because it helps to promote deep regional bias against imports because the theoretical relationship between imports and economic growth is more complex than exports and growth. Many researchers have conducted studies on the Libyan economy. However, most of these studies are based on descriptive statistics of economic data. Researchers are limited to conducting empirical work using macroeconomic estimates and trade variables. There are few attempts to apply simple econometric analysis to data., Therefore, this study attempts to promote a more balanced and comprehensive approach to analyzing the relationship between capital goods imports and economic growth in the Libyan economy using Modern econometric analysis, which in turn contributes to increasing the empirical studies on this relationship in the literature of development and economic growth.

1.2 Hypotheses Of The Study

The paper draws on five hypotheses to test causation and common integration between the capital goods imports and economic growth of Libya as following :

H_{01} : there is a common integration between capital goods imports and the economic growth .

H_{02} : there is long-run relationship running from the economic growth to the capital goods imports .

H_{03} : There is a long-term relationship running from the capital goods imports to the economic growth .

H_{04} : There is a short-term significant causality relationship running from the economic growth to the capital goods imports .

H_{05} : There is a short-term significant causality relationship running from capital goods imports to economic growth .

H_{06} : There is bidirectional significant causality relationship between the capital goods imports and the economic growth.

1.3 Objectives Of the Study

The main objective of this study is to highlight the importance of the imports sector in the economy of Libya this study provides evidence of causality between imports and economic growth in long and short-term especially capital goods imports.

2. Literate Review

Theoretical models have shown the positive and negative effects of economic growth on imports Economic growth can be determined by increasing capital imports. Although it is emphasized that import activities can stimulate economic growth (directly or indirectly), the idea that expanding the import of capital goods prior to economic growth is the subject of The most debate in the literature of economic growth and development, It is believed that increased economic activity stimulates imports through consumption. On the other hand, economic growth improves the efficiency of imported alternative companies and leads to an increase in the domestic market, changes the quality of manufacturing and economic structure of modern economic activity and can be considered as a source of positive external operations for others Sectors. Therefore, it will increase potential growth in the economy and thus contribute to economic development. Production can also be seen as an essential means of job creation, poverty reduction and the promotion of economic development and growth policies.

The purpose of this paper is to examine the causal relationship between capital goods imports and economic growth in the Libyan economy during the period 1970-2018. Unlike previous studies, which most of it studied the causal relationship between total imports and economic growth only , and does not focuses on capital goods imports and its relation to economic growth , the most important of these studies are these Literary Studies following :

The study of (Islam, F., Muhammad Adnan Hye, Q., & Shahbaz, M. (2012) applied Auto-Regressive Distributed Lags (ARDL) to cointegration to explore long-run relation; and Granger procedure within Vector Error Correction Model (VECM) to test direction of causality between imports and economic growth for a sample Countries ,, of ten each from high; upper-middle; lower middle and low-

income–nations. they found there is a long-run bidirectional causality between imports and economic growth in high-income nations except Japan.

The study of (Ali, G., & Li, Z. (2016) student the role of imports and its determinants in economic growth in Pakistan applying ARDL Bound testing approach. This study found optimistic and noteworthy effect of imports and its determinants, and other trade policy variables too isupportive of Pakistan economic growth.

The study of (Fukushige, S. S. M. (2007) investigated the causal relationships among exports, imports, and economic growth in North Korea by using time series data for the period between 1964 and 2004. The empirical results show that there was Granger causality from imports to GNP in the first half of the period. However, there was a causal relationship from GNP to imports in the second half of the period. This implies that economic growth stimulates imports in North Korea. therefor The North Korean economy escaped many economic crises that .at the end The findings revealed import-led to economic growth in North Korea.

The main objective of study (Rufus, M. M.(2015) was to investigate the relationship between exports, imports and economic growth in Kenya. for the period 1960 to 2010 , Correlation analysis was employed. The findings revealed that exports led to economic growth. There was a strong positive or direct relationship between the exports and the economic growth. However, the correlation coefficient exports and economic growth compared to the correlation between the imports and economic growth was slightly small. For this case, it would mean that imports had a greater impact on economic development in Kenya. Also, the findings indicated that there was a strong positive or direct relationship between the imports and the economic growth in the country. It was easy to conclude that that the association is very strong as compared to exports. This may be attributed by the huge quantity of imports capital goods main in the agriculture, industry and transport sector in Kenya during the same period.

This study of (Uğur, A. (2008) attempted to analyze empirically the relationship between imports and economic growth in Turkey. In order to make an elaborate examine of the import-economic growth relationship, import was analyzed to its categories and then a multivariate VAR analys was used to determine the relationship. Empirical results derived from IRFs and VDCs show that while there is a bidirectional relationship between GDP and investment goods

import and raw materials import, there is a unidirectional relationship between GDP and consumption goods.

The study of (Lee, J. W. (1995). presented an endogenous growth model of an open economy in which the growth rate of income is higher if foreign capital goods are used relatively more than domestic capital goods for the production of capital stock. Empirical results, using cross data for The Developing Countries during period 1960-1985 ,the Results confirm that the ratio of imported to domestically produced capital goods in the composition of investment has a significant positive effect on per capita income growth s across countries, in particular, in developing countries. Hence, the composition of investment in addition to the capital goods is highlighted as an important determinant of economic growth..

This study of (Habib, G ; Abderrahmane, T., & Lakhdar, A. 2014) aimed to measure the impact of imports on the economic growth in Algeria, basing on time series from 1990 up to 2010, the study showed that Algeria has proceeded to liberalize its trade since 1990. It indicated the Algerian imports' tendency to EU countries and the countries of North America. The study indicated also the importance of imports in the Algerian economy since the latter is yield. The study has confirmed the contribution of each of the raw materials and industrial supplies positively on economic growth, which confirms Algeria's adoption on imports in the productive sector to the outside world (where the contribution of each unit of the raw materials and industrial supplies was 22.21 and 5.97 in Gross Domestic Product GDP), and through this study, Finally, the study indicated that imports play a key role on growth economic through the impact of capital goods imports on growth .

The study of (Fernández-Núñez, T; Maesso, M., & Márquez, M. A 2016) Theories of endogenous growth emphasize that imports of inputs (intermediate and capital goods) and foreign direct investment [FDI] may play a key role on economic growth as a means of international diffusion of technology and knowledge. Nevertheless studies which analyze together the importance of both imported inputs and FDI for economic growth are less frequent. also this study contributed for two goal The first aim is to examine the simultaneous impact of the different categories of imports by end-use and FDI on the economic growth in 53 countries during 1996-2010. The second target is to capture the different responses in the economic growth derived of the consideration of advanced and

emerging economies. results reveal that imports of inputs (intermediate and capital goods) play a key role on growth economic while FDI is not significant.

The study of (EbrahimiI ; Nasser 2017) analyzed the relationship of imports and economic growth in Iran using unsystematic cointegration methods and neural networks and to compare them with each other. The data used in this study are the real gross domestic product (GDP) and the total capital goods imports of Iran during the years 1961 to 2010. In this study, the concerned time series were tested by unit root testing. Then the data were examined and the results were analyzed using an autoregressive distributed lag modeling, error correction model, and maximum likelihood method of Johansen-Julius. The statistical and estimated processes of the present study were carried out and using artificial neural networks were also modeled . The findings showed that no cointegration relationship is supported between GDP and imports when the real GDP is a dependent variable and total import is an independent variable. However, the existence of cointegration relationship between total import and real GDP is supported when the total import is a dependent variable and the GDP is an independent variable shows a reliable result. The study of EbrahimiI, Nasser (2017) analyzed the relationship of imports and economic growth in Iran using systematic and unsystematic cointegration methods and neural networks and to compare them with each other. The data used in this study are the real gross domestic product (GDP) and the total capital imports of Iran during the years 1961 to 2010. In this study, the concerned time series were tested by unit root testing. Then the data were examined and the results were analyzed using an autoregressive distributed lag modeling, error correction model, and maximum likelihood method of Johansen-Julius. The statistical and estimated processes of the present study were carried out and using artificial neural networks were also modeled . The findings showed that no cointegration relationship is supported between GDP and imports when the real GDP is a dependent variable and total import is an independent variable. However, the existence of cointegration relationship between total import and real GDP is supported when the total import is a dependent variable and the GDP is an independent variable shows a reliable result.

(Awokuse 2007, Kim et al. 2007; Rahman Shahbaz 2011). Shahbaz and colleagues. 2012; Awokuse 2007) They analyzed Turkish imports in different categories, which shows that the scientific process between imports and growth depends on the type of goods. Specifically, they used for Granger approach to the

test of causation . from the Results They concluded that there is a bi-directional reason between economic growth and overall imports.

Chen, Jefferson ; Singh 1992 and Zhao, X ; & Wu, Y. 2007) have studied experimentally the transition to a market economy and the import-led growth hypothesis presented by (Narayan, P. K. 2005). suggests an important source of economic growth. According to the model that generates the effects on economic in that study growth , The study reached to these results as following: First, the import of capital goods develops industrial infrastructure, and thus promotes economic growth. Second, that the quantity of capital goods that a country can import limits the rate of economic growth that can be achieved, thirdly , that the quantity of capital goods that a country can import limits the rate of economic growth that can be achieved.

(Lawrence ,1999) shows empirically that import competition brought about growth in US industries. is that imports contributed to total factor productivity growth for manufacturing industries on the panel data set. And therefore the influence on US economic growth.

Augier, P ; Cadot, O & Dovis, M. (2013) found that in the Brazilian manufacturing sector, the competitive effects of total imports on competition are large even though the also effect of capital imports on labor productivity is small .

3. Data and Methodology

3-1 . Data

The data used for this study are based on data on the Libyan economic time series in US dollars covering the period from 1970 to 2018. The two economic variables included in this study are capital goods imports and real GDP, a measure of economic growth. Data were obtained from the Libyan Central Bank and some local statistics. Both of these series are converted to a record format(natural logarithm) , Changing the registry can reduce the problem of heterogeneity because it presses the scale at which variables are measured, reducing the decimal difference between two values to a two-level difference (Gujarati, D. N. 2009). The time series in this study analyzes the variables as follows:

LNGDP = Economic Growth.

LNCAPIMT = Capital Goods Imports.

The "LN" prefix refers to the natural logarithm of the time series in question, and "D" refers to the relevant time difference. All economic estimates were made in this paper using observations wearing soft, (Eviews Version 10 and stata Version 12).

In this study we will examine causal relationship between capital goods imports and economic growth using annual time series for Libyan economic for the same Previous period , This study used two models for the empirical analysis of the causality between The two economic variables included in this study :

First model the analysis of the of capital goods imports as a dependent variable and the economic growth as an independent variable, which requires the use of the model (VECM) (vector error correction model) or model (VAR) (Vector Auto Regression model) to analyze the significant long-term and short-term causal relationship from economic growth to capital goods imports .The second model Analysis of economic growth as a dependent variable and the capital goods imports as an independent variable which also requires the use of the model (VECM) or the model (VAR) to analyze the significant long-term and short-term causal relationship from capital goods imports to economic growth.

First model : analysis of the of capital goods imports as a dependent variable and the economic growth as an independent variable, which requires the use of the model (VECM) (vector error correction model) or model (VAR) (Vector Auto Regression model) to analyze the significant long-term and short-term causal relationship from economic growth to capital goods imports.

Second model : Analysis of economic growth as a dependent variable and the capital goods imports as an independent variable which also requires the use of the model (VECM) or the model (VAR) to analyze the significant long-term and short-term causal relationship from capital goods imports to economic growth.

At first , we will determinate the degree of integration of each variable. If the variables are all integrated in level, we apply an estimate based on a linear regression. However, if the variables are integrated in the first difference we will look into the cointegration between the variables. In this step, if the cointegration test denotes the absence of cointegration relationship, we will use the model (

VAR) . but if the cointegration test the presence of a cointegration relation between the different variables studied, the model (VECM) will be applied.

3-2 Testing for stationarity

Before testing the ***Johansen*** integration and Ganger relationship, the econometric methodology needs to examine the installation process for each individual time series. This study uses the Dickey-Fuller (ADF) and Phillips-Perron (p.p) sterilizers to examine the data series stability of the study variables.

3 .2.1 unit roots test

The next step is to show how stationary can be tested. Many empirical papers concerning cointegration start with using either ADF test or (p.p) test for stationarity of the economic data [Kasa (1992), Richards (1995).

We will test whether there are one or more unit roots in the data - whether the individual series are I(1), the performing such tests at the beginning of any analysis is necessary because of the possibility of getting misleading results if non-stationary variables are included. There are various ways to test for stationarity, but the most commonly used test is the Dickey-Fuller test ADF (Dickey and Fuller, 1979).

3 .2.2 Phillips and Perron (p.p) test

The Phillips and Perron (1988) test is a generalisation of the ADF test procedure that allows for weak assumptions regarding the distribution of errors. This study employs the Phillips-Perron test to test for the existence of unit roots in the variables. The advantage of the Phillips-Perron test is that it allows for the effect of serial correlation and heteroskedasticity .There is evidence that the Phillips-Perron test Supports the augmented Dickey-Fuller test (Davidson, R., & MacKinnon, J. G. 1993) If the variables are found to be I(1) stationary.

3.3 Cointegration Analysis

The concept of joint integration was developed by Engle and Granger. If two or more strings are the same, but the linear group is constant, then the chain is said to be interrelated.

In general, two methods are widely applied to test integration. One is the Engle-Granger test, which is used only in one series. The alternative approach is Johansen's fitting for a multivariate case. The Johansson setting allows for the testing of long-term equilibrium assumptions between variables. In order to investigate the relationship between capital goods imports and economic growth, Johansson's integration technique is used in this study.

1.3.3 Johansen and Juselius Cointegration Test

procedures uses two tests to determine the number of cointegration vectors: the Maximum Eigenvalue test and the Trace test. The Maximum Eigenvalue statistic tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations for r = 0, 1, 2…n-1. This test statistics are computed as :

$$LR_{\max\, r}(r/n+1) = -T * \log(1-\hat{\lambda})$$

Where is the Maximum Eigenvalue and T is the sample size. Trace statistics investigate the null hypothesis of r cointegrating relations against the alternative of n cointegrating relations, where n is the number of variables in the system for r = 0, 1, 2…n-1. Its equation is computed according to the following formula:

$$LR_{\mathrm{tr}\, r}(r/n) = -T * \sum_{i=r+1}^{n} \log(1-\hat{\lambda})$$

In some cases Trace and Maximum Eigenvalue statistics may yield different results and [$\hat{\lambda}$] indicates hat in this case the results of trace test should be preferred (Johansen, S., & Juselius, K. (1990).

4 . Lag length selection

Before the Johansen test, the length of the delay and the determination of the inevitable elements must be determined first.

The choice of the delay period depends mainly on the information criteria According (Bozdogan ; Hamparsum ,1987) there are four types of criteria for the length of underdevelopment, Standard Bayezian Schwartz (SBC), Standard Akaike (AIC), and) Hannah Cowen Standard (Headquarters

Probability Ratio Test (LR) .The best model to determine the optimal delay length is the model that works to increase the LR, or reduce the previous information standards. Compared to the LR test.

5. Vector Error Correction Model (VECM)

When the variables are and cointegrated, the suitable method to examine the causality relationship is the Vector Error Correction model. The VECM is equivalent to VAR model in first differences with only one difference: the addition of a vector of cointegrating residuals (Liu, X., Shu, C., & Sinclair, P. (2009). Therefore, the VECM is represented as follows :

$$\Delta LNCAPIMT_t = \alpha 0 + (LNCAPIMT_{t-1} - \gamma\, LNGDP_{t-1}) + \Sigma\, \alpha 1i \Delta LNCAPIMT_{t-i} + \Sigma\, \alpha 1i \Delta LNGDP_{t-i} + v1t \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\Delta LNGDP_t = \beta 0 + \delta 2\,(LNCAPIMT_{t-1} - \gamma\, LNGDP_{t-1}) + \Sigma\, \beta 1i \Delta LNGDP_{t-i} + \Sigma\, \beta 2i \Delta LNGDP_{t-i} + v2t \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where (LNCAPIMT) and (LNGDP) refer to Capital Goods Imports and economic Growth , respectively, the (LNCAPIMTt−1 − γLNGDPt−1) is an error correction term taken from the cointegrating equation in which (Δ) refers to the first difference operator. (δ1, δ2) represent the error coefficients which capture the adjustments of both (ΔLNCAPIMT) and (ΔLNGDP) to long-run equilibrium. In addition, the coefficients on (ΔLNCAPIMTt ,ΔLNGDPt), which are (α1i , α2i , β1i and β2i), are expected to capture the short-term dynamics of the model. For that reason, inferences regarding the causality between Capital Goods Imports and economic Growth can be made as follows (LNCAPIMT) causes (LNGDP) if either (δ1) is statistically significant (the long-run causality) or the (α2i) s are jointly significant (short-run causality). Likewise, :

(LNCAPIMT) causes (LNGDPt) if (δ2), is statistically significant (the long-run causality) or the (β1i) s are jointly significant (short-run causality). For (δ1 = δ2 = 0) which implies no long-run equilibrium relationship between Capital Goods Imports and economic Growth.

5-1 .Granger-causality test Under the Vector Error Correction (VEC) Model

According to the equations of VECM (1) and (2), the causality between the variable (LNGDPt−1) and a variable (LNCAPIMTt−1) can be made as follows.

The variable (LNGDP $_{t-1}$) causes a variable (LNCAPIMT$_{t-1}$) in two cases; in the first case ($\delta 1$) is statistically significant (the long-run causality relationship) while in the second case the ($\alpha 2i$) are jointly significant (short-run causality relationship). Likewise, the variable (LNCAPIMT $_{t-1}$) causes (LNGDP $_{t-1}$) if either ($\delta 2$) is statistically significant (the long-run causality relationship) or the ($\beta 1i$) are jointly significant (short-run causality relationship). For ($\delta 1 = \delta 2 = 0$) which means there is no long–run equilibrium relationship between (LNCAPIMT $_{t-1}$) and (LNGDP $_{t-1}$). From equations (1) and (2), it is clear that the causality test in the VECM framework reduces to the Standard Granger-causality test in the VAR framework (Hall, S., & Asteriou, D. (2011).

4. Empirical results and discussion

4,1 unit roots tests

The Figure 1 and 3 depicts that both variables, LNGDP and LNCAPIMT, are not constant at their levels. while the Figure 2 and 4 depicts that both variables , become constant after the first difference DLNGDP and DLNCAPIMT.

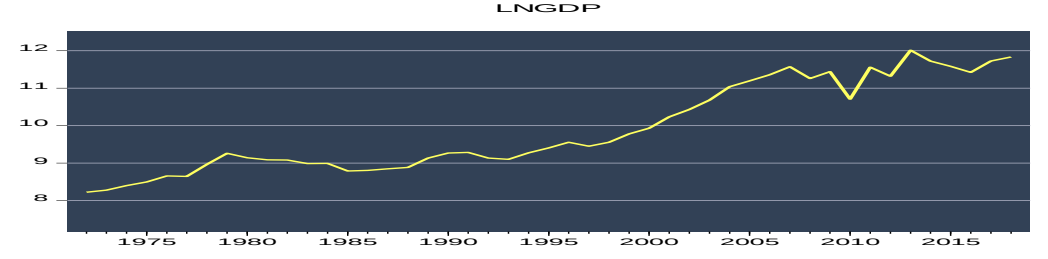

Figure 1

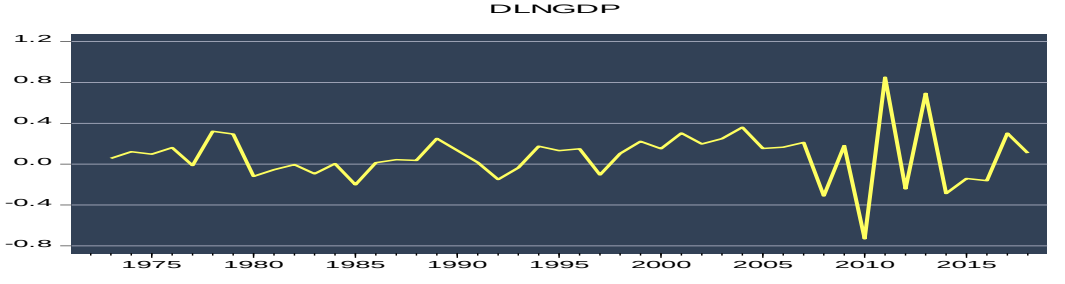

Figure 2

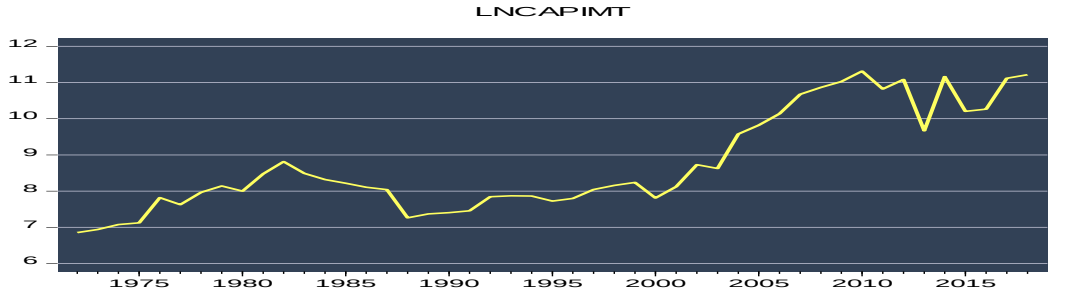

Figure 3

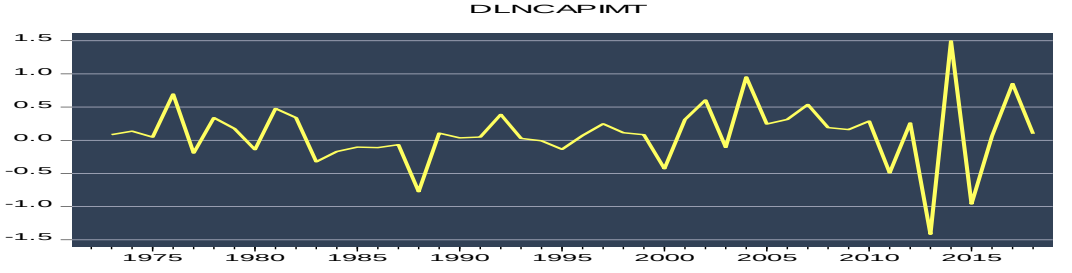

Figure 4

Table 1. Results of (ADF) Unit root test for level and first differences

	critical value		1st diffrenece	Leve	level	
		ADF test	ADF test	1%	5%	10%
LNGDP	Intercept	0.35004	3.70464	-3.18588	-2.92097	-2.60306
	Constant and Trend	-2.26773	-3.67500	-3.18091	-3.51552	-3.18825
	Non	1.79572	-3.11614	-2.6657	-1.94949	-1.61213
LNCAPIT	Intercept	1.77665	8.56492	-3.58474	-2.92814	2.60225
	Constant and Trend	-2.81616	8.56350	-4.170583	-3.51074	-3.18512
	Non	1.68807	8.07165	-2.61736	1.94831	-1.69222

Table 2 . Results of (PP) Phillips-Perron test for level and first differences*

	level	1st diffrenece	Leve	critical value		
		pp test	pp test	1%	5%	10%
LNGDP	Intercept	-0.2735	9.5208	-3.6811		-2.6014
	Constant and Trend	-2.1949	9.4389	-3.9107		3.1855
	Non	3.5714	8.4423	-1.92481		-1.6123
LNCAPIT	Intercept	-1.7323	-11.4602	3.5647	-.9281	2.6022
	Constant and Trend	-3.2818	17.2844	-4.1756	-.5130	-3.3861
	Non	-0.9374	9.5402	-2.5161	1.9181	1.6132

The (ADF) and (PP) results indicate that both variables, LNGDP and LNCAPIMT, are not fixed at their levels. In other words, they have a root unit. We then repeated the unit root test for the first difference of the two variables. The results indicate that LNGDP and LNCAPIMT become constant after the first difference, because the calculated values (in absolute value) are greater than the critical values (absolute value) at 1%, 5%, 10% of importance as in Table (1 and 2) .

4.2 Lag order selection

To ensure proper specification of our models , it is necessary to determine the optimum lags lengths (p), which are determined using five criterions: table (2) states that SIC suggests the use of (1) delay in the system, also AIC suggests delay (1) , SIC is best test for medium samples (Lütkepohl, H., & Poskitt, D. S. 1991), while at the same time, deceleration 1 is the smallest possible gap, Multivariate residues are natural and homogenous, with no evidence of serial correlation. Therefore, one arrears (p=1) are approved at the level .

Table 3 . Lag Order Selection Criteria for LNGDP LNCAPIMT

Lag	LogL	LR	FPE	AI	S	HQ
0	-94.67232	NA	0.307478			4.526595
1	-10.59404		0.007421	0.521445*	1.017565*	0.862440
2	-6.821972	6.666905	0.007512		1.191999	0.933458
3	0.935388	12.98907*		0.607656	1.181070	0.819114
4	6.788931	9.256766			1.258692	0.793319*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

4.3 Johansen Cointegration Test

Johansson's method of cointegration is based on two levels of testing: impact testing and eigenvalue testing. , as in Table NO (4) and (5) .

Table 4 . Johansen Co-integration Test Statistics Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.317882	17.22741	15.49471	0.0272
At most 1	0.000279	0.012537	3.841466	0.9106

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

denotes rejection of the hypothesis at the 0.05 leve

**MacKinnon-Haug-Michelis (1999) p-values

Table: 5 Unrestricted Cointegration RankTest (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.317882	17.21487	14.26460	0.0166
At most 1	0.000279	0.012537	3.841466	0.9106

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 leve

**MacKinnon-Haug-Michelis (1999) p-values

The results of table 4 and 5 indicate the results of the co-integration test. There are two test statistics for cointegration , the Trace test and Maximum Eigen value test. The Trace-Statistic value is shown to be greater than the critical values at the 5% levels. Therefore, we reject the null hypothesis of no co-integrated equation among the variables. Thus, we conclude that there is one co-integrated equation among the variables. The results of Maximum Eigen value test statistics also Show same here. Finally, we can say that there is one cointegration relationship , so the error-correction model can be retained.

5-The Results of Estimation VECM

Once the variables are fixed in order 1, and there is a 1 cointegrating cooperative relationship , the econometric ruler instructs us to use the error correction model. The estimate of the relative error correction model is determined in two parts , the first part is to study the impact of economic growth on capital goods imports in long-term and short term the second part is to study the impact of capital goods imports on economic growth in long-term and short term .

5. 1 First part

In our studies , the objective of an estimate an error correction (ECM) model is to determine the effect of economic growth on capital goods imports also the effect of capital goods imports on economic growth (both short-term and long-term), the first part of the VECM estimation show the effect of economic growth on capital goods imports as table 6 .

Table:6 Vector Error Correction Estimates , LNCAPIMT= F (LNGDP)

Cointegrating Eq:	CointEq1
LNCAPIMT(-1)	1.000000
LNGDP(-1)	-0.891403 (0.07872) [-11.3239]
C	1.248748

From table 6 it can be formally d deriving the long-run cointegration equation (3) between capital goods imports and economic growth as following:

1.248748 - 0.891403 LNGDP ……..... (3)= LNCAPIMT

Equation 3 refers to the VECM equation, which demonstrates that there is a significant negative long-run relationship between the capital goods imports LNCAPIMT and the economic growth LNGDP , this means that the economic growth impacts negatively on the capital goods imports thus decreasing economic growth will lead to increasing in the capital goods imports about 89% , the negative relationship between capital goods imports and economic growth can be explained by increasing the share of imports of capital goods in a large part of the GDP in Libyan economy , as support for locally produced goods (Herzer et al., 2006). Also this category of imports also subject to excess price fluctuations Which does not provide knowledge about that Myrdal, 1957) , but this considered insufficient to explain the direction of the long and short relationship between the capital goods imports LNCAPIMT and the economic growth LNGDP.

5.2 Short-Run Causality Relationship under the VECM Running from economic growth to capital goods imports .

we used error correction terms equation 4 , D (LNCAPIMT) as estimated to (VECM) equation NO 4 , in order to firstly estimate the probability values, and secondly, to know the direction of the long and short-run relationship from the economic growth to capital goods imports as in tables 7 and 8 .

Estimated Model Equation

Equation *D(LNCAPIMT) = C(1)*(LNCAPIMT(-1) - 0.891402837031*LNGDP(-1) + 1.24874773162) + C(2)*D(LNCAPIMT(-1)) + C(3)*D(LNCAPIMT(-2)) + C(4)*D(LNCAPIMT(-3)) + C(5)*D(LNCAPIMT(-4)) + C(6)*D(LNCAPIMT(-5))*

*+ C(7)*D(LNGDP(-1)) + C(8)*D(LNGDP(-2)) + C(9)*D(LNGDP(-3)) + C(10)*D(LNGDP(-4)) + C(11)*D(LNGDP(-5)) + C(12) …… (4)*

At this stage, from the estimation of the Vector Error Correction Model, we applies the VECM using the equation : D (LNCAPIMT) as a dependent variable to see if an independent variable economic growth is sufficiently significant to explain the capital goods imports as dependent variable in table 7 . we also used the Wald test to ascertain the short-run relationship between them .

Table :7 Results of Vector Error Correction Model Using Equation D(LNCAPIMT)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.431000	0.199204	-2.163616	0.0389
C(2)	0.108632	0.193114	0.562529	0.5781
C(3)	-0.428976	0.188081	-2.280800	0.0301
C(4)	0.191760	0.150292	1.275917	0.2121
C(5)	-0.147116	0.150679	-0.976356	0.3370
C(6)	0.309705	0.171190	1.809128	0.0808
C(7)	-0.213462	0.327709	-0.651377	0.5199
C(8)	-0.502099	0.303600	-1.653815	0.1090
C(9)	0.391738	0.276119	1.418728	0.1666
C(10)	-0.470623	0.303248	-1.551940	0.1315
C(11)	0.180732	0.310981	0.581167	0.5656
C(12)	0.103038	0.082698	1.245954	0.2228

F statistic=5.2109 R-squared= 0.6640

Dependent Variable: D(LNGDP)
Method: Least Squares (Gauss-Newton / Marquardt steps)

The long-run causality relationship exists if the sign of the C (1) is negative, significant and the probability value is less than 5%. Consequently, it can be said that there is a negative long relationship running from the economic growth to the capital goods imports because the value of C (1) is negative - .431000 and the probability value is significant; less than 5%. Furthermore, from the C (1), it can determine the speed of adjustment, which equals 43% .

Also from Table 7 , the F-statistic value is 6.2109 which is considered highly significant equal zero at the 5% level, but does not mean the existence of short-run relationship running from economic growth to capital imports , which will be tested by applying the Wald test.

The three result is R-Squared, it can determine the percentage of the change in the D(LNCAPIMT) as dependent variable, which is explained by the economic growth as an independent variable. The R-Squared equals .6640 that means just 66.40 % of the change in the capital goods imports can be explained by the economic growth whereas the 33.60 % is unexplained, which belongs to the variables not involved in this study .

after we had employed the VECM using the equation (4): *D(LNCAPIMT)*, The next step is applies the Wald test to detect if there was any the short-run causality relationship running from the economic growth to capital goods imports as shown in table 8.

Table 8. Wald test using equation *: D(LNCAPIMT*

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	1.378432	(5, 29)	0.2613
Chi-square	6.892159	5	0.2288

The estimation of the Wald test, as in table 8, demonstrates that it can accept the null hypotheses

Null Hypothesis **:** C(7)*D(LNGDP(-1)) + C(8)*D(LNGDP(-2)) + C(9)*D(LNGDP(-3)) + C(10)*D(LNGDP(-4)) + C(11)*D(LNGDP(-5)=0

This is because the probability value of Chi-square is 0.2288 as in table 8 which is more than 5%. This implies that there is no short-run causality relationship running from economic growth to capital goods imports.

Based on the above analysis, to estimate VECM using equation: (LNCAPIMT) as a dependent variable, at the end it can be said that there is a long-term negative causal relationship extending from economic growth to capital imports , whereas there is no short--term causal relationship running from economic growth to capital goods imports .

5. 2 **second part:**

Likewise, we can apply the VECM again, but this time using the Equation D (LNGDP) as the dependent variable, rather than D (LNCAPIMT) , to know:

firstly , is the capital goods imports was sufficiently significant to explain the changes that occurred in economic growth as the dependent variable.

Secondly, is there long and the short-run relationships from the capital goods imports to the economic growth as in table 10 . From this table, three issues can be detected.

The first issue is that the type of the long- run relationship is a negative or the positive, which runs from the capital goods imports to the economic growth.

The second issue is the possibility of applying the Wald test to know if there was short causality relationship running from the capital goods imports to the economic growth.

The third issue was determining the percentage of the changes in the economic growth which can be explained by the capital goods imports movements as an independent variable. table 10 shows that .

The second part of the VECM estimate is showen in Table 11. it Explain a long-term causal relationship and short-term causal relationship from capital goods imports to economic growth.

5.2.1.Short-Run Causality Relationship under the VECM Running from capital goods imports to economic growth.

From table 9 it can be formally deriving the normalized long-run cointegration equation between economic growth and capital goods imports.

Table:9 Vector Error Correction Estimates , LNGDP, = F (LNCAPIMT)

Cointegrating Eq:	CointEq1
LNGDP(-1)	1.000000
LNCAPIMT(-1)	-1.121827 (0.09836) [-11.4051]
C	-1.400879

1.21827- 1.400878 LNCAPIM …….. (5) = - LNGDP

Equation 5 refers to the VECM equation, which demonstrates that there is a significant negative long-run relationship between economic growth and capital goods imports .

Equation 6 shows the results of the estimation of short- and long-term error correction coefficients between economic growth and capital goods imports at the following estimate :

Equation ***: D****(LNGDP) = C(1)*(LNGDP(-1) - 1.12182725751*LNCAPIMT(-1) - 1.40087924308) + C(2)*D(LNGDP(-1)) + C(3)*D(LNGDP(-2)) + C(4)*D(LNGDP(-3)) + C(5)*D(LNGDP(-4)) + C(6)*D(LNGDP(-5)) + C(7)*D(LNCAPIMT(-1)) + C(8)*D(LNCAPIMT(-2)) + C(9)*D(LNCAPIMT(-3)) + C(10)*D(LNCAPIMT(-4)) + C(11)*D(LNCAPIMT(-5)) + C(12)* ***……..****(6)*

From table 10 it can be said that there is no a negative long relationship running from the capital goods imports to the economic growth because the value of C (1) is not negative .211167 and the probability value is significant; more than 5%. Furthermore, from the C (1), it can determine the speed of adjustment, which equals 21 % .

From Table 10 , the F-statistic value is 2.582431 which is considered significant equal zero at the 5% level, that mean the existence of short-run relationship running from the capital goods imports to the economic growth , which will be tested by applying the Wald test .

Table :10 Results of Vector Error Correction Model Using Equation D(*LNGDP*)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.211167	0.149164	1.415673	0.1675
C(2)	-0.491154	0.275284	-1.784174	0.0849
C(3)	0.186623	0.255032	0.731764	0.4702
C(4)	-0.530077	0.231947	-2.285340	0.0298
C(5)	-0.483759	0.254736	-1.899063	0.0675
C(6)	0.100798	0.261232	0.385855	0.7024
C(7)	0.243594	0.162221	1.501622	0.1440
C(8)	0.211656	0.157993	1.339655	0.1908
C(9)	0.130437	0.126249	1.033177	0.3101
C(10)	-0.176082	0.126574	-1.391142	0.1748
C(11)	-0.076112	0.143804	-0.529278	0.6006
C(12)	0.150601	0.069469	2.167891	0.0385

F statistic*= 2.582431* ***R-squared****= 0.494833*

Dependent Variable: D(LNGDP)
Method: Least Squares (Gauss-Newton / Marquardt steps)

From R-Squared, it can be determined that the percentage of the changes in the economic growth , which is explained by the capital goods imports as an independent variable. The R-Squared equals 0.494833 that means just 49.4833 % of the economic growth that can be explained by changes in the capital goods

imports while the 50.5167 % is unexplained, which belongs to the variables not included in the this study.

Likewise, after this, we employed the VECM using the equation; D (LNGDP) as the dependent variable, rather than the Equation D (LNCAPIMT). we can now employ the Wald test under the VECM using the equation D(LNGDP) as the dependent variable to test if there was a short-run causality relationship running from capital goods imports to economic growth. the table 12 shows that the Wald test accepts the null hypothesis:

Null Hypothesis: C(7)=C(8)=C(9)=C(10)=C(11)=0
Null Hypothesis : C(7)*D(LNCAPIMT(-1)) + C(8)*D(LNCAPIMT(-2)) + C(9)*D(LNCAPIMT(-3)) + C(10)*D(LNCAPIMT(-4)) + C(11)*D(LNCAPIMT(-5) =**0**

Table 11: Wald test using equation *: D(LNGDP)*

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.970971	(5, 29)	0.0073
Chi-square	19.85485	5	0.0013

from the table 11, the probability value of the Chi-square is 0.0013 i, which is less than 5%. This implies that there is short-run causality relationship from capital goods imports to economic growth .

According to the results of the VECM using the Equation D(LNGDP) as the dependent variable, there was no a long-run causality but there is a short-run causality relationship running from capital goods imports to economic growth.

To confirm the previous results in respect to the short-run causality relationship between economic growth and capital goods imports in the part one and two . We applied the Pairwise Granger causality test using the first difference series of the previous variables , both variables are integrated of order one, I~(1) , the results as in the table 12.

Table 12: Pairwise Granger Causality Test Results for the European Union

Null Hypothesis:	Obs	F-Statistic	Prob.
LNCAPIMT does not Granger Cause LNGDP	45	0.34702	0.7089
LNGDP does not Granger Cause LNCAPIMT		8.61659	0.0008

from table 12 It can be seen that there is no a short-run Granger-causality relationship from economic growth to capital goods imports one lag , because the probability value (0.0008) in this case for are less than 5% , but there is a short-run Granger-causality relationship from capital goods imports to economic growth one lag, because the probability value (0.7089) more than 5% . this result confirms the result obtained from the Wald test application in the first and second part of this study .

6 . CONCLUSION

The purpose of this study is to determine the relationship between capital goods imports and the economic growth of the Libyan economy in the period 1970-2018. The Johansen test, the VECM model and the Granger Causality tests were used to examine the Causality relationship between capital goods imports and economic growth in the long-term and short-term . According to our empirical analysis, Dickey-Fuller (ADF) and Phillip Person (pp) showed that both economic growth and capital goods imports were not fixed in the series, while they were fixed in the first series of differences. Thus, all variables were treated as integrated in the results of a single order of cointegration of Johansen test. which indicate that There is evidence of a single relationship between economic growth and capital goods imports, means that economic growth and capital goods imports are moving together in a long-term relationship. Therefore, it can be said that the first objective of this study was achieved.

While the causal relationship was examined by applying the Granger causality test under VECM, this study also applied the Wald test in the VECM model, in order to verify the causal presence in the short-term between variables in this study , according to the overall study aim, and hypotheses. The study confirmed the that there is a common integration between capital goods imports and economic growth , there is long-run relationship running from the economic growth to the capital goods imports ,there is a short-term significant causality relationship from imports goods capital to economic growth . and there is no

bidirectional significant causality relationship between capital goods imports and economic growth . The results of the Granger Causality (Pair-Wise) test supported the earlier hypothesizes . At the end we Recommend that the Libyan economy need to carry out economic reform policies on different fronts; mainly by liberalizing exchange rates, interests rates, pricing policies, opening up domestic markets , rationalizing government expenditure, reforming monetary and taxation systems, and high use the capital goods imports designed to promote the economic growth in the short-run , While not relying solely on capital goods imports alone in economic development programs of the Libyan economy in the long-run.

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IMPROVING THE PERFORMANCE OF (HgCdTe) PHOTODETECTORS OF INFRARED SEARCH AND TRACK SYSTEMS FOR (3-5 µm) BAND

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المستخلص :

يتطلب تصميم كواشف الأشعة تحت الحمراء بكفاءة عالية والتي تستخدم في أنظمة كشف وتتبع الأشعة تحت الحمراء (IRST) دراسة عدة متغيرات (بارامترات) و تحسينها. و قد تم اختيار الكاشف ($Hg_{1-xcd}Cd_{xcd}Te$) حيث يعتبر هذا الكاشف الأكثر شيوعا و ملائمة في تطبيقات هذه الأنظمة في النافذة (3−5μm) .

إن الهدف من هذه الدراسة هوالعمل على تطوير و تحسين فعالية هذا النوع من الكواشف و ذلك بدراسة وتحسين خواصه الكهربائية والبصرية، ولهذا الغرض فقد تم استخدام برنامج (MATLAB software) لمعرفة مدى تأثير قيم (x_{cd}) على الخواص الكهربائية والضوئية للكاشف عند قيم مختلفة لدرجة الحرارة.

تم تحديد القيم المناسبة لـ (x_{cd}) التي تكون فيها استجابة وحساسية الكاشف ملائمة في النطاق (3−5μm) للأشعة تحت الحمراء، ومن خلال النتائج تبين أن الاستجابة العظمى لهذا النوع من الكواشف تكون محققة في المدى ($0.40 > x_{cd} > 0.28$).

ABSTRACT

The design of high performance photodetectors for infrared search and track (IRST) systems requires a study of the various parameters of the photodetectors and improve these parameters by modelling and optimizing of specific figures of merit of photodetectors for IR system. As the most often used and the most convenient photodetector material for (IRST) applications in 3-5µm, window mercury cadmium telluride, ($Hg_{1-x}Cd_xTe$) was chosen.

The objective of this study is to investigate the performance improvement method of (HgCdTe) infrared photodetectors for (3-5µm) band. In order to improve their electrical and optical parameters their figures of merit The

MATLAB software is applied and the approaches to their optimization have been investigated.

The influence of different important parameters has been investigated, i.e. the operating temperature, composition (x_{cd}), etc. From our results it was found that the maximum responsivity of such type of photodetectors is fulfilled at (3-5μm) band, when the value of x_{cd} lies in the range of ($0.40 > x_{cd} > 0.28$).

1. INTRODUCTION

Infrared photodetector is the heart of an infrared search and track (IRST) systems because it plays a key role in determining system-level parameters including spectral operating band, sensitivity, and resolution. Mercury-Cadmium-Telluride (HgCdTe) also referred to as MCT is the dominant material for development of high sensitivity infrared photodetectors for military applications, medical imaging, and surveillance, and many other applications. The adjustable energy gap of (HgCdTe) with sensitivity spanning from short wavelength (SWIR) to very long wavelength (VLWIR) infrared windows enables it for tremendous potential applications to be realized using advance material growth methods and different (HgCdTe) photodetectors design. (HgCdTe) can be used for photodetectors operated at various modes, and can be optimized for operation at the extremely wide range of the IR spectrum (1–50μm) and at temperatures ranging from that of liquid helium (*4 K)* to room temperature.

2. THE PRINCIPAL COMPONENTS OF IRST SYSTEM.

Infra-Red Search and Tracking (IRST) System sensor is used for battlefield night vision, surveillance of unlit area, and fire detection within smoke-filled space onboard ships. The typical sensor of (IRTS) provides a visual representation of an object at night or under poor lighting conditions. The principal components of an IR tracking system are:

1. Radiation sources (Target and background)
2. Atmospheric window
3. Optics
4. Detector and cooler system if required
5. Electronics (signal and image processing systems)
6. Display.

Typical scenario for IRST system is shown in figure (2.1).

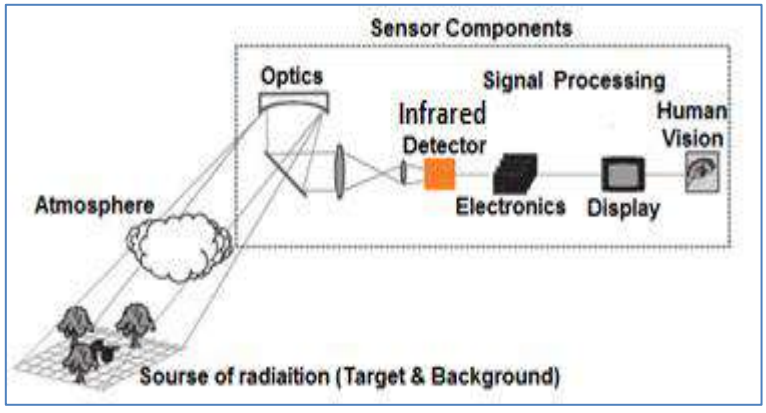

Figure (2.1) Typical scenario of an IRTS system [1].

2.1 SOURCES OF RADIATIATON

The first component in the (IRST) system is the objects that are viewed by the sensor. Objects, as seen by sensors, include targets and backgrounds. Target characterization is very important part of the overall sensor analysis and design process. Sensor band selection for a scenario begins with the targets and background. The radiation emitted by the sun, which is considered to be a blackbody approximately at 5800 K, reaches its maximum in the visible region of the spectrum. Therefore, the sun is in tune with human eyes. On the other hand, subjects at temperature 900 K emit almost entirely in the (IR) band and thus are not visible to the eye unless they reflect light coming from other sources. A target-background difference in existence (or emittance) must be present in the band of interest.

2.2 ATMOSPHERIC WINDOW

From the standpoint of the designer and user of the (IRST) systems, it is unfortunate that most of the systems view their targets through the earth's atmosphere. Before it reaches the IR receiver unit, the target radiation flux has been changed due to numerous processes. In calculating the optical transmission from an object to a sensor, there are three primary processes that affect the radiation: scattering, absorption, and turbulence. The effect of these three factors is both a reduction in the amplitude of the signal that reaches the sensor from the

target and an atmospheric blurring of the image. Figure (2.2) is a plot of the transmission through (6000 ft) of air as a function of wavelength. Specific absorption bands of carbon dioxide, oxygen, and water molecules are indicated which restricts atmospheric transmission to two windows at (8-14μm) and (3-5μm).

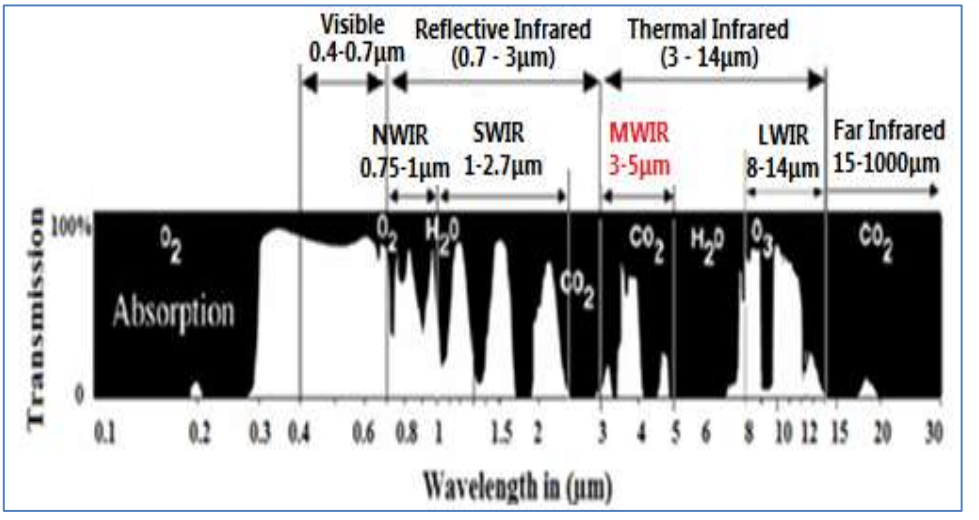

Figure (2.2) Typical atmospheric transmission as a function of wavelength.

2.3 OPTICS SYSTEM

In the design of the (IRST) optics system, it is important to understand the limitations that optical components introduce in the overall system parameters. Among the parameters that the optics defines are spatial and spectral properties of the sensor system, field of view (FOV), and resolution. All elements are considered to be centered; that is, the centers of curvature of each surface all lies on the same straight line called the optical axis. The IR-transmitting materials potentially available for use as windows and lenses are shown in Figure (2.3).

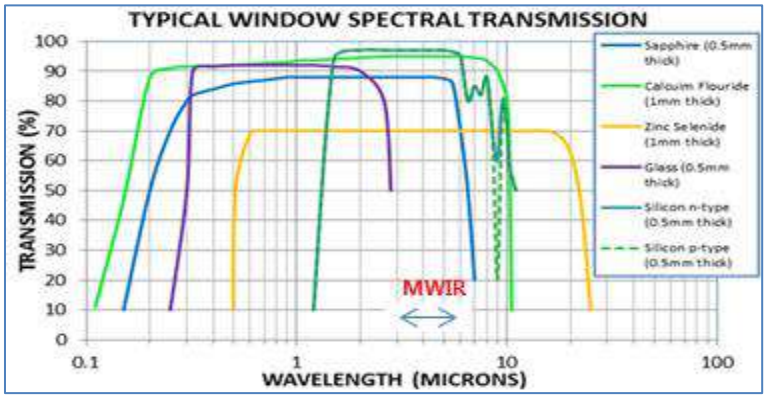

Figure (2.3) Infrared materials, transmission range [2].

2.4 IR DETECTORS

The detector component in sensors of the IRST systems plays a key role in determining system-level parameters including sensitivity, resolution, and spectral operating band. The spectral response is determined by the detector material characteristics and the operating temperature. The detector sensitivity is a function of material (i.e., band gap), detector size, bandwidth, wavelength, and shielding.

There are two general classes [3, 4] of detectors: *photon* and *thermal* detectors. Photon detectors include photoconductors (PC), photovoltaic (PV), and photo-emissive detectors, they exhibit both a good signal−to−noise performance and a very fast response. But to achieve this, the photon IR detectors require cryogenic cooling. Thermal detector materials have at least one inherent electrical property that changes with temperature. This temperature-related property is measured electrically to determine the power on the detector [5]. The detector material most employed in IR system is Mercury Cadmium Telluride (HgCdTe). The adjustable bandgap of (HgCdTe) photodetectors with sensitivity spanning from (SWIR) to (VLWIR) infrared bands enables it for tremendous potential applications to be realized using advance material growth methods and different detectors design.

2.5 ELECTRONICS

The function of electronics is to transform the output of the IR detector into a signal that can be processed or viewed. This transformation must be accomplished with minimal degradation of system performance. Issues of primary importance are high gain, low output impedance, large dynamic range, low noise and good

linearity. Figure (2.4) shows an example of the basic operation circuit for MCT photoconductive detectors.

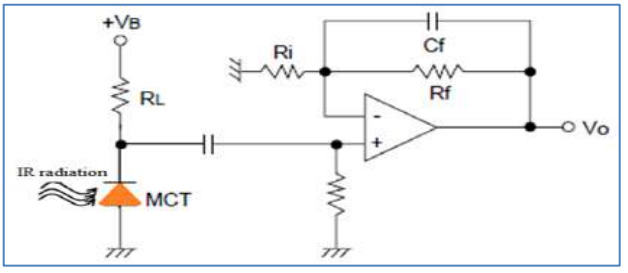

Figure (2.4) Basic operation circuit for MCT photoconductive detectors [6].

This type of circuit is used for low output impedance, nominal-input impedance, and high-gain. However, there is a signal inversion (i.e., the signals are 180 deg. out of phase) from the detector voltage to the output voltage [7].

2.6 IMAGE PROCESSING

The principal IRST technical challenges are tracking subpixel targets in moving clutter and additive noise and with a bipolar format, allowing targets to be below or above the immediate background level. In general, targets may exhibit both negative and positive contrasts with respect to the background.

Discrimination is the process of differentiating between target and (false target) background clutter. In IRST systems discrimination may be implemented through differences in signal frequency or amplitude, motion, spatial characteristics, or received IR spectrum. Differences can be detected in ways ranging from simple thresholding to sophisticated space-time correlations. All are generally employed in modern IRST systems [8].

2.7 DISPLAYS, HUMAN PERCEPTION

Displays are the interface between the IR sensor and the human vision system. The display converts the electrical signal from the IR sensor to a visible signal that is subsequently presented to the viewer. Occasionally, systems are designed where humans do not interpret the data, so displays are not required. Imaging system with automatic target trackers are a good example. Various levels of human interpretation of imagery are seen in the targeting community. One example that is increasingly successful and gaining popularity is the targeting sensor coupled to a computerized automatic target recognizer (ATR), automatic target cueing (ATC) system, or aided target recognizer (AiTR).

3. INFRARED SPP.

Semiconductor Photoconductive Photodetectors (SPP) works on the principle of change in electrical conductivity when illuminated by infrared radiation. When a semiconductor is illuminated by IR radiation, the concentration of carriers is increased by optical absorption by excitation over the band gap. This increase in the conductivity is the basis of photoconductive detection. The principle of photoconductive detector detection is shown in Figure (3.1).

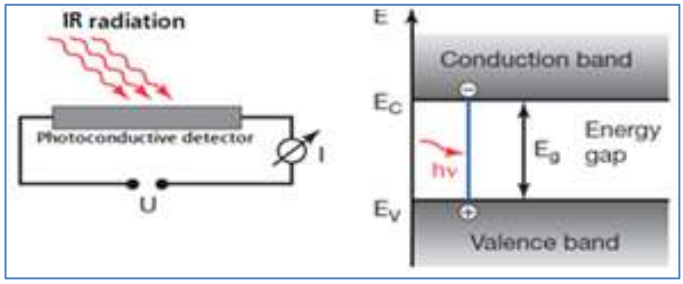

Figure (3.1) The incident radiation leads to charge carriers within the conduction and valence bands of the semiconductor materials.

In view of the fact that the atmospheric transmission has windows in the SWIR (1-2.7 µm), MWIR (3-5 µm), and in the LWlR (8-14 µm) bands, so we are interested in IR detection in these bands, the energy gap of the semiconductor should correspond to the energies of photons in these regions of the spectra. The three window regions correspond to photon energies in the range of (0.50-1.24 eV), (0.2-0.41 eV) and (0.09-0.15 eV), respectively.

The detector material most employed in IR system is Mercury Cadmium Telluride ($Hg_{1-xcd}Cd_{xcd}Te$). The band gap of this type of photodetectors can be varied continuously from 0 to 1.6 eV by varying x_{cd}.

3.1 IRSP PARAMETERS AND FIGURES OF MERIT

In order to specify and compare the performance of various photodetectors it is necessary to define certain figures of merit to describe this conversion efficiency and the magnitude of the signal-to-noise ratio of the photodetector in terms of the incident radiation power.

3.1.1 Quantum Efficiency (η)

The quantum efficiency ($0 \leq \eta \leq 1$) of a photodetector is defined as the probability that a single photon incident on the device generates a photo-carrier

pair that contributes to the detector current. When many photons are incident, η is the ratio of the flux of generated electron-hole pairs that contribute to the photodetector current to the flux of incident photons [9].

$$\eta = \frac{i_p\, h\nu}{q\, P_o} \quad \text{..... (3.1)}$$

Where: i_p: is the photocurrent, q : is the carrier charge, P_o: is the optical power, h: Plank' s constant, and v : incident photon frequency.

3.1.2 Responsivity (R)

One of the most important properties of any photodetector is its responsivity (R), which defined as the photodetector output signal per unit incident radiation power. The responsivity (R) relates the electric current flowing in the device to the incident optical power.

$$R = \frac{\eta e}{h\nu} = \eta \frac{\lambda_o(\mu\text{m})}{1.24} \quad \text{..... (3.2)}$$

The responsivity can be degraded if the photodetector is presented with an excessively large optical power. This condition, which is called photodetector saturation, limits the photodetector's linear dynamic range, which is the range over which it responds linearly with the incident optical power [9].

3.1.3 Noise Equivalent Power (NEP)

Although the responsivity effectively defines the sensitivity of a device it gives no indication of the minimum radiant flux that can be detected. This minimum detectable flux is defined as the incident radiation power required to producing an output signal (V_s) equal to the internal noise level of photodetector (V_n), in other words, a signal-to-noise ratio of unit, and is known as the noise equivalent power.

$$NEP = \frac{V_n}{R} \quad \text{..... (3.3)}$$

3.1.4 Detectivity (D)

It can be seen that the higher the performance of a photodetector the lower the value of noise equivalent power (NEP). This is described by the photodetector detectivity as:

$$D = \frac{1}{NEP} \qquad [\ \text{Hz}^{1/2}/\text{W}\ ] \quad \text{..... (3.4)}$$

When the detectivity is used to characterize a photodetector it is necessary to specify the wavelength of the incident IR radiation, the photodetector temperature, any bias current applied to the device, the chopping frequency, the area of the photodetector and the bandwidth of the amplifier used to measure the photodetector noise.

3.1.5 Specific Detectivity (D*)

The detectivity is not an ideal parameter for comparing different detectors as it varies inversely as the square root of both the bandwidth (Δf) and the sensitive area. Hence the specific detectivity or D^* (D-star) measured in [$cmHz^{1/2}/W$] has been introduced such that:

$$D^* = \frac{\sqrt{A\Delta f}}{NEP} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

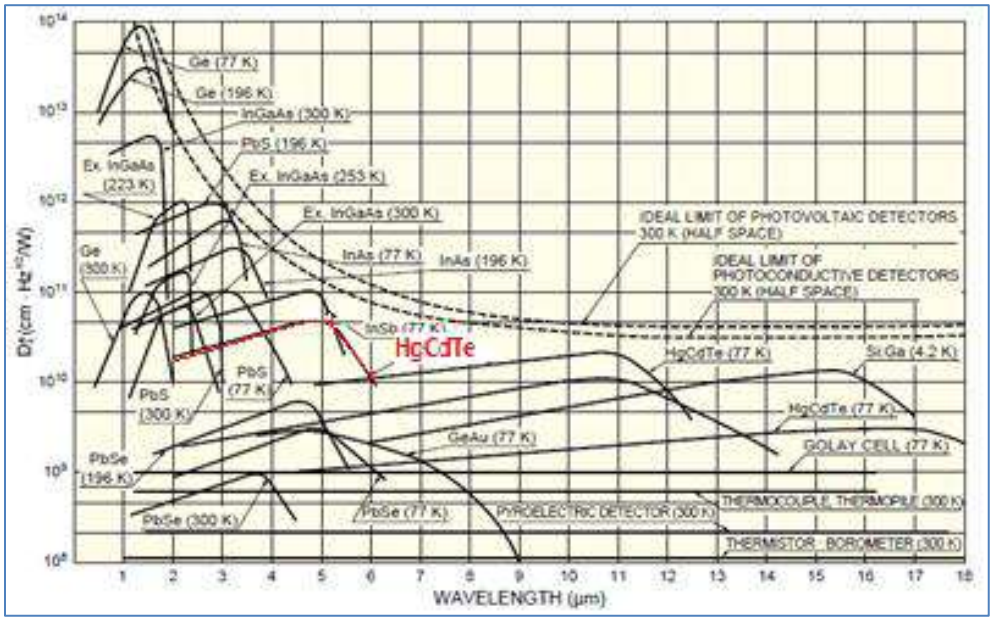

Figure (3.2) Spectral response characteristics of various infrared detectors [10].

4. BASIC PARAMETERS OF MCT PHOTOCONDUCTIVE.

There are some important parameters of MCT photoconductive such as Bandgap(E_g), Intrinsic Carrier Concentration (n_i) , Electron Effective Mass(m_n^*) , Electron mobility (μ_n) , Hole mobility (μ_p) , and Absorption coefficient (α) . These parameters can be briefly illustrated as follows.

- Band-Gap (BG):

There are a number of expressions, approximating E_g as a function of Cadmium molar fraction x_{cd} and temperature T are available at present. The widely used expression is due to Hansen et al [11].

$$E_g(x_{cd}, T) = -0.302 + 1.9x_{cd} + 5.35 \times 10^{-4}T(1 - 2x_{cd}) - 0.81x_{cd}^2 + 0.832x_{cd}^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

- Intrinsic Carrier Concentration(ICC):

$$n_i = (5.85 - 3.82x_{cd} + 1.735 \times 10^{-3}T - 0.001364x_{cd}T) \times [10^{20}E_g^{3/4}e^{-E_g/2k_bT}] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.2)$$

- Electron Effective Mass(EEM):

$$m_n^* = \frac{m_0}{1 + 2m_0P_1^2\frac{q}{3}\left(\frac{2\pi}{h}\right)^2\left(\frac{2}{E_g} + \frac{1}{E_g + 1}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

Where, q : is the magnitude of the electron charge.
P_o : is the optical power .
h : Plank' s constant.
m_0 : is the electron rest mass.

- Electron Mobility(EM):

$$\mu_n = 1.46 \cdot 10^5\left(\frac{0.14}{x_{Cd}}\right)^{7.5}\frac{1}{T^{2(0.14/x_{Cd}}} \quad \ldots\ldots\ldots(4.4)$$

- Hole Mobility(HM):

$$\mu_p = (\mu_n/100) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.5)$$

- Absorption Coefficient (AC):

$$\alpha = (1480x_{Cd} + 0.26T + 90)e^{3.915\mathrm{sgn}(E-E_g)(E-E_g)^{1/3}} \left\{th\left[120th\left(10x_{Cd} - 1.5\right)\left(E - E_g\right)\right] + 1\right\} \quad \text{…… ……..……..(4.6)}$$

5. SIMULATIONS, RESULTS AND DISCUSSION

The Detectivity (D*), Sensitivity (S), and Quantum efficiency (μ) of HgCdTe Photoconductors are calculated using the following parameters:

- Cadmium molar fraction x_{cd} =0.40, 0.32, 0.29 and, 0.28
- Detector dimensions (width = 1000 μm, length =1000 μm, thickness=0.184 μm),
- Bias voltage =1.5V, and
- Optical infrared power of illumination= 0.0001 W.

5.1 Calculation of (D*), (S), and (μ) for x_{cd} =0.40

Figure (5.1a) shows the Detectivity (D*) versus wavelength (λ), with detector temperature (T) as a parameter. The D*(λ) dependence was calculated for five different values of T, these being T1=77 K, T2=100K, T3=150 K, T4=200 K, and T5=300 K. Also, the S (λ) and η(λ) were calculated for the same previous parameter with the same constants. The range of (λ), varied from zero to 4 μm,

The results of each (D*), (S) and η(λ) against the wavelength (λ), with the detector temperature (T) are shown in figures (6.1a, b, and c) respectively.

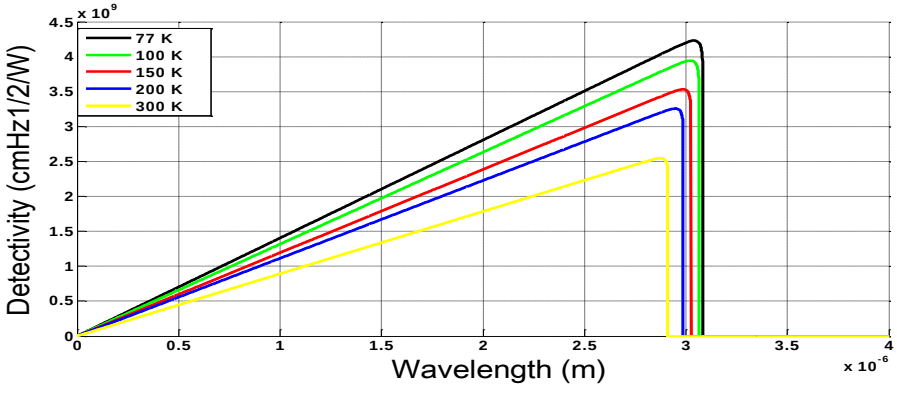

Figure (5.1a) Detectivity (D*) of MCT versus wavelength (λ) for x_{cd} =0.40

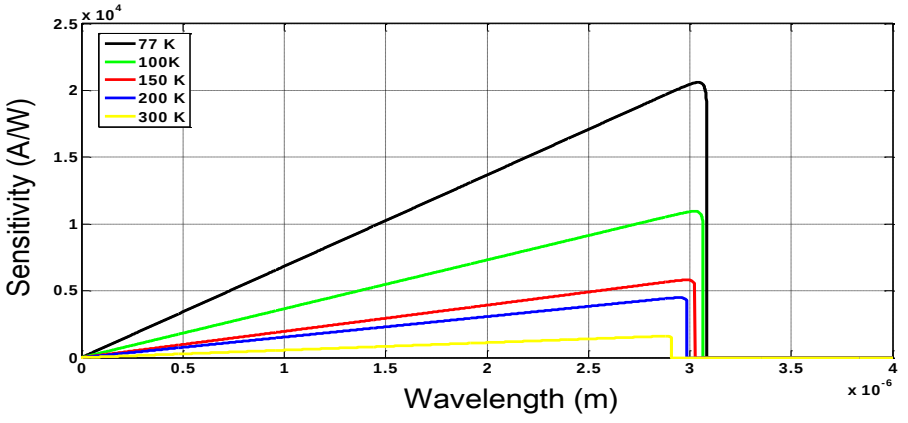

Figure (5.1b) Sensitivity (S) of MCT versus wavelength (λ) for x_{cd} =0.40

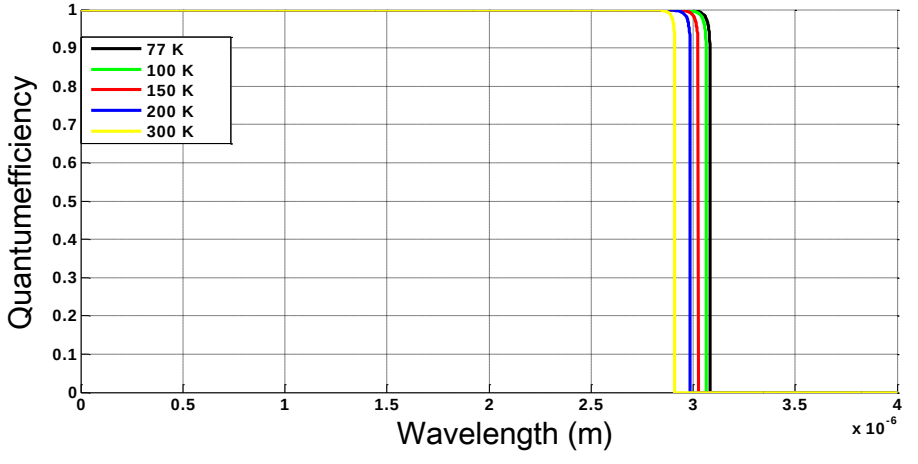

Figure (5.1c) Quantum efficiency (μ) of MCT versus wavelength (λ) for x_{cd} = 0.40

From Figure (5.1a), it can be seen that D* first rises with λ, reaching a maximum value of λ about 3.04μm at T1, 3.02μm at T2, 2.98μm at T3, 2.94μm at T4, and 2.87μm at T5, and then quickly drops with λ, reaching zero. Therefore, the values of D* lies in the range (0 - 4.23×10^{9}) (cmHz1/2/W).

Consequently, it can be seen from Figure (5.1b) that S(λ) slowly rises first with λ, reaching a maximum value of λ 3.04μm at T1, 3.02μm at T2, 2.98μm at T3, 2.94μm at T4, and 2.87μm at T5, and then quickly drops with λ, reaching zero, Moreover, it was found the values of S lies in the range (0 to 2.62×10^{4}) (A/W).

From Figure (5.1c) it was found that η(λ) reached values in the range (0 – 1). Here η starts with a maximum value (1) up to wavelength of about 2.79μm at T1, 2.78μm at T2, 2.75μm at T3, 2.73μm at T4, and 2.68μm at T5, and then quickly drops with λ if increased with T, reaching to zero.

The maximum values of (D*), (S), and (μ) of Hg0.60Cd0.40Te detector with their corresponding wavelengths, are shown in Table (5.1).

Table (5.1)

x_{cd} = 0.40	Temperature (K)	77	100	150	200	300
D* (cmHz$^{1/2}$/W)	$D^*_{(\lambda max)}$	4.23×10^9	3.94×10^9	3.53×10^9	3.25×10^9	2.54×10^9
	λ_{max} (μm)	3.04	3.02	2.98	2.94	2.87
S (A/W)	$S_{(\lambda max)}$	2.62×10^4	1.09×10^4	5814	4490	1600
	λ_{max} (μm)	3.04	3.02	2.98	2.94	2.87
η	$\eta_{(\lambda max)}$	1	1	1	1	1
	λ_{max} (μm)	< 2.80	< 2.79	< 2.76	< 2.74	< 2.69

5.2 Calculation of (D*), (S), and (μ) for x_{cd} =0.32

Again the same procedure was repeated for x_{cd} =0.32 and T being at T_1=77K, T_2=100K, T_3=150K, T_4=200 K, and T_5=300 K. The results are shown in the figures (5.2a, b, and c).

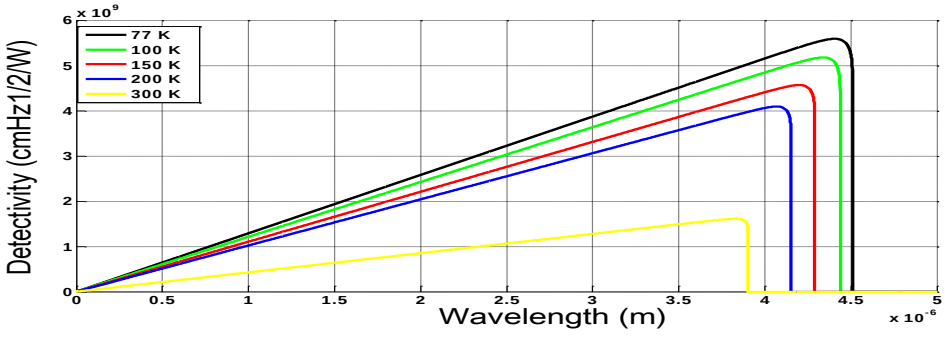

Figure (5.2a) Detectivity (D*) of MCT versus wavelength (λ) for x_{cd} =0.32

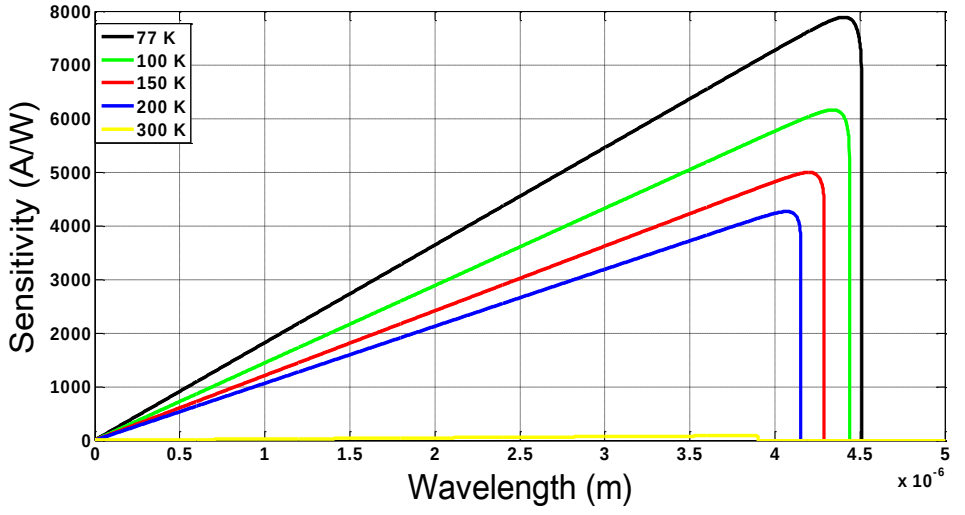

Figure (5.2b) Sensitivity (S) of MCT versus wavelength (λ) for x_{cd} = 0.32

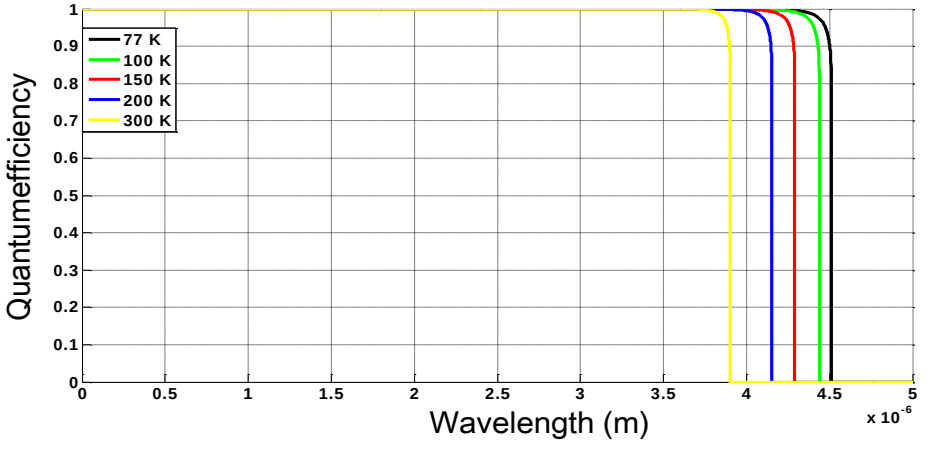

Figure (5.2c) Quantum efficiency (μ) of MCT versus wavelength (λ) for x_{cd} =0.32

The maximum values of the (D*), (S), and (μ) of $Hg_{0.68}Cd_{0.32}Te$ detector with their corresponding wavelengths are shown in Table (5.2).

Table (5.2)						
x_{cd} =0.32	Temperature (K)	77	100	150	200	300
D* (cmHz$^{1/2}$/W)	$D^*_{(\lambda max)}$	5.59×10^9	5.17×10^9	4.56×10^9	4.09×10^9	1.61×10^9
	λ_{max} (μm)	4.40	4.33	4.19	4.06	3.82
S (A/W)	$S_{(\lambda max)}$	7887	6158	4994	4263	86.51
	λ_{max} (μm)	4.40	4.33	4.19	4.06	3.82
η	$\eta_{(\lambda max)}$	1	1	1	1	1
	λ_{max} (μm)	< 3.71	< 3.67	< 3.59	< 3.52	< 3.37

5.3 Calculation of (D*), (S), and (μ) for x_{cd} =0.29

The same procedure was repeated for *xcd* = 0.29 and T being at *T1*=150K,*T2*=200K, *T3*=250 K, and *T4*= 300 K. The results of (D*), (S) and (η) are shown in the figures (5.3a, b, and c) respectively.

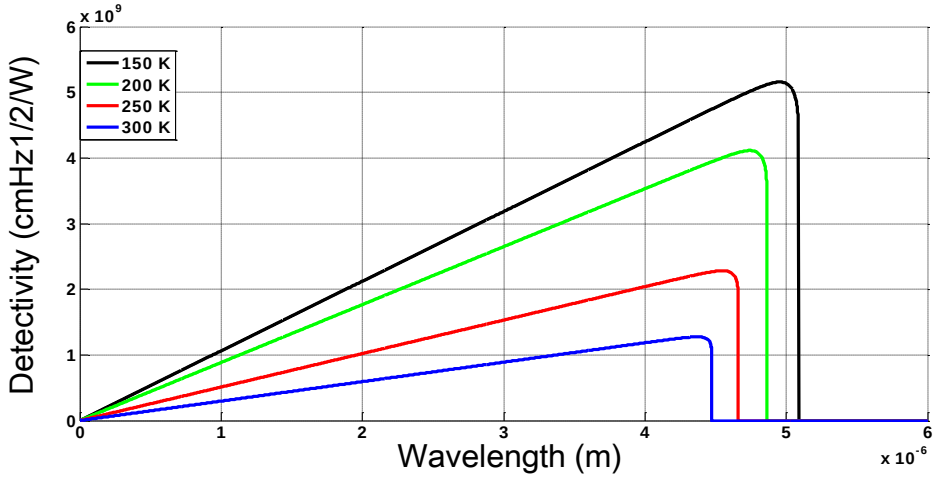

Figure (5.3a) Detectivity (D*) of MCT versus wavelength (λ) for x_{cd} =0.29

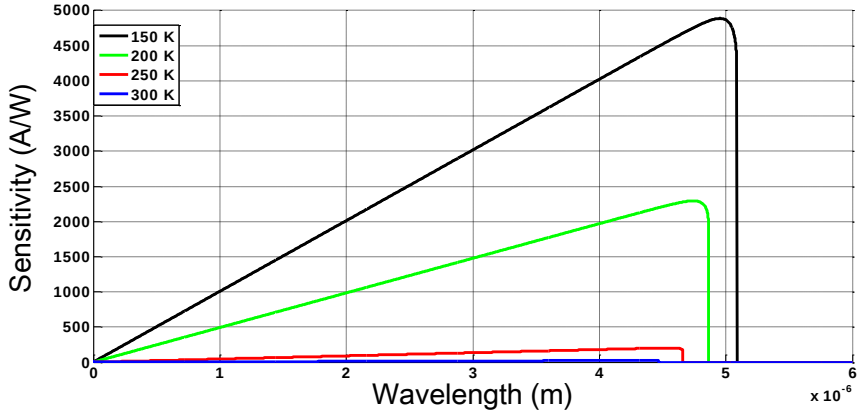

Figure (5.3b) Sensitivity (S) of MCT versus wavelength (λ) for x_{cd} =0.29

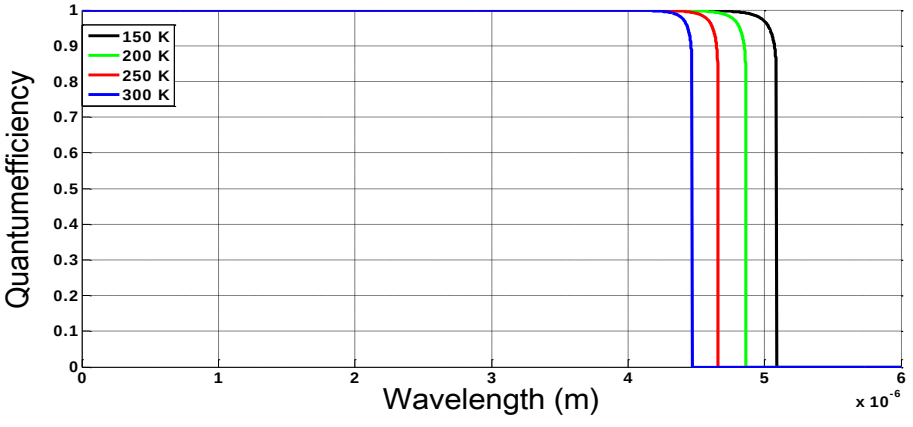

Figure (5.3c) Quantum efficiency (μ) of MCT versus wavelength (λ) for x_{cd} =0.29

The maximum values of the (D*), (S), and (μ) of $Hg_{0.71}Cd_{0.29}Te$ detector with their corresponding wavelengths, are shown in Table (5.3).

Table (5.3)					
x_{cd} =0.29	Temperature (K)	150	200	250	300
D* (cmHz$^{1/2}$/W)	$D^*_{(\lambda max)}$	5.15×10^9	4.11×10^9	2.28×10^9	1.27×10^9
	λ_{max} (μm)	4.94	4.74	4.53	4.35
S (A/W)	$S_{(\lambda max)}$	4888	2295	201.7	24.6
	λ_{max} (μm)	4.94	4.74	4.53	4.35
η	$\eta_{(\lambda max)}$	1	1	1	1
	λ_{max} (μm)	< 4.02	< 3.93	< 3.81	< 3.71

5.4 Calculation of (D*), (S), and (μ) for x_{cd} =0.28

Finally the procedure was repeated for x_{cd} = 0.28 and T being at T_1=200K, T_2=250K, and T_3=300 K. The results are shown in the figures (5.4a, b, and c).

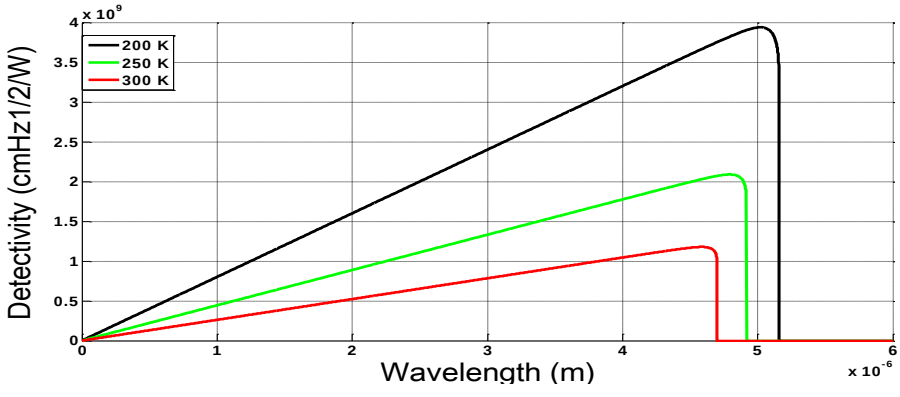

Figure (5.4a) Detectivity (D*) of MCT versus wavelength (λ) for x_{cd} =0.28

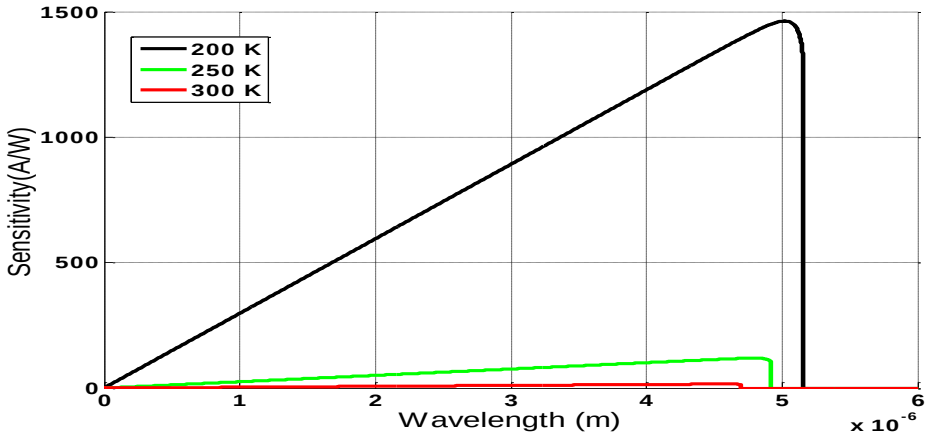

Figure (5.4b) Sensitivity (S) of MCT versus wavelength (λ) for x_{cd} =0.28

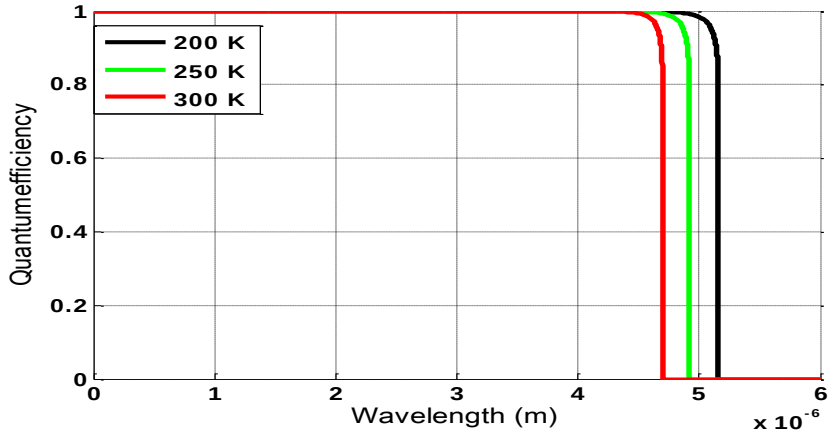

Figure (5.4c) Quantum efficiency (μ) of MCT versus wavelength (λ) for x_{cd} =0.28

The maximum values of the (D*), (S), and (μ) of $Hg_{0.72}Cd_{0.28}Te$ detector and their corresponding wavelengths are shown in Table (5.4).

Table (5.4)				
x_{cd} =0.28	Temperature (K)	200	250	300
D* (cmHz$^{1/2}$/W)	$D^*_{(\lambda max)}$	3.93×10^9	2.08×10^9	1.17×10^9
	λ_{max} (μm)	5.01	4.77	4.60
S (A/W)	$S_{(\lambda max)}$	1463	119.4	16.16
	λ_{max} (μm)	5.01	4.77	4.60
η	$\eta_{(\lambda max)}$	1	1	1
	λ_{max} (μm)	< 4.06	< 3.95	< 3.83

6. SUMMERY AND CONCLUSIONS

Based on the results presented and discussed in Section 5 several important conclusions may be drawn regarding the optimization of detectivity (D*), sensitivity (S) and quantum efficiency (η) of MCT photoconductive photodetectors for MWIR:

The very important parameter is obviously the mercury cadmium telluride composition x_{cd}. For some values of x_{cd} there is no response in the (3–5μm) band and temperatures at all, while for ($0.40 > x_{cd} > 0.28$) this response is very large. By analyzing the shape of the (D*), and (S) versus wavelength we can see that the optimum composition is the one furnishing a maximum of the (D*), and (S), and this value is the one close to the cutoff wavelength.

Lower temperatures 77 K, and 100 K are more convenient to reach high values of D*, (S), and (η), but even for higher operating temperature one can optimize the composition to obtain high detectivities and sensitivities.

For shorter wavelengths the penetration depth through the MCT photoconductive photodetectors is small because of the too large thickness and thus the (η) is too low, it gradually increases with wavelength and reaches its optimum.

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